Umberto® LCA+
(v10)

User Manual

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Contents

1 Introduction

Umberto LCA+ is a software tool that helps you calculate the potential environmental impacts of products. It uses graphic modelling of the product life cycle, and allows analysing, assessing and visualizing the environmental impacts in different impact categories.

Umberto LCA+ is a member of the Umberto software[1] family, and has been tailored specifically to be used for life cycle assessment studies. It is targeted at the LCA practitioner.

We find it important to have a visual approach for calculating a product carbon footprint, rather than working with tables and grids. Therefore, the user starts by drawing the life cycle model (or process map). Specification of the processes and activities in the model is the next step, before the calculation of the material and energy flows, and the Life Cycle Impact Assessment (LCIA) can be launched. Results are displayed graphically and in tables. The life cycle model can be displayed as Sankey diagrams, both for material and energy flows, as well as for weighted "impact flows", i.e. the environmental impact loads cumulated along the stages of the life cycle.

One determining issue in calculating LCA models is the availability of background LCI datasets that can be used to model upstream raw material and energy supply chains or downstream end-of-life treatment paths. To this end, Umberto LCA+ is shipped with the ecoinvent LCI database[2] and/or the GaBi LCI databases[3]. The process modules can be used in the LCA models in Umberto LCA+.

Impact assessment (LCIA) methods provided by the dataset suppliers are also included in the software package and can be used to calculate the scores for different impact categories.

We hope you enjoy working with Umberto LCA+!

[1] http://www.umberto.de
[2] http://www.ecoinvent.org. Depending on the licenses obtained, your software package may include ecoinvent v2.2 and/or ecoinvent v3 datasets
[3] http://www.gabi-software.com/databases/gabi-databases/
GaBi database licenses to be obtained separately.

About this User Manual

This user manual gives an introduction and serves as a reference to the functions of Umberto LCA+.

A brief introduction to the 'Life Cycle Assessment' topic with reference to further reading is given. The datasets from ecoinvent and hints on the use of these datasets are given.

The main part of the user manual describes functions of the software. It is intended to be used as a reference section, to get information about specific functions, rather than learning how to practically use the software.

If you are more interested in directly trying out the features using practical examples, you might want to check out the tutorials presented in separate documents. These tutorials show how LCA models are built with the software and how the environmental impacts can be calculated and assessed. The tutorials can be used to self-study the software, and to get acquainted with the most important functionality.

An index allows you to quickly access the pages were specific functions of Umberto LCA+ are mentioned.

Note: The PDF file of this user manual and tutorials can be accessed directly using the quick link on the start page or the command 'Open Manual' in the Help menu.

The following visuals are used to highlight specific content:

A hint or additional advice.

An important advice or warning

Cross-reference to a related topic within the user manual or in the Umberto LCA+ Tutorial.

Hint specific to ecoinvent LCI database. Refer to documentation of the ecoinvent database (http://www.ecoinvent.org) for more detail.
For questions relating to the content of the datasets, please contact support@ecoinvent.org.

Hint specific to GaBi LCI databases. Refer to documentation of the GaBi databases (http://www.gabi-software.com) for more detail.

Reference to ISO standard. Refer to ISO 14040 and ISO 14044 or the mentioned standards for details.

Reference to ILCD handbook. Consult the chapter of the ILCS handbook for further explanation.

2 Installation

Administrator rights are required to install Umberto LCA+ on your computer. Contact your administrator, if you only have limited rights on your machine.

2.1 System Requirements

To install and run Umberto LCA+ the following requirements have to be met:

- Operating system Windows Vista, 7, 8, or 10
- Microsoft .NET Framework 4.6[4]
- Memory 4 GB RAM or higher
- Available hard disk space: up to 10 GB or more (depending on installed LCI databases, see list in section 2.4)
- Monitor with at least 1280 x 1024 px resolution (recommended)

A monitor with a screen resolution of at least 1280 x 1024 pixels or higher is recommended, to be able to handle several windows of the application being visible side-by-side. The software can be run in a multi-screen modus.

2.2 Running Umberto Software Installer File

Run the Umberto installer file by clicking on the downloaded executable (the file is named 'setup-umberto-lcaplus.exe' or 'umberto-lcaplus_trial-v7.x.x.xxxx.exe' or 'umberto-lcaplus-v7.x.x.xxxx.exe' where 'x' represents a digit). You need local administrator rights on your machine for the installation.

The installer will analyse the operating system and install the 32-bit or the 64-bit version of Umberto LCA+ depending on the system type.

The installation is guided by a wizard and only requires some 60 to 90 seconds. If an older version of Umberto LCA+ is found on the computer, the installation routine will offer to uninstall the older version prior to continuing the installation of the current version.

You will be asked to accept the Umberto End User License Agreement (EULA). Please confirm that you have read and agree to the EULA by checking the confirmation box.

By default, the installation directory for the application is "C:\Program Files (x86)\ifu Hamburg GmbH\Umberto LCAPlus" (32-bit) or "C:\Program Files\ifu Hamburg GmbH\Umberto LCAPlus" (64-bit). You may of course opt to choose to install to a different directory by clicking on the 'Options' button.

One additional folder "Umberto LCA+" is installed as data subfolder of "C:\My Documents". It is used to store the database files (file extension '.umberto'), and the Module Gallery files.

[4] The existence of the Microsoft .NET Framework 4.6 will be checked during installation, and if it is not available, it will be downloaded. If there is no connection to the internet, you will be asked to install it first, before proceeding with the Umberto installation. Windows 10 already has the framework pre-installed. Windows 8 and Windows 7 might require you to download and execute the .NET Framework 4.6 installer (62 MB). For further information, see www.microsoft.com

Note that after having run the software installer for Umberto LCA+ the installation does not yet include any master databases (such as the LCI database ecoinvent v3). Only a sample master database ("Tutorial Example") with fictitious datasets is installed. Each master database is shipped as a separate installer and must be installed individually using the license key that has been provided.

Read below in section 2.4 on how to install the master databases with LCI data.

Trial Version

When starting up Umberto a licensing dialog box will be prompted. If you have already purchased a license, you can enter the license key in this box to register your version.

If you do not enter license key, you can run Umberto as a trial version for 14 days from installation. The trial version almost has the same functionality as the full version, but the following limitations:

- watermark over the life cycle model
- only approximately 40 fictitious LCI sample datasets (see below)
- no print function
- no export to Excel

The trial version always prompts for a registration key on start-up, and shows the remaining day of the trial period.

Note that in the trial version of Umberto LCA+, no full LCI database is included for licensing reasons. Only a limited number of fictitious LCI activity datasets (so-called "tutorial datasets") are available.
Activity datasets from LCI databases are shown in the trial version as stubs without flow data, and only meta information can be viewed.
Upon acquisition of an LCI database license, an installer is provided that installs the full LCI master data (see below).

Users of the trial version of Umberto LCA+ can purchase licenses for additional LCI databases by contacting a sales representative at ifu Hamburg (sales@umberto.de).

Update of Umberto Software: When new versions of Umberto are released, a notification on the start page will indicate the availability of an update. Click on the link to access a web page where you can download the new version.

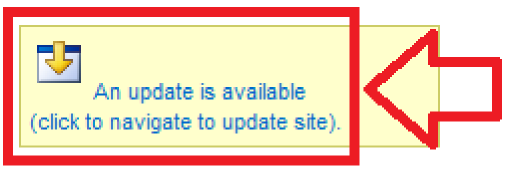


Figure 1: Information of the start page that an update of Umberto is available

2.3 License Activation

When launching an unregistered copy of Umberto, a licensing dialog will be displayed. Use this dialog to enter the license key you have received when purchasing the software and to authenticate the license key.

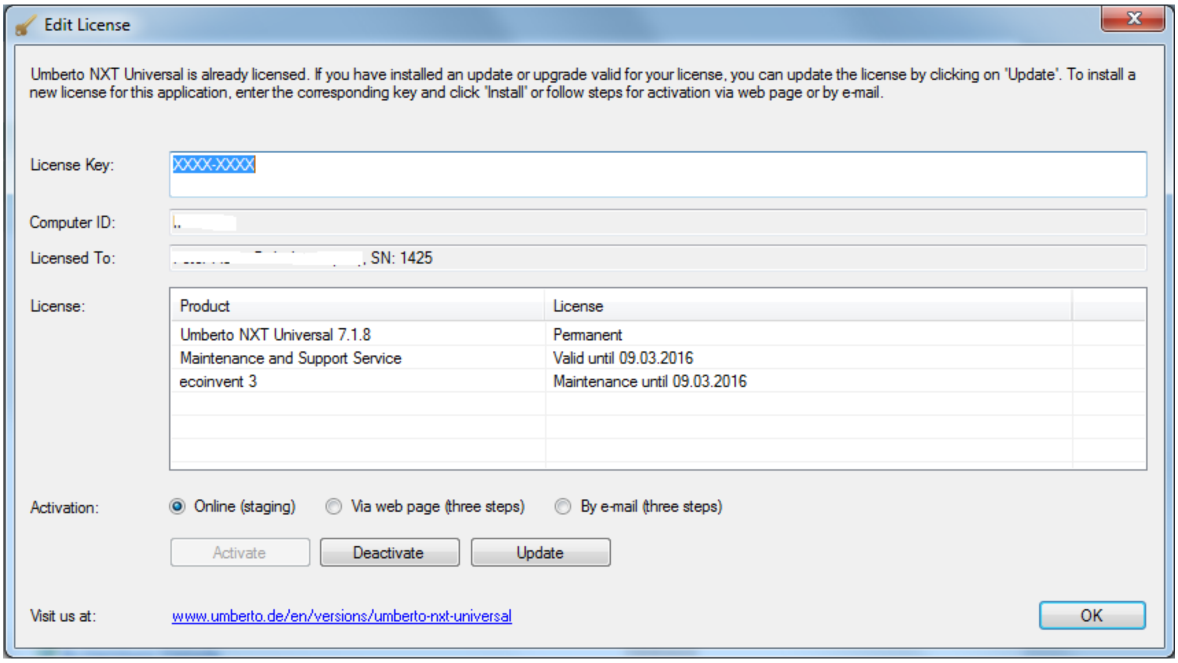


Figure 2: Entering the license key and activating the software.

This dialog can also be launched via the Help menu of Umberto using the menu entry 'Enter Umberto License...' or using the link on the start page.

- **Online**: This is the fastest way to activate a license and should be used if you are connected to the Internet and if the security setting of your network connection allows communication with a server over the Internet. License data will be transferred encrypted to our license management server. The server will send the activated license back to your computer within seconds.
- **Via Web Page**: You will be redirected to a web page to enter your user data. This is a three step process.
- **By E-mail**: You can send the data by e-mail and receive the authentication code back in an e-mail too. This is also a three step process.

Should you wish to extend the software functionality and install an update (newer version) or upgrade (larger version with more features), or should you have purchased additional databases that you wish to install next to the existing databases, you will most likely receive a new license key with your purchase. In this case it is required to replace the license (i.e. deactivate the existing license and activate the new license instead). In this case, first click on the button 'Deactivate'. Then enter the license in the "License Key" field and click on the button 'Activate'. The newly licensed features or databases will be available upon the next start of the software.

License Transfer/Deactivation: In case you have obtained a new computer, or you decide to continue to use Umberto on a different computer where you originally installed it, the license needs to be transferred. To transfer (move) a license of the software to another computer, proceed as follows:

- In the existing Umberto installation, run Umberto a last time: From the Help menu choose 'Enter Umberto License...' to open the licensing dialog or use the link in the 'Version' panel on the start page.
- Click on 'Deactivate' in this dialog. The license will be removed.
- On the new computer: Use the installation file and install the latest version of the software (see above). Enter the license key in the license dialog.

If a deactivation of the license is not possible any more (e.g. because your computer has been stolen, the hard disk has crashed, etc.), please contact support@umberto.de to deactivate the license. Should you have lost your license key information, please contact support@umberto.de to retrieve it.

2.4 Running LCI Database Installer Files

In addition to the Umberto software installation, additional third-party LCI databases can be installed. These additional databases contain background LCI datasets for modelling of LCAs.

The installed and usable databases are signalled in the 'Version' panel on the start page. They can also be viewed in the "Enter/Edit License" dialog (see above).

The installed product is shown in black along with license information. The duration of any maintenance and support scheme you are subscribed to is shown below, along with its expiration date.

Any installed and up-to-date LCI license on your computer is shown under the heading 'Databases'. If your license allows use of other LCI databases, which have not (yet) been installed, this is shown with the word "missing" in grey.
If a newer version of one of the licensed LCI master databases is available for download on the server, a link will be provided to access the download page ("check online").

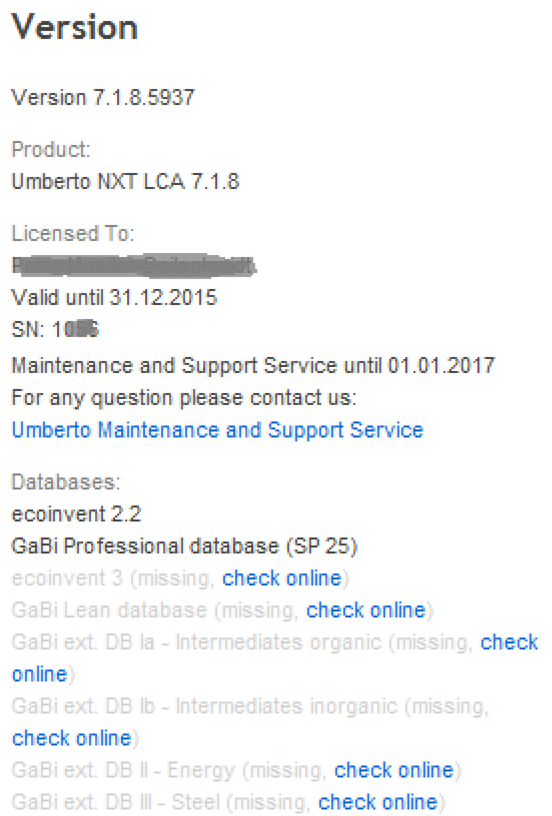


Figure 3: The 'Version' panel shows product information: In this example the GaBi Professional database is installed in addition to the ecoinvent databases. Further GaBi extension databases are available and the license key is enabled to run them, but the installation of these databases has not been done (yet).

To install updated or additional third-party LCI databases, click on the link supplied in the 'Version' panel or use the 'Check for Updates...' command from the Help menu. The list of available download packages will be shown in your browser page. Download the available installation files to your hard disk.

Once downloaded, run the LCI database installer file by clicking on the executable. You need local administrator rights on your machine for the installation. The installation is guided by a wizard.

The third-party LCI databases are governed by licensing terms of the provider of the data. During the installation of the additional LCI Databases you will be asked to accept the End User License Agreement (EULA) for the data.

At present the following additional LCI databases are available as separate installer files (depending on your license):

LCI Database	Installer File Name	Req. Hard Disk Space
ecoinvent v2.2 database	ecoinvent2_for_umberto-lcaplus-v10.x.x.xxx.exe	1.5 GB
ecoinvent v3.2 database	ecoinvent3_for_umberto-lcaplus-v10.x.x.xxx.exe	12.8 GB
GaBi Professional database	GaBiProf_for_umberto-lcaplus-v10.x.x.xxx.exe	570 MB
GaBi Lean database	GaBiLean_for_umberto-lcaplus-v10.x.x.xxx.exe	70 MB
GaBi Extension database Ia - Intermediates organic	GaBiIa_for_umberto-lcaplus-v10.x.x.xxx.exe	30 MB

GaBi Extension database Ib - Intermediates inorganic	GaBiIb_for_umberto-lcaplus-v10.x.x.xxx.exe	20 MB
GaBi Extension database II - Energy	GaBiII_for_umberto-lcaplus-v10.x.x.xxx.exe	200 MB
GaBi Extension database III – Steel	GaBiIII_for_umberto-lcaplus-v10.x.x.xxx.exe	10 MB
GaBi Extension database IV - Aluminium	GaBiIV_for_umberto-lcaplus-v10.x.x.xxx.exe	20 MB
GaBi Extension database V - Non-ferrous metal	GaBiV_for_umberto-lcaplus-v10.x.x.xxx.exe	5 MB
GaBi Extension database VI - Precious metals	GaBiVI_for_umberto-lcaplus-v10.x.x.xxx.exe	10 MB
GaBi Extension database VII - Plastics	GaBiVII_for_umberto-lcaplus-v10.x.x.xxx.exe	25 MB
GaBi Extension database VIII - Coatings	GaBiVIII_for_umberto-lcaplus-v10.x.x.xxx.exe	15 MB
GaBi Extension database IX - End of life	GaBiIX_for_umberto-lcaplus-v10.x.x.xxx.exe	20 MB
GaBi Extension database X - Manufacturing	GaBiX_for_umberto-lcaplus-v10.x.x.xxx.exe	7 MB
GaBi Extension database XI - Electronics	GaBiXI_for_umberto-lcaplus-v10.x.x.xxx.exe	45 MB
GaBi Extension database XII - Renewable raw materials	GaBiXII_for_umberto-lcaplus-v10.x.x.xxx.exe	25 MB
GaBi Extension database XIII - ecoinvent 2.2 integrated	GaBiXIII_for_umberto-lcaplus-v10.x.x.xxx.exe	920 MB
GaBi Extension database XIIIb - ecoinvent 3.1 integrated	GaBiXIIIb_for_umberto-lcaplus-v10.x.x.xxx.exe	3.0 GB
GaBi Extension database XIV - Construction materials	GaBiXIV_for_umberto-lcaplus-v10.x.x.xxx.exe	590 MB
GaBi Extension database XV - Textile finishing	GaBiXV_for_umberto-lcaplus-v10.x.x.xxx.exe	20 MB
GaBi Extension database XVI - Seat covers	GaBiXVI_for_umberto-lcaplus-v10.x.x.xxx.exe	10 MB
GaBi Extension database XVII - Full U.S. database	GaBiXVII_for_umberto-lcaplus-v10.x.x.xxx.exe	145 MB
GaBi Extension database XVIII - NREL U.S. LCI integrated	GaBiXVIII_for_umberto-lcaplus-v10.x.x.xxx.exe	30 MB
GaBi Extension database XIX - Bioplastics	GaBiXIX_for_umberto-lcaplus-v10.x.x.xxx.exe	30 MB
GaBi Extension database XX – Food & Feed	GaBiXX_for_umberto-lcaplus-v10.x.x.xxx.exe	75 MB
GaBi Extension database XXI – India	GaBiXXI_for_umberto-lcaplus-v10.x.x.xxx.exe	20 MB

For more detail on the LCI database content of different third-party databases, please check http://www.ifu.com

The LCI databases will be extracted upon first launch of Umberto after installation. This process may take several minutes and is indicated in the splash screen with a message. Please be patient as this large database is extracted. The start-up of the application will be faster after the first launch.

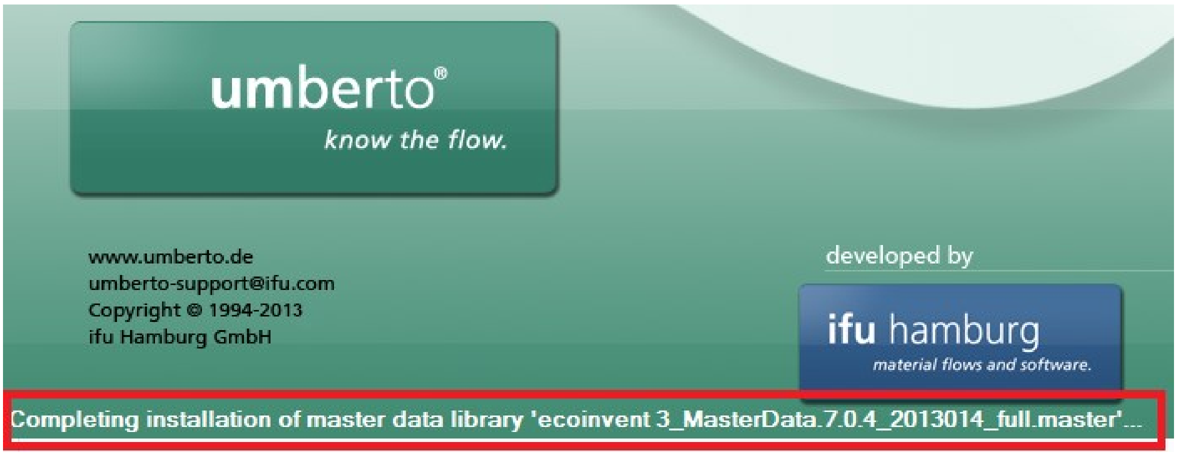


Figure 4: Extraction of the master database upon first start-up of the application

Update of LCI Databases: When new versions of the third-party LCI databases are released, a notification on the start page will inform about the update, if your license is enabled to run this database. Click on the link shown to access a web page where you can download the new version.

A web browser will show the update notification page and one or more new or updated files.

You can also use the command 'Check for Updates…' from the Help menu, to find out whether updates for the software or for one of the licensed LCI databases are available.

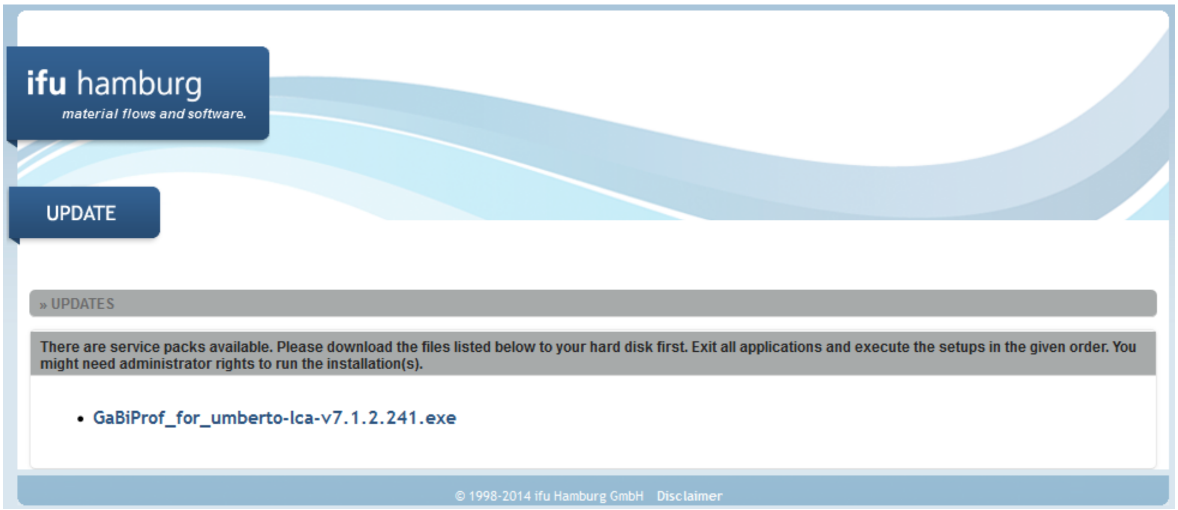


Figure 5: The update notification page information indicates when new or updated database installation files are available. The installer file can be downloaded and installed directly.

An update installation of the LCI master databases does not automatically update the models that have been created using datasets from previously installed LCI master databases. Please read in section 9.1 on how to update your models after new master databases were made available in the software.

Please mind that both, the automatic update notification as well as the check for updates feature might not work, if you don't have access to the Internet, or if security settings of your firewall prohibit communication with the update server. In this case, please check the community board for announcements regularly, and contact ifu Hamburg GmbH for a new version to be sent.

The update notification service can be deactivated in the Options dialog accessible via the Tools menu.

2.5 Support

The help system (Menu Help > Index, or press F1 on the keyboard) is always the first option when you have a question on the software. It describes the functions available, but also contains hints on the use of Umberto LCA+, and on modelling the product life cycle.

For technical support issues the help desk can be reached by e-mail at support@umberto.de or umberto-support@ifu.com. Please indicate the exact version number (see About dialog) of Umberto LCA+ you are using, and the operating system of your computer. Please try to be as specific as possible when explaining the technical problem that occurred.

In some cases our help desk will ask you to submit log files from your computer, which can help us identify the issue. The log files can be found in Window 7/8/10 at the following default location (localized operating systems might have different folder names): C:\Users\%uSER%\AppData\Local\ifu Hamburg\UmbertoLCAPlus\%version%\Logs

The log files "platform.general.log" and "umberto.full.log" are the ones that our help desk requires in most cases. They can be viewed with a simple text editor.

A community forum (bulletin board) is available at http://my.umberto.de. It contains useful tips and tricks, and also has a FAQ (frequently asked questions) section. You can browse the posts of other users of Umberto LCA+ and discuss with them.

For support on ecoinvent LCI data and questions pertaining to the content of the datasets, please contact support@ecoinvent.org.

For support on GaBi LCI databases and questions pertaining to the content of the datasets, please contact ifu Hamburg GmbH.

2.6 Uninstalling

To uninstall Umberto LCA+ from your computer, run the de-installation from the command in the Start menu group. Alternatively, you may want to remove the software via the Control Panel > Add/Remove Programs.

A deinstallation of the product is proposed when running the installation of a newer version of the software. The installation wizard will advise to uninstall a previous version, when a newer version is being installed. Please uninstall prior to installing a new version.

3 A Primer on Life Cycle Assessment

The information is intended as a short summary on Life Cycle Assessment. It is not thought to substitute the use of official guidance publications or standards; neither does it replace books that have been written on how to do a Life Cycle Assessment study A list of selected recommended literature is given in section 3.7.

3.1 Definitions

The Life Cycle Assessment (LCA) methodology has been established since the late 1990ies and its elements are specified in the ISO standards 14040:2006 and 14044:2006.

The Society of Environmental Toxicology and Chemistry defines Life Cycle Assessment as follows: "The life cycle assessment is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and material usage and environmental releases, to assess the impacts of those energy and material uses and releases to the environment, and to evaluate and implement opportunities to effect environmental improvements. The assessment includes the entire life cycle of the product, process, or activity, encompassing extracting and processing raw materials; manufacturing transportation and distribution; use/re-use/maintenance; recycling, and final disposal." (Guidelines for Life-Cycle Assessment: A 'Code of Practice', SETAC, Brussels, 1993)

ISO 14040 defines Life Cycle Assessment as follows: "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product by:
1. Compiling an inventory of relevant inputs and outputs of a product system;
2. Evaluating the potential environmental impacts associated with those inputs and outputs;
3. Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.
LCA studies the environmental aspects and potential impacts throughout the product's life (i.e. cradle to grave) from raw materials acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences".

The ILCD Handbook defines Life Cycle Assessment as follows: "Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardised method. It quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with the entire life cycle of any goods or services ('products')."

3.2 Goal and Scope

Life Cycle Assessment (LCA) is a method to assess the environmental impacts associated with goods and services covering the whole lifespan of a product. It can serve to improve the overall environmental performance of a product, or it can be the basis for communicating achievements of the manufacturer towards sustainable production. Umberto for LCA is a tool to reach these goals in accordance with international standards.

When starting with LCA, before modelling or calculating product flows and emissions, certain characteristics of the study should be defined. This part of LCA is commonly referred to as defining the scope.

The topic 'Goal and Scope' is addressed in section 5.2 of the ISO14040:2006 standard

Goal and scope definition are addressed in sections 5 and 6 of the ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance

Depending on the target group of the study two major approaches to LCA are relevant. When the target group is the consumer of a product a full scale LCA comprising of five life cycle stages is advised. These life cycle stages are raw material extraction, manufacturing, distribution/retail, use and disposal of the product. This type of LCA is called a cradle-to-grave LCA. When the production process under study is itself a production of semi-finished products a cradle-to-gate LCA can be undertaken. This means all processes from raw material extraction up to the own factory gate are assessed but the distribution, use and disposal stages do not form part of the analysis. This type of LCA usually applies for communication to downstream manufacturers or for an environmental product declaration (EPD) according to ISO 14025.

The user may however choose any number of life cycle stages to assess. For example all transportations of raw materials or products can be located in a separate life cycle stage. When assigning a process to a stage in Umberto LCA+ the environmental burden associated with this process will also be assigned to that stage in the calculation results.

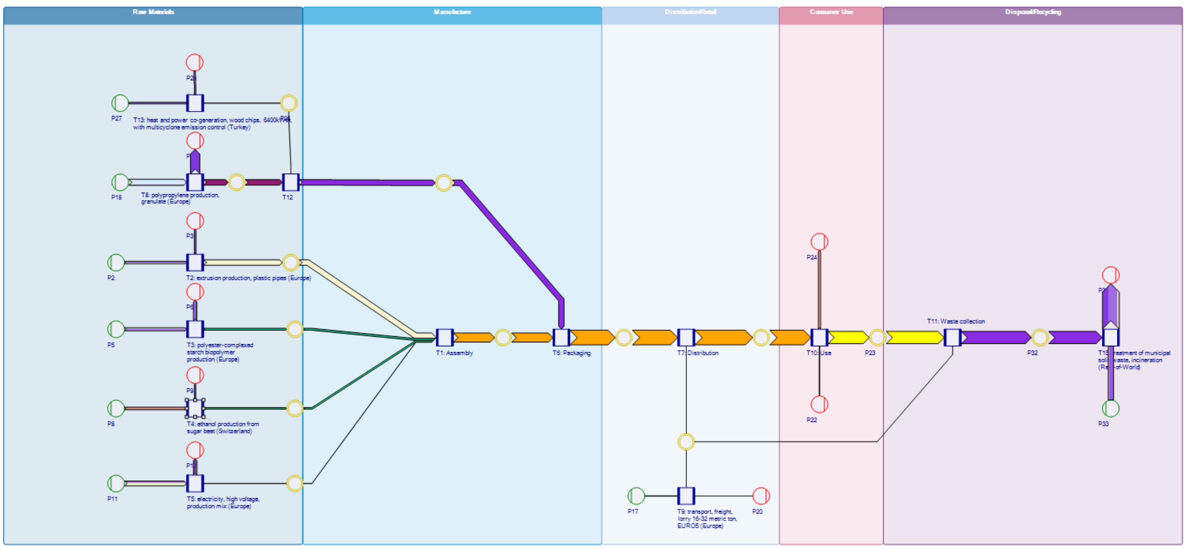


Figure 6: Model of a production system consisting of five life cycle stages

Functional Unit

After the scope of LCA is determined the functional unit must be defined. According to ISO 14040 the functional unit is the "quantified performance of a product system to use as a reference flow". That means that the functional unit must fulfil a function and it must be scalable. Especially when a cradle-to-grave LCA is performed the lifespan or performance of the product forms part of the functional unit.

The functional unit for paint production may be "covering 1 square meter of interior wall over 10 years" while for a service technician a LCA may assess the functional unit "ensuring less than 5% downtime over 1 year". For cradle-to-gate LCAs the functional unit is typically one unit of product, e.g. "1 kg expandable polystyrene at factory gate".

The topic 'Functional Unit' is addressed in section 5.2.2 of the ISO14040:2006 standard

The topic 'Functional Unit' is addressed in section 6.4 of the ILCD Handbook – General guide to LCA

System Boundary

With the definition of type and functional unit of the LCA it is usually apparent which processes in the product life cycle should be included and which processes can be omitted. All included processes are within the system boundary. When defining the system boundary it should be ensured that all processes have the same depth, i.e. all raw materials are included beginning with the extraction from soil/biosphere and emissions are followed until the release into the environment.

The system boundary can be defined in respect of technological boundaries, geographical boundaries and temporal boundaries. A common example of a temporal system boundary is the assessment of the global warming potential (GWP), which is typically assessed for 20, 100 or 500 years depending on the context of the study.

The topic 'System Boundary' is addressed in section 5.2.3 of the ISO14040:2006 standard

The topic 'System Boundary' is addressed in section 6.6 of the ILCD Handbook – General guide to LCA

Cut-Off

During the assessment it may become clear that certain processes are likely to have only a minor impact on overall results according to the scope of the study and other processes contribute more than expected to the environmental performance. Then it might be an option to change the system boundary to exclude irrelevant processes and study relevant processes more closely. The international standards ISO 14040/14044 encourage this type of iterative procedure: cut-offs can be made, if the following criteria are met: In regard to mass, the contribution of an input is less than 1% of the overall mass inputs to the product system, and less than 5% of the mass inputs to the individual process. In regard to energy, the contribution of an energy input is less than 1% of the overall energy inputs to the product packaging system, and less than 5% of the energy inputs to the individual process. Furthermore, before doing a cut-off, it must be checked that the environmental relevance of the excluded flow can be considered minor.

The topic 'Cut Off' is addressed in section 4.2.3.3.3 of the ISO 14040:2006 standard

The topic 'Cut Off' is addressed in section 6.6.3 of the ILCD Handbook – General guide to LCA

3.3 Life Cycle Inventory (LCI)

The international standard ISO 14044 recommends drawing a flow diagram including all processes (ISO calls them "modules") within in the system boundary and their material flows. This can be an iterative process starting with a rough overview of production phases and later redefining more specific processes.

Umberto LCA+ supports a graphical approach to modelling. The LCA model set up in the Net Editor is the central working instrument of the LCA. The model can be modified, adapted and expanded. The parameters defined in the model can be adapted to study the differences caused by variations. Copies of the model can be created to study alternatives.

When the production system is modelled, each process must be specified. Specifying a process means that all inputs and outputs of each process are linked by functions. The easiest type of specification and for most cases the most fitting type is a linear specification using coefficients (see figure below). The specification can be read as: in order to produce 1 kg of product 1.1 kg of raw materials and 2 MJ of energy are needed and result in unwanted emissions of 0.1 kg.

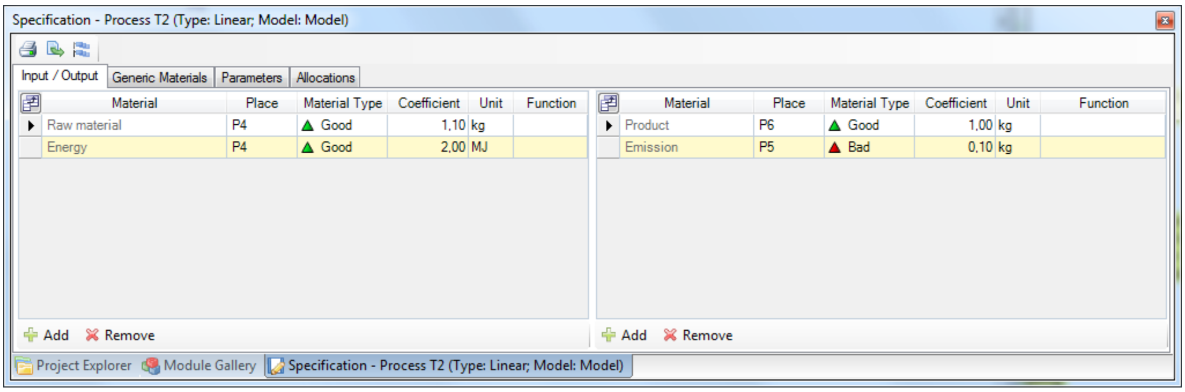


Figure 7: Simple linear process specification (sample only, fictitious values)

All processes in the life cycle model should be specified completely, so that all inputs and outputs are accounted for. A good way to estimate the completeness of a process specification is to check the process for mass balance, energy balance, or carbon balance, depending on the context of the study. However, most standards and guidelines allow for cut-off criteria which allow a certain percentage of mass or anticipated environmental effects to be left out of the specification.

Data Handling

In order to specify all relevant processes, data must be collected. The first option is to collect primary data directly from the production site and from suppliers. The quality of the collected data is crucial for the validity of the obtained results. Assumptions made on faulty data may lead to contrary effects in regard to the intended results.

Usually not all data can be collected as primary data (e.g. based on measurements) throughout the production cycle. Some data can maybe only be estimated based on expert knowledge; other data must be approximated with the use of secondary data from published sources.

Umberto LCA+ can be used with the ecoinvent LCI database and/or GaBi LCI databases as sources for secondary data used in the background for processes where no primary data is available.

When estimating data, a conservative approach should be used, i.e. the worst case scenario should be assumed. In many cases processes that must be estimated do not contribute significantly to the overall results. However, if they do, it is advisable to investigate the process in question more and refine the estimation.

For some processes the specification is difficult because more than one product leaves the process and it is difficult to determine which product contributes how much to the overall process. This is called an allocation problem and will be discussed further below.

Secondary data can be grouped into two types of activity data: Unit Processes and System Terminated (Aggregated) Processes.

Unit Processes: Unit process modules represent individual processes or single processing steps within the production chain. They feature input and outputs of one production step with the coefficients representing the functional relationship between inputs and outputs. These inputs and outputs are typically the so-called intermediate exchanges (see section 6.3) since these flows are within the technosphere. There might also be direct intakes from nature or direct emissions to nature (the system environment). These direct intakes or emissions are typically elementary exchanges (see section 6.4).

Unit processes with their inputs and outputs are typically used when describing a process with using primary data. The practitioner must take care to connect a delivering process for each intermediate exchange on the input side and processes that consume (take up) every intermediate exchange on the output side, in order to embed a unit process into the process chain. These connected processes can again be unit processes or – in case detailed data is not obtainable or the scope of the study does not allow more in depth research – a system terminated process (also called a result process).

Unit and Result Processes (Activities) and their use in the Life Cycle Model are described in section 3.3 of this user manual.

System Terminated (Result) Processes: Result processes represent a whole life cycle inventory of products or services. By using a system terminated process module, the complete production chain with all (sometimes many hundred) process steps is included. This allows accounting for an upstream or downstream process chain and closing (terminating) a supply chain. For example when using electric energy in a life cycle assessment study for a product many guidelines suggest to use the country specific consumer mix of electric energy. The system terminated or result process module for electric energy includes the complete life cycle with the individual energies produced from different energy carriers or fuels. Almost all production chains use electric energy but it does not need to be modelled individually in every LCA.

The use of system terminated (result) processes has advantages and disadvantages. The good thing is that the use of a system terminated activity dataset from a reliable source reduced tremendously the work load, since these datasets already represent an average for the product or service, and can be used in an LCA study as a good approximation and representation of the actual production process, which would otherwise have to be researched and modelled by the practitioner by himself/herself. On the other hand, if information about the individual process steps and about the contributions of the individual stages of the supply chain to certain environmental impacts are to be studied, the system terminated (result) dataset does not reveal details. In this case the practitioner must dissolve the encapsulated dataset and model further individual processing steps as unit processes.

Secondary data on processes can be found in many sources, and the ecoinvent LCI database (providing activity datasets both as unit process and as system terminated (result) processes) is one of these sources. Further sources for secondary data include governmental sites, trade organisations, or technical documentation. It is important to check whether the secondary data has been published for purposes of LCA and whether it is consistent with the scope of the LCA. A common uncertainty is the inclusion or exclusion of infrastructure which may contribute significantly to overall results. An important check for the appropriateness of secondary data is the plausibility.

Literature data is a special class of secondary data as it results from peer reviewed scientific publications. These publications may cover only a special case or a fraction of a production process. Therefore this literature should be used with the same critical approach as all other data.

Especially when estimating data and using secondary data from non-reviewed sources, it becomes difficult to ensure an appropriate data quality.

The topic 'Data Quality' is addressed in section 4.2.3.6 of the ISO 14044:2006 standard

The ILCD handbook on LCA provides specific guidelines to assess the data quality for every process. See Chapter 12, Annex A: Data quality concept and approach

3.4 Allocation

In some life cycle models all processes are specified in regard to a single product being produced. All activities can be attributed with their environmental burdens entirely to the one product being produced, the system reference flow.

In real-world production systems, however, the manufacturing process often yields more than one output. For example, there are side-products (co-products) in a production step that can be used in other production processes, or off-heat of a process can be used to produce energy. In these cases a decision must be made what fraction of inputs and what fractions of the emissions are assigned to each of the products yielded by the process. This decision is called allocation and it may have a significant effect on the modelling results. All LCA frameworks advise to use the same allocation technique, sometimes referred to as system model, throughout the whole life cycle analysis.

The topic 'Allocation' is addressed in section 4.3.4 of the ISO 14044:2006 standard

The topic 'Allocation' is addressed in section 6.6.3 of the ILCD Handbook – General guide to LCA

In the following different approaches to handle allocation are shown.

Subdivision (Partitioning)
When facing an allocation problem, the first step should always be to analyse the process with the allocation further and maybe subdivide this process into individual processes that each yield a single process. This may lead to avoiding allocation altogether.

System Expansion
If avoiding of allocation is not possible it may be advisable to expand the function of the system to include the second product of the process under study. For example the production of heat is often connected with many production processes. When the excess heat energy is used for heating of buildings not associated with the production it can be regarded as a co-product. The system boundary would therefore be expanded to include not only the production of the product under study but also the production of heat energy to be used for heating of buildings.

System Expansion with Avoided Burden (Credit)
In some cases the specific scope of the study does not allow the inclusion of co-products into the results. In these cases an allocation has to be executed.

One approach to identify the contribution of a co-product to the overall results is the calculation of the avoided burden. In the above example the avoided burden are the environmental impacts that do not occur because of the production of heat in the product system under study. If the production process would not produce heat, the external building would have to be heated with the combustion of fuels such as heating oil. Avoiding the consumption of heating oil and its associated emissions is the value of the co-product.

The topics 'Allocation using Partitioning' and 'Allocation using System Expansion' is addressed in section 4.3.4.2 of the ISO 14044:2006 standard

The topics 'Allocation using Partitioning' and 'Allocation using System Expansion' is addressed in section 6.6.3 of the ILCD Handbook – General guide to LCA

Another topic discussed in the context of allocation is the question of consequential versus attributional handling of co-products yielded by a process.

Consequential Co-Product Handling

It has been argued in many methodological debates that simply calculating the avoided burden with an equivalent process is not displaying results adequately due to the exclusion of off-setting mechanisms. For example it could be argued, that the heat in the previous example would not only displace combustion of fuel as in the avoided burden approach. Depending on market mechanisms it is also possible that instead of heating with more fuel, the external building would be equipped with better insulation. Therefore, in this example, not only the combustion of fuel but also the production, installation and disposal of insulation material would be part of the avoided burden associated with the co-product of the manufacturing process under study. It is important to communicate all assumptions and market constraints that lead to the calculation of the avoided burden.

Handling the co-products in a consequential manner is not equivalent to the consequential system modelling. Consequential modelling on a system level is "aiming at describing how environmentally relevant physical flows to and from the technological system will change in response to possible changes in the life cycle" (Ekvall, 2004).

Attributional Co-Product Handling

Another approach to analyse the effects of a multi-product process is attributional co-product handling. In this approach it is attempted to assign physical flows directly to one or other products of a process. ISO states that physical relationships shall be used. That means a science based decision on the ratio of inputs and outputs to the products. The easiest way is the allocation by mass, simply dividing all inputs and outputs by the ratio of the mass of the products. However, all other science based allocation rules are possible as well and might be the best choice for a specific allocation problem. Examples are calorific value, dry mass, carbon content or others. Even while all these properties may be a basis for allocation, it is very important to state exactly which property has been used as a basis for allocation in order to allow for reproducible results. An allocation due to economic value is also possible; however, as prices may change over time, results may be irreproducible.

Use the tab "Allocations" in the transition specification to define the allocation method. The default method is allocation by mass as it is applicable for most processes. If you want to use another method simply add allocation factors for each input and emission by choosing user defined allocation. Press [F9] to start the calculation of the life cycle inventory.

Attributional and consequential modelling are addressed in section 7 of the ILCD Handbook – General guide to LCA

3.5 Life Cycle Impact Assessment (LCIA)

Impact assessment is the part in LCA where predictions on environmental effects of the production system are made. For an impact assessment life cycle inventory results are associated with specific environmental impact categories. The link between life cycle inventory results and impact categories are the characterization factors for each elementary flow, i.e. each flow across the system boundary that is not a product.

Important Hint: While some methods of impact assessment only calculate impact category indicators based on characterization factors others attempt to rate the environmental performance of a production system based on normalization, order, points or other criteria. Throughout Umberto the term valuation is used for any method of impact assessment based on material flows crossing the system boundary. When performing a LCA be sure to regard the guidelines and requirements of the standard underlying your LCA.

The choice of impact categories, as well as the level of detail, depends on the goal and scope of the study. The other elements of an impact assessment are classification and characterization of the LCI results leading to the category indicator results (LCIA results). Optional elements are normalization, grouping and/or weighing of the LCIA results.

Currently 36 different groups of impact assessment categories are supported by Umberto LCA+ calculating both the mandatory and the optional impact assessment elements. The user may choose individual impact categories throughout all available models and show environmental impacts of the production system as Sankey diagrams.

To view the characterization factor for the materials right-click on the material in the project explorer and choose "View Impact Assessment Factors". As a default only the activated impact categories are shown.

3.6 Interpretation

Interpretation is the part in a life cycle assessment study where results of the LCIA step are discussed and interpreted. The interpretation is based on the definition of the goal and scope of the study.

The life cycle interpretation of an LCA comprises three main elements: identification of the significant issues based on the results of the LCI and LCIA phases of the LCA study, evaluation of results, including completeness, sensitivity and consistency checks. Results from uncertainty analysis and data quality analysis are considered as well. Finally, the interpretation draws conclusions and gives recommendations mentioning limitations of the study.

3.7 Literature on Life Cycle Assessment

Baumann, Henrikke; Tillman, Anne-Marie (2004): The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application. January 2011. Lund: Studentlitteratur.

DIN EN ISO 14025 (2006): Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures

DIN EN ISO 14040 (2006): Environmental management -- Life cycle assessment -- Principles and framework

DIN EN ISO 14044 (2006): Environmental management -- Life cycle assessment -- Requirements and guidelines

Ekvall & Finnveden (2001) Allocation in ISO 14041 – a critical review, Journal of Cleaner Production 9(2001): 197-208

Ekvall & Weidema (2004) System boundaries and input data in consequential life cycle inventory analysis, Int J LCA 9(3): 161-171

European Commission – Joint Research Centre – Institute for Environment and Sustainability (2010/2011): International Reference Life Cycle Data System (ILCD) Handbook. Series of guidance documents for good practice in Life Cycle Assessment. Luxembourg: Publications Office of the European Union

Guinée J B (Ed.) (2002) Handbook on Life Cycle Assessment, Operational Guide to the ISO Standards, Kluwer, Dordrecht

Hendrickson et al. (1998) Economic Input-Output Models for Environmental Life-Cycle Assessment, Env. Sci. & Tech. 32: 184A-191A

Klöpffer, Walter; Grahl, Birgit (2009): Ökobilanz (LCA). Ein Leitfaden für Ausbildung und Beruf. Weinheim: Wiley-VCH.

Lindfors, Ekvall, Eriksson, Jelse and Rydberg / IVL Swedish Environmental Institute (2010): The ILCD Handbook in a Nutshell. A brief analysis of the ILCD Handbook and the Draft Guidance on Product Environment Footprint. IVL Report B2020

Society of Environmental Toxicology and Chemistry SETAC (1993): Guidelines for Life-Cycle Assessment: A 'Code of Practice', SETAC, Brussels

United Nations Environment Programme UNEP (1999): Towards a Global Use of Life Cycle Assessment

United Nations Environment Programme UNEP (2003): Evaluation of Environmental Impacts in Life Cycle Assessment

United Nations Environment Programme UNEP (2005): Life Cycle Approaches - The road from analysis to practice

United Nations Environment Programme UNEP (2007): Life Cycle Management: A business guide to sustainability

United Nations Environment Programme UNEP (2008): Life Cycle Assessment - A product-oriented method for sustainability analysis. Training Manual November 2008

United Nations Environment Programme UNEP (2009): Guidelines for Social Life Cycle Assessment of Products

United Nations Environment Programme UNEP (2011): Towards a Life Cycle Sustainability Assessment - Making informed choices on products

United Nations Environment Programme UNEP (2011): Global Guidance Principles for Life Cycle Assessment Databases - A Basis for Greener Processes and Products

4 General Functions of Umberto LCA+

4.1 Handling Windows

The default window pane layout when starting up Umberto LCA+ has the following four main areas:

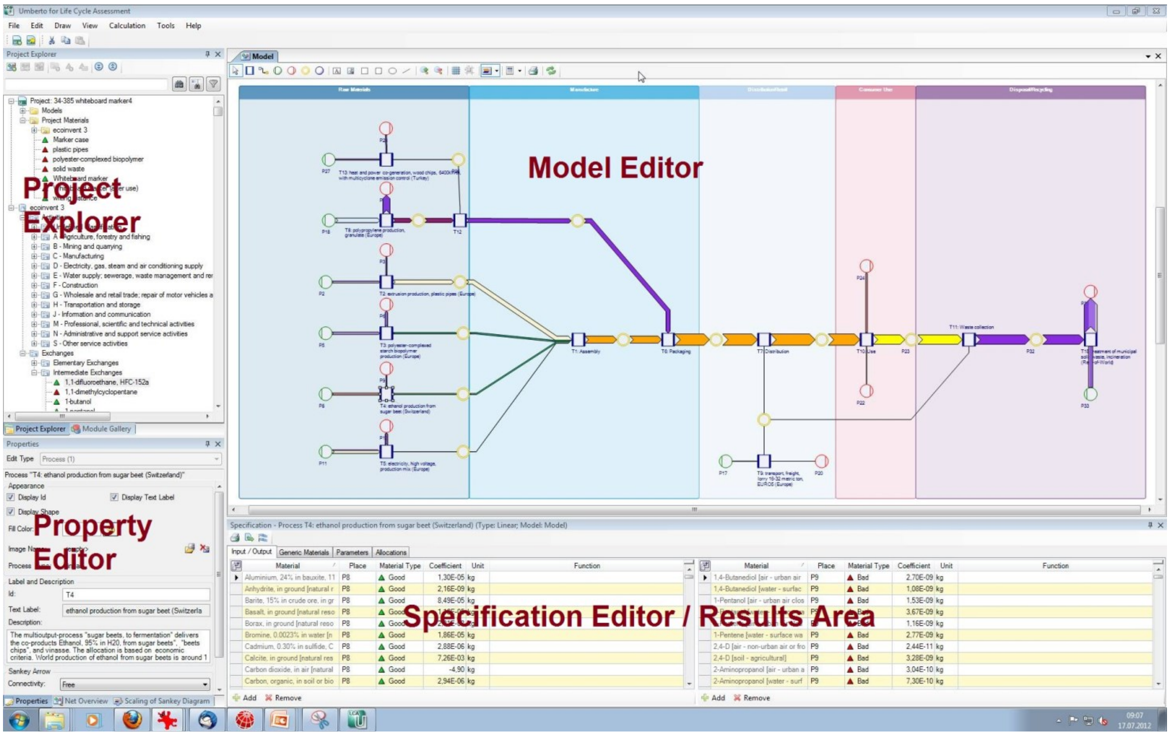


Figure 8: Typical windows layout of Umberto LCA: Project Explorer with material list on the left, the Model Editor with the graphical product life cycle model in the middle, and the Specification Editor pane. The Property Editor in the bottom left area shows properties of the selected model element or object.

The layout of the application in regard to the order of the window panes can be adapted. Windows can be tabulated, made floating, docked, pinned or set to auto hidden, and much more.

Tabulating Windows: To tabulate several windows one behind the other, drag it onto an existing window pane, and drop it onto the blue icon showing a tabbed window pane. You can access the window hidden behind another by clicking on the tab register.

Floating Windows: If you drop the window pane at a random location in the program window, it becomes a 'floating' window. If you don't want a floating window, you must dock it again.

Docking Windows: "Docking" a window means to attach it to an edge of the program window. This allows repositioning the various tool windows such as the Model Editor, the Property Editor, or the Specification / Results pane to dock against different application edges. To do this, move the floating window pane by clicking in the title bar of the window pane, drag it to the edge where you want to dock it, and drop it onto one of the blue arrows that appears near the edges of the program window.

Auto Hiding Windows / Pinned Window: In the top-right corner of every window pane, a button with a pin is located. If you click this button, the window pane is hidden (or "pinned" to the edge of the program window). However, you can still see the title of the window pane along the edge of the program window. When hovering the mouse over the title, the window pane temporarily displays again until you move the mouse off the window pane. Click the button again to "un-pin" the window pane.

Moving Windows: You can move a window pane wherever you want it by clicking the blue title bar and dragging the window where you want it.

Resizing Windows: You can easily resize the program window, dialog windows, and floating window panes by clicking the edge of the element and dragging it to the desired size.

Reset Window Layout: To reset the window panes to the default setting (Project Explorer on the left at the top, Property Editor on the left below, Model Editor taking the upper part of the main screen, Specification Editor and Result tables at the bottom) just select the 'Reset Window Layout' command from the View menu.

Double click on the title bar of a floating window to bring it back into its original position.

Umberto LCA+ is designed to work as multi screen application. You may want to keep the Model Editor window open on a large screen to allow for comfortable drawing of the life cycle model, while the main application windows are open on the other monitor.

Grid Handling: Most of the grids (tables) you find in Umberto LCA+ can be adapted to better suit your requirements and individual preferences. Some of the grids that can be modified that way are Process Specification (with tabs Input/Output, Generic Materials, Parameters, Allocations), and the result display on the pages Inventories and 'Results'.

Filtering: Some table grids, such as in the 'Search Material' dialog, offer the possibility to filter the entries displayed. Lists that can be filtered show a filter bar (as in the screen shot below). Click on the button next to the filter field for a column to set the filter condition. The default is "Contains". In the filter field type a string to set the filter, and reduce the number of entries shown in the list. Remove the filter by emptying the filter field or remove all filters with the button 'Clear All Filter' at the very left of the filter bar.

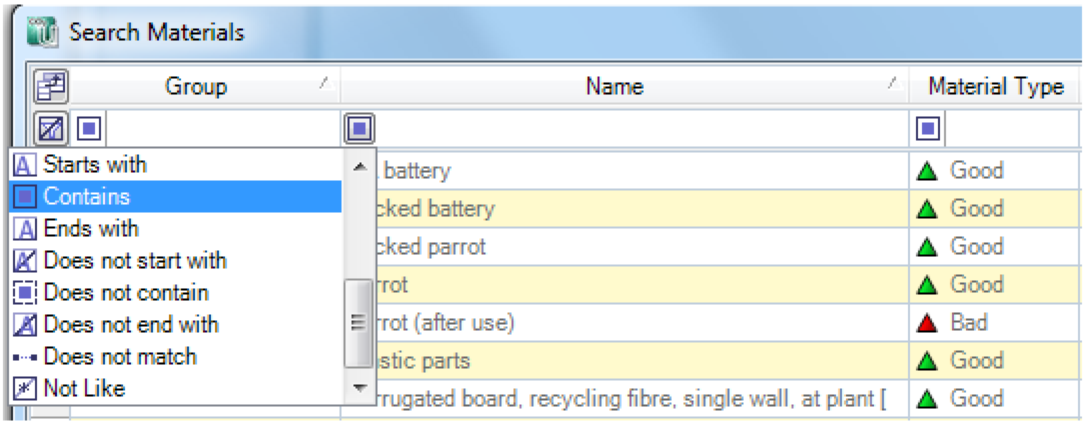


Figure 9: Filter setting in grid

Adapt Column Width: Drag the separator line of a column to the left or to the right to adapt the column width.

Change Column Order: Drag the column header horizontally and drop it on a separator line, to insert the column between two neighbouring columns. Two arrows indicate that you can drop the column header at the marked position.

Sort Order: Sort a table according to any column by clicking on the column header. A triangle in the column header indicates that the sort order of the grid depends on this column. Toggle ascending and descending sort order by clicking on the column header again (the indicator triangle turns round). To sort by more than one column, shift-click on a second column header.

Field Chooser: For each grid shown the columns can be configured to meet the needs. Click on the icon in the top left corner of a grid, to open the field chooser box. It will allow you to select and deselect each column. Deselected columns will be hidden. Note that pulling the column header out of the window will also remove a column from the display (deselect it in the field chooser box). To show hidden columns again, set a tick mark in front of its name in the field chooser.

Grouping: By dragging a column header to the area right above the column headers, you can group the entries in the table by that column. Hierarchical grouping is possible too. The entry groups can be collapsed by clicking on the minus symbol in the group header, the can be expanded by clicking on the plus sign.

To remove a table column from grouping, drag it from the grey grouping area back between the other column headers.

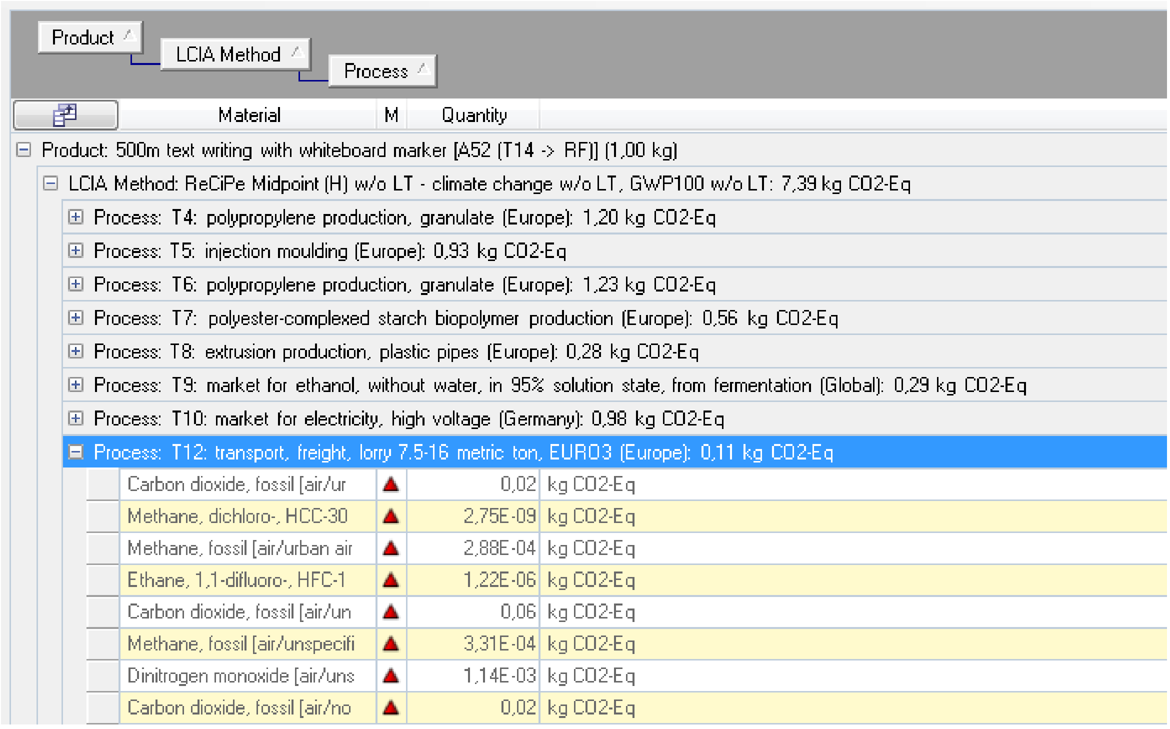


Figure 10: Grouping by per process for one impact category group in the LCIA Details pane

Grouping is helpful, e.g. to structure long inventory or result tables. For example, the inventory of a LCA model based on ecoinvent datasets with many hundred elementary exchanges can be grouped by processes.
There are also many different pre-configured views available which can be used for the most common grouping of tables.

Multi-Selection in Grids: Selecting multiple entries in a grid is possible: Individual entries can be marked by keeping the CTRL key pressed while clicking on entries. Several subsequent entries in a grid can be selected by clicking on the first entry, keeping the SHIFT key pressed, and clicking on the last entry to be selected.

Multi-selection in a specification window (e.g. Input/Output tab of the process specification) can be used for assigning places or for dragging entries. Dragging multiple items must start on the marker triangle in the first column.

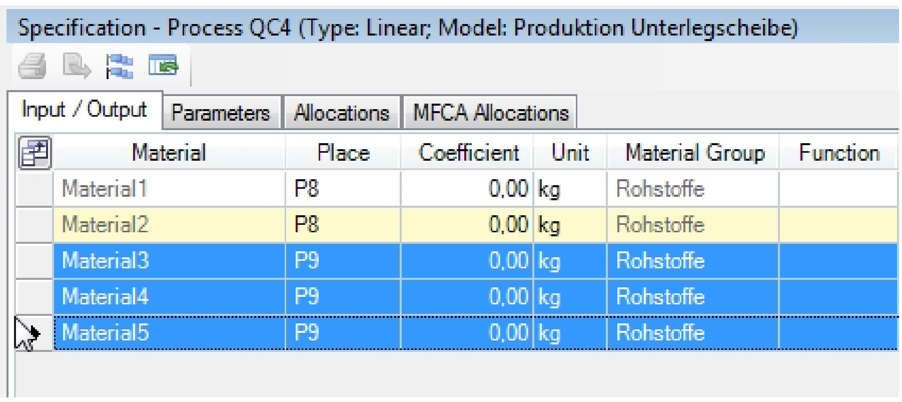


Figure 11: Selecting several entries in a grid, e.g. to drag them onto an element

4.2 Undo/Redo

Umberto LCA+ has an Undo and Redo functionality for almost all actions performed by the user in the course of a work session with the software.

Undo: To undo (revert) an action that has been done in the software, click on the button 'Undo' in the main toolbar or use the menu entry 'Undo' in the Edit menu. The hint of the button and the menu entry show the last action performed that will be undone. Alternatively use the keyboard shortcut CTRL-Z. Several actions can be reverted (undone) by repeating this action.

Redo: To redo (revert undo) an action that has been undone, click on the button 'Redo' or use the menu entry 'Redo' in the Edit menu. The bubble hint of the button and the menu entry show the last action performed that has been undone and that will be reverted. Alternatively use the keyboard shortcut CTRL-Y. Several actions can be redone by repeating this action.

Exemptions from Undo/Redo: The following actions cannot be undone

- Editor Actions for which an on/off toggle button exists (i.e. switch on/off editor grid)
- Copying a model or a section of a network model to the Module Gallery). Undo will not revert the deletion of the file stored to the Module Gallery.
- Export of a Diagram or a File, e.g. a graphics file or an Excel file that has been saved will not be deleted by an Undo action (file based action)
- Printing

4.3 Options

The options dialog can be called via the 'Tools' menu using the command 'Options...'. It contains application-wide option settings and the number format setting.

Application Settings: The update notification service can be deactivated in the Options dialog on the 'Application' tab. In this case, the software will not try to connect to the update server https://update.ifu.com to check whether updates are available.

If the option 'Confirm Unlocking of Activities' is set, a message will be displayed every time the user unlocks an activity master data set (see section 9.3 for a description of this feature). Experienced users can remove the warning by removing the tick mark for this option.

Number Format: The number format used in the project can be set by selecting the command 'Options' from the menu 'Tools'. A project must be open to define the number format.

On the 'Number Format' tab of the Options dialog, select the number format for the display of all numbers in the application (e.g. for the coefficients in the specification of a process, or for numbers in the result display tabs).

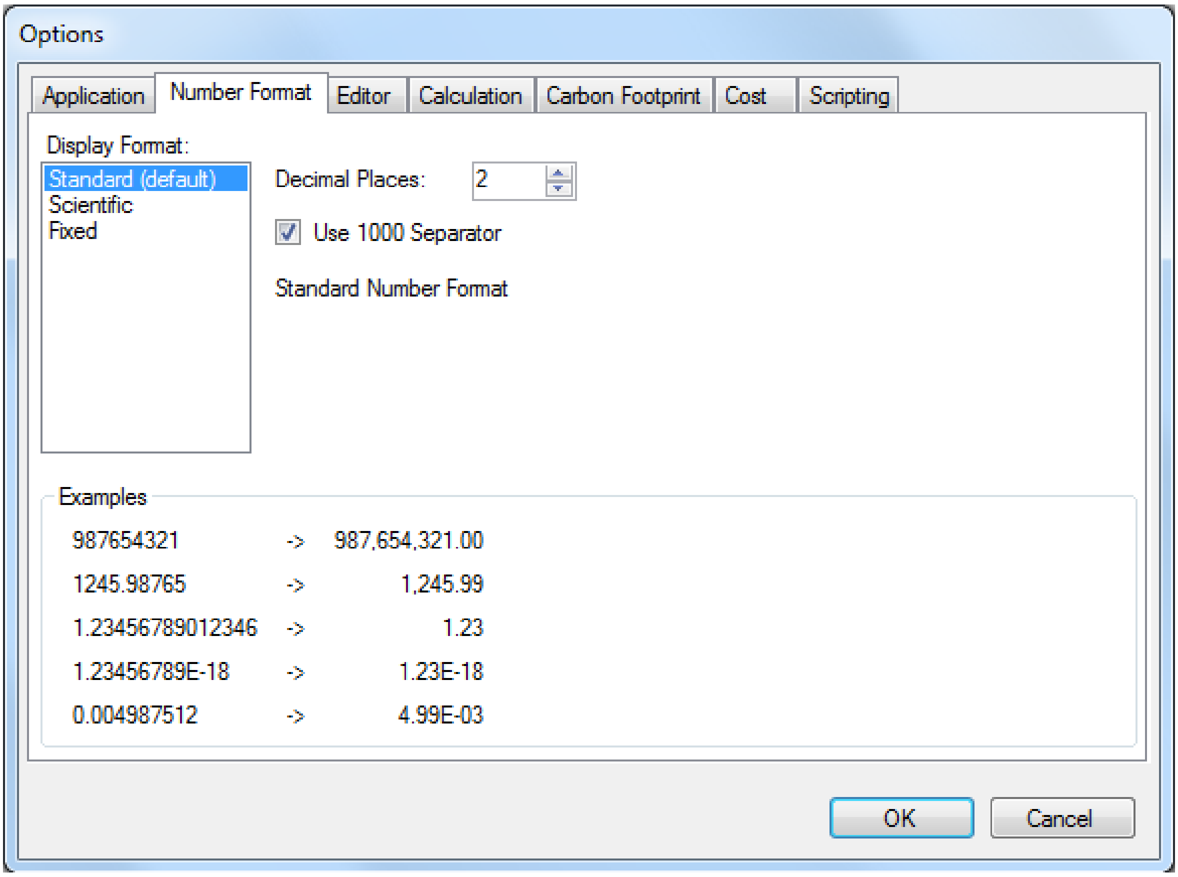


Figure 12: Number Format page of Options dialog

- **Default**: The default (standard) number format is with two decimal places, thousands separator and rounding where required. Numbers will be formatted to a width matching the display field.
- **Scientific**: The scientific number format is with an "E" (exponent) followed by a "+" or a "-" sign and the power shown with two digits.
- **Fixed**: The fixed number format rounds to the number of decimal digits defined in the "Decimal Places" field.

Examples for each number format in the individual setting are shown in the bottom panel of the window.

Mind that when the number format is set other than to 'Standard', e.g. to 'Fixed' with two decimal digits, the displayed value might be misleading at first sight, since these values will be rounded. Very small values will show as "0.00". The calculation is of course done using the exact value.

Editor: Set options for the default size of network elements 'Process' and 'Place' on this tab page of the Options dialog. The default setting is 32 px.

Additionally, you can opt to filter the number of flows shown in a Sankey diagram view of the LCA model. This improves the visual aspect and the performance of the diagram in case there is a multitude of flows that are to be displayed (such as the case for input and output elementary flows of Result processes from the ecoinvent LCI library, see 9.2).

You can turn of balance warnings in the panel 'Show Input/Output Imbalance Warnings'.

Calculation: There is only one option for calculation on this tab of the Options dialog. It refers to the calculation of LCIA results for intermediate flows. This calculation is indeed only necessary, if you are looking at cumulative impacts at a certain flow within the life cycle model, or if you are displaying the LCIA results for a subsection of the overall life cycle model. If you wish to see these intermediate LCIA values you can set a tick mark for the option "Include LCIA data of intermediate exchanges".

The option is turned off by default to increase calculation speed

Carbon Footprint: Select whether you wish to use impact assessment coefficients of the 'IPCC 2007 – climate change, GWP100a' (Fourth Assessment Report, AR4) or the 'IPCC 2013 – climate change, GWP100a' (Fifth Assessment Report, AR5) method.

This option is only relevant for the Carbon Footprint Result view and the MFCA Carbon Footprint Result views. Users working with one of the LCI databases (ecoinvent or GaBi) select their impact assessment methods in the 'LCIA Factors' from the Tools menu (see section 12.1)

Read more about scripting in the chapter 18.

Cost: On the 'Cost' tab the project currency can be defined. It is used in Umberto LCA+ for the market price of materials in one specific currency.

Choose the currency that should be used throughout your project from the drop down list. Note that there is no automatic currency conversion.

Scripting: Set the directory paths for library files used for scripting.

Read more about scripting in the chapter 18.

5 Projects and Models

5.1 Projects

When no project is open in Umberto LCA+, the icon of the root node in the Project Explorer indicates "No project open".

New Project: To create a new project, choose the command 'New' from the File menu. Alternatively you can use the button 'Create New Project File' or the quick link on the Start Page of the application.

When the project is opened, the 'Project Explorer' pane on the left side shows the models in this project in the 'Models' folder, and the 'Project Materials' folder for materials used in the models of the project.

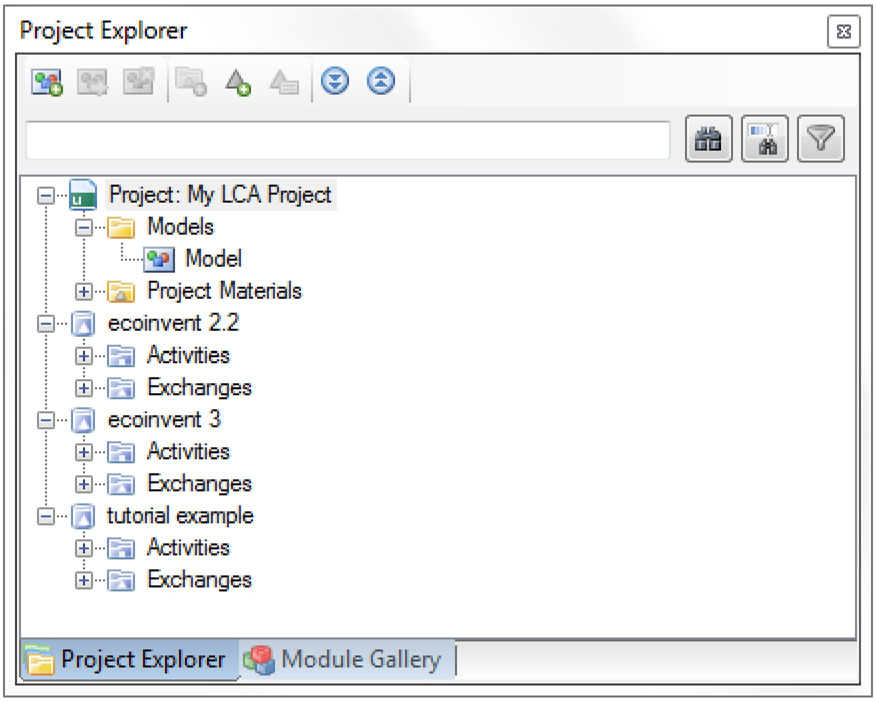


Figure 13: Project Explorer with open project, and three LCI databases installed.

Open Existing Project: To open an existing project file select the command 'Open' from the File menu. Alternatively you can use the button 'Open Project File'. Any project currently open will be closed before the other project is opened.

In the 'Open Umberto project file...' dialog choose the project file you wish to open. The project files have the file suffix ".umberto". The default storage location for project files is under the 'My Documents' folder (e.g. C:\Users\<username>\Documents\Umberto LCA+), but the project file can be stored anywhere (e.g. on a network drive, on a USB pen drive).

An alternative way to open a project file is to double-click on the file with the extension ".umberto" directly in the Windows file explorer.

Note that the files created with Umberto NXT CO2 also have the file extension ".umberto". Files created with the carbon footprint software Umberto NXT CO2 can be opened with Umberto LCA+ but will be converted. After having opened them in Umberto LCA+ they cannot be opened any more in Umberto CO2. It is recommended to create a backup copy of the project file, if you are using both software tools.

Close Project: To close the project file currently open use the command 'Close' from the File menu. It is not necessary to "save" your work, as Umberto LCA+ is a database application, where changes are always committed instantly.

Rename Project: It is currently not possible to rename an open project directly in the application. In order to give another name to the project, edit the file name directly in the Windows Explorer when Umberto LCA+ is closed.

Backup and Export Project: In order to backup a copy of your project (e.g. on an external drive or a CD), or to send the file to another user, you can just copy the project file. Make sure that Umberto LCA+ is not running with the project you intend to copy while making a backup copy. Projects in use cannot be copied.

Project files are stored with the file extension '.umberto'. The default directory for these files is "c:\My Documents\Umberto LCA".

5.2 Models

Within a project several LCA models can be created and opened. A model consists of a graphical representation of the life cycle of the product, made up from several elements, such as process, place and arrow. For further details see chapter 7 on network elements.

A model is made up at least from one net ('Main Net'). It may also contain one or more net layers on sub-levels, called subnets. Hence, a hierarchical model structure can be built. Subnets are explained in chapter 13.4.

Different models within one project can either represent different product life cycle models that are being compared within a Life Cycle Assessment study, or, variations of the same life cycle model e.g. with different parameters, different upstream materials, or different end-of-life scenarios.

New Model: To create a new model within a project click on the button 'New Model' in the Project Explorer window. Alternatively select the command 'New Model' from the context menu of the 'Model' root folder group, or use the quick link on the Start Page (when project is already open).

Open Existing Model: To open an existing model, double-click on the entry for the model in the Project Explorer window. Alternatively you can mark one model in the 'models' folder and click on the button 'Open Selected Model'.

The model opens in the Net Editor area on the right side of the screen. Several models can be opened at the same time; they are shown as tabbed windows in this area. To switch between different models, use the tabs or the dropdown menu in the top right corner of the Net Editor.

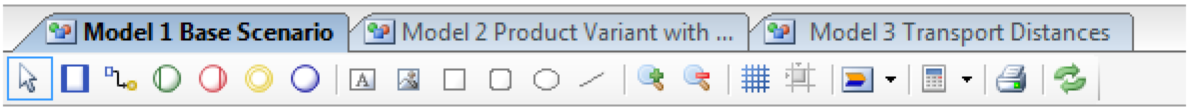


Figure 14: Several models are open within the project

Model Properties: Properties of a model, such as its name or a description can be edited in the Properties Editor. Click the entry for the model in the Project Explorer and make sure the Properties Editor is in front. Alternatively call the properties for a model via the context menu of the entry in the Project Explorer.

Read more about the elements that make up a life cycle model in the chapter 7.

Copy Model: To copy a model, or sections of a model, you can use copy&paste: Mark all elements of the model using CTRL-A, or select the network section to be copied. Then use the shortcut CTRL-C or the copy command from the Edit menu. The model (or model section) is copied to the clipboard. Directly switch to another model open and paste the clipboard content there (CTRL-V).

Note that flows manually specified in any arrow of the model or model section are not copied and may have to be entered, if required for calculation.

Alternatively, if you wish to reuse a model or a section of a model at another point in time or in another project, it can be stored to the Module Gallery (see section 7.6).

Close Model: To close a model click on the 'Close' button in the top right corner of the Net Editor (with the model being visible on top).

Delete Model: To delete a model, right mouse-click on the entry for the model in the Project Explorer and choose the command 'Delete' from the context menu.

5.3 Life Cycle Phases

Life cycle phases are the phases of the life cycle of a product. These are most commonly defined as 'Raw Materials', 'Assembly', 'Distribution', 'Use', and 'End-of-Life/Disposal', but can of course be defined differently in your specific model.

In Umberto LCA+ a breakdown of the result by phases of the life cycle is done using a graphical element overlay which helps to identify the limits of the individual phases in the editor.

Creating a Life Cycle Phases Frame: When creating a new model a dialog is shown that allows selecting a pre-defined life cycle phases frame or choosing one with two to fourteen unnamed phases. The typical five phases (cradle-to-grave) as well as the three phases for cradle-to-gate models are readily available. For other phases, click on the entry you prefer, then select 'OK'. If you click 'Cancel' no life cycle phases frame will be created.

The life cycle phase frame can be created at a later stage via the 'Life Cycle Phases' command in the 'Draw' menu.

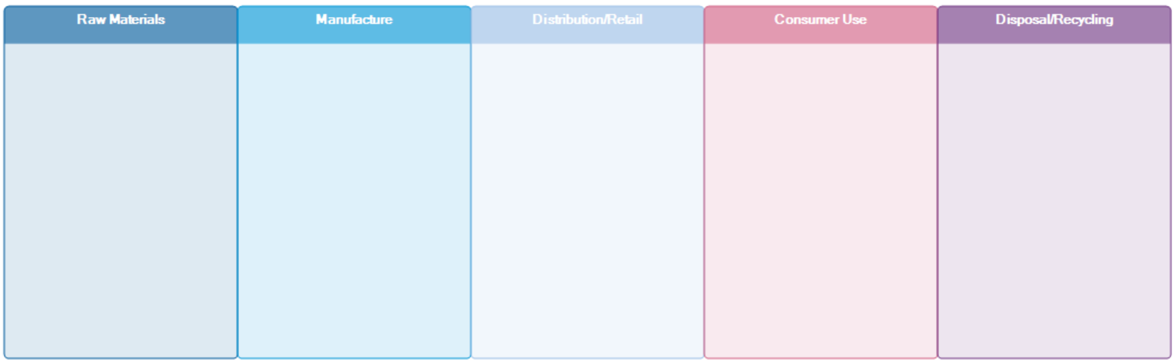


Figure 15: Life cycle phases frame with five phases. The preset colors and phase names can be adapted.

At present the life cycle phases frame is only available with a left-to-right orientation. It is advisable to build up your LCA model with a general left-to-right direction too.

The life cycle phases frame has two roles. Firstly, it serves to graphically structure the model, and to clearly see, in which phase a process lies. Secondly, it is also used for the display of the inventory results, when showing the contributions from each life cycle phase. The elementary exchanges of the life cycle inventory and the associated environmental impacts will be assigned to the phase where the place symbol is located. For more details see below in the chapter 12.1 on LCIA Results.

Moving and Resizing Life Cycle Phases Frame: The life cycle phases frame is created with a default size. However, as your model grows, it might be required to resize the frame, and to adapt the width of the columns that represent the phases.

To change the size of the life cycle phases frame, click on its border to mark it. Then drag a corner marker point to the desired size. To modify the height, drag the middle marker point in the top or bottom borderline segment to move it vertically. The left and right borderlines don't show marker points, as a change of the width also relates to the widths of the individual columns.

The column widths can be individually adapted by clicking in the header area of a phase. A grey marker appears, that can be dragged horizontally only. Adjust the width in such a way that processes lie in the phase they are assigned to. Note that it is not important in which phase connection places are located. You can of course also drag the process into the correct phase, rather than changing the width of a phase.

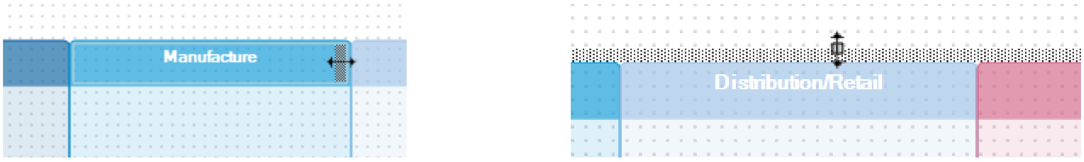


Figure 16: Change phase size and phase frame size

Remember that the life cycle phase frame and the location of the processes are important for a breakdown of the life cycle inventory results by contributions from the individual phases of the product life cycle. Changing the width of a life cycle phase or shifting elements from one phase to another may lead to a shifting of burdens into another life cycle phase.

Changing Properties of the Phases in a Life Cycle Phases Frame: To modify the properties of the phases in a life cycle phases frame, click on the border of the frame, to bring up its property editor.

At the top the life cycle phases are listed. Mark one entry in the list to edit its properties below. The name of the phase, shown in the header area, can be changed. To change the pre-defined default name of a life cycle phase click on the name in the header of the column and edit it in the Property Editor.

The colour that represents a phase can be adapted individually, by double-clicking on the colour mark, or clicking on the button 'Select Color'. The transparency of the column body and of the column header (caption) area can be set with the sliders below. Note that the colours set for the phases are also the colors that will be used for the chart showing the contribution analysis results (see section 12.1).

Should you wish to create a vertical spacing between the individual phases, enter a value in the 'Spacing' field. The border line can be turned off by removing the check mark in front of the 'Display Border' option.

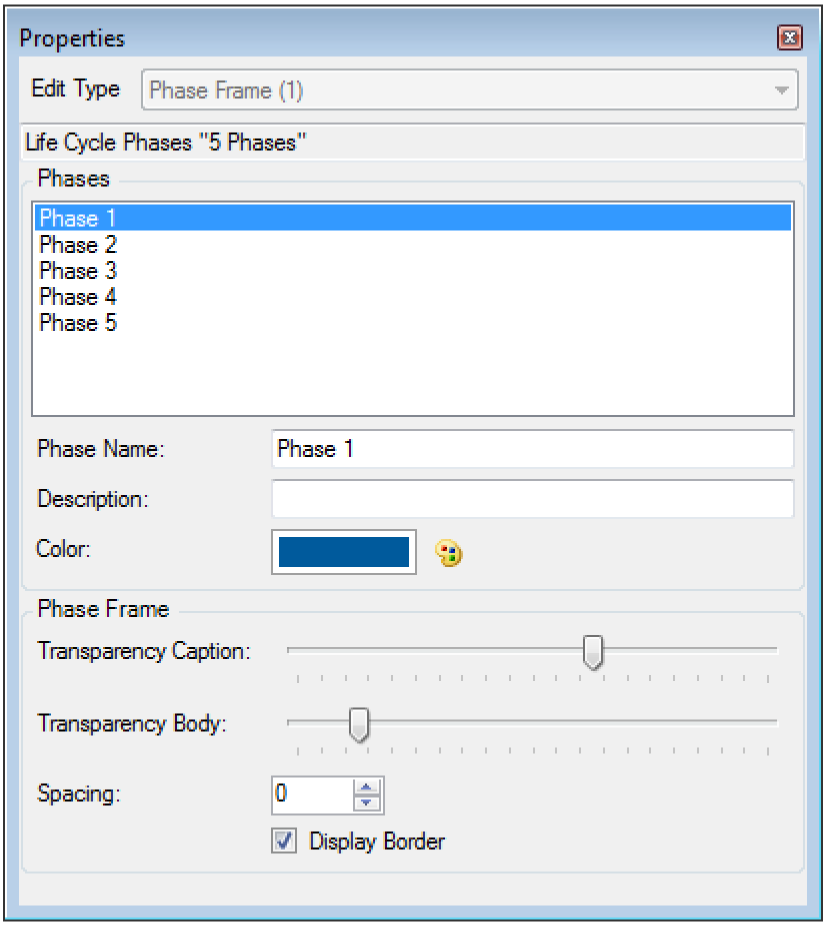


Figure 17: Life cycle phases properties

Deleting Life Cycle Phases Frame: To delete a life cycle phases frame, mark it by clicking on the borderline of the frame, then press 'Del' on the keyboard. Alternatively select 'Delete' from the context-menu.

If a life cycle phases frame has been deleted (or if no frame has been selected, when the project was created), it can be created anew by using the command 'Life Cycle Phases' from the Menu 'Draw'.

6 Materials

Note: The term material should not been taken literally but rather as an abstract term. It is used as a proxy for any kind of flow, substance, component, semi-finished or finished good, or even for immaterial service inputs. It does not necessarily have to be a physical item, but may also be used for energy, work, service, area, etc.

6.1 Exchanges (Flows) from LCI Databases

In the Project Explorer below the 'Models' and the 'Project Materials' groups, the LCI master databases can be found. These LCI databases contain entries for activities and exchanges.

Several master material databases are available for Umberto LCA+, each of which may have their own set of exchanges (flows, materials) and their own taxonomy.
The 'Tutorial Example' master database is available in the basic Umberto LCA+ installation (trial version). It contains fictitious values in the activities, but uses the exchanges (material names) of the ecoinvent 3 LCI master database. The exchanges are accessible even if no license for the ecoinvent 3 LCI master database is installed.

When an activity dataset is inserted into the model from a master database, the exchanges (flows, material names) contained in the activity will appear in the 'Project Materials' group in a new subfolder named after the master database. This allows identifying the database where the material originally was taken from. Additionally, the master database is also shown as 'Data Source' in the material properties.

Exchanges in the master material databases cannot be edited. Exchanges inserted into the 'Project Materials' from the master databases can also not be edited. Only local copies of the materials and material entries defined by the user can be edited.

Mark an exchange entry in one of the folders of a master database to view its properties in the Material Properties pane. Only the Sankey diagram color can be changed and another display unit can be chosen. By maintaining the materials from the master databases non-editable, it is made sure that they can be updated when new database versions are released.

Using Exchanges from different Master Databases: It is technically possible to use exchanges and activities from different databases (the ecoinvent v2.2, ecoinvent v3 or GaBi databases) in one LCA project. However, there are some major differences between these third-party master databases that should be observed.

The nomenclature (naming conventions) of the exchanges was partially modified from ecoinvent v2.2 to ecoinvent v3, so that these exchanges might appear twice in the inventories with slightly different name.

The LCIA characterization factors for the different impact methods have been assigned to the elementary exchanges from both ecoinvent v2.2 to ecoinvent v3 master databases. As a consequence the environmental impacts are calculated correctly, independent of whether an exchange or activity has been chosen from ecoinvent v2.2 or ecoinvent v3. While in the inventory they might be shown as separate exchanges, their environmental impact is summed in the LCIA step.

Characterization factors for elementary exchanges from GaBi have been imported and are available for users of the GaBi databases in Umberto NX LCA. Where LCIA factors existed, the names have been matched to the existing ones. Some LCIA factors available in GaBi databases exclusively have been added and can be used only with GaBi elementary exchanges (see Annex B).

In Umberto LCA+ the set of units defined the exchanges from ecoinvent v3 are being used. Exchanges from ecoinvent v2.2 were matched to ecoinvent v3 and are assigned the corresponding unit.

The units from GaBi databases have been matched to ecoinvent units where possible. Units that didn't exist in the unit list available from ecoinvent were added (see Annex D for a list of units).

Only experienced LCA practitioners who are able to manage data from different data sources (different LCI databases) in one model, and who are able to justify this decision and to interpret the calculation results should "mix" the data in one project.

6.2 Material Groups

When a project is open, the Project Explorer window shows (at the top) a folder for models, and the folder 'Project Materials' for the materials that have been copied to the project (from master databases, or by using a module from the gallery). The 'Project Materials' group can be organized by material groups in a hierarchical structure.

New Material Group: To create a new material group, mark one folder under which the material group is to be inserted, then click on the button 'New Material Group'. Alternatively right mouse-click on the material group, and choose the command 'New Material Group' from the context menu.

Material Group Properties: Properties of a material group, such as its name or a description can be edited in the Properties Editor when the material group is selected.

Move Material Group: If you wish to insert a material group at a different location in the material hierarchy, just drag&drop the folder symbol onto another material group folder under the root item 'Project Materials'.

Delete Material Group: To delete a material group, right mouse-click on the material group folder in the Project Explorer and choose the command 'Delete' from the context menu. Please note that it is not possible to delete a material group, if it contains materials which are already in use in the specification of a process or a flow within any of the models in the project.

It could be helpful to create a material group 'My Entries' in order to store your newly defined materials and to keep them clearly separated from the materials in the groups of the material master data (e.g. from ecoinvent).

The material group 'Imported Materials' will be created automatically, if you are inserting model sections into a model from the Module Gallery that contains new materials. These materials can then be moved from the group 'Imported Materials' to another existing material group.

6.3 Intermediate Exchanges

What are Intermediate Exchanges? Intermediate Exchanges are the flows that run within the technosphere, i.e. flows that are outputs of a technical process, such as a product, a semi-finished product, processed goods or a component. They are also used as inputs to a process (from other processes). Intermediate exchanges (in contrast to elementary exchanges, see below) do not play a role in life cycle impact assessment (LCIA) as they typically have no characterization factors. Intermediate exchanges can be defined by the user in the project as individual flows.

Other names for intermediate exchanges are "technosphere flows", "process flows", "product or waste flow" (ILCD) or simply "material".

New Intermediate Exchange: To define a new intermediate exchange in the project click on the button 'New Material'. Alternatively, use the command 'New Material' (CTRL+M) from the context menu of the material root folder, or any of the material groups. The exchange will be inserted in the material group that is currently marked, or in which a material is currently marked. Otherwise it will be inserted into the 'Project Materials' root folder.

All information for the newly created intermediate exchange material can be edited in the Property Editor window when the material is selected in the material list.

Mind that for intermediate exchanges the flag 'Elementary Exchange' in the 'Material Properties' panel remains unchecked.

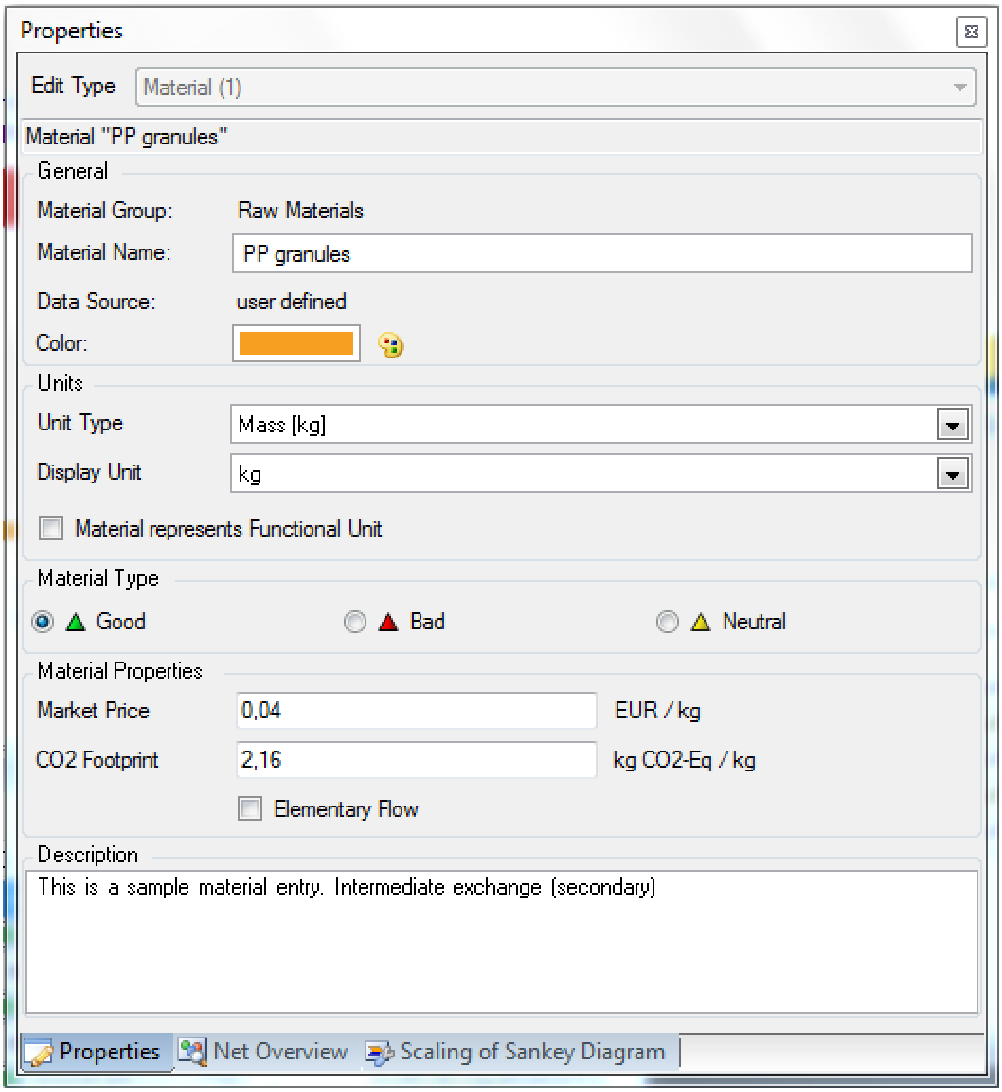


Figure 18: Properties of a material

The material name and a description of the material can be entered. The same material name may not be used twice in the same project. A number will be appended, if the user tries to add a material that already exists.

The unit type and the display unit can be chosen from the dropdown lists in the "Units" panel. There is a list of predefined unit types, each of which has a basic unit. A display unit can be chosen for each unit type. It is used to enter and display quantities (e.g. the market price, coefficients in the process specification window). Values will be converted to the basic unit for calculation.

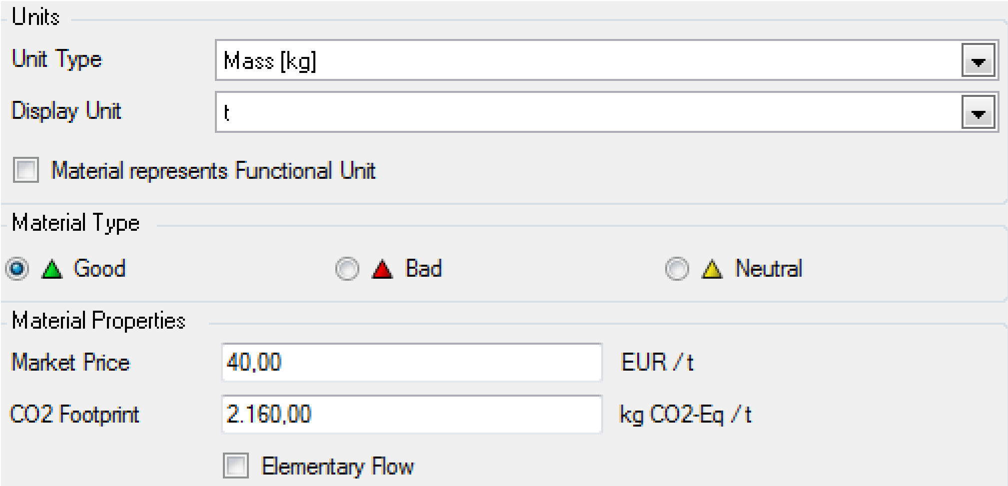


Figure 19: For a material entry from the "Mass" unit type the basic unit is "kg", the display unit is set to "t". Market price and carbon footprint are shown per one display unit.

If this material is used as a reference flow (product, co-product) for which the life cycle product model is to be calculated, the flag 'Material represents Functional Unit' can be set. Two additional input fields will become available. In the field 'Functional Unit' enter the name of the functional unit, i.e. the unit of product (e.g. "one printed T-Shirt Size XL"). The quantity and unit of the functional unit (e.g. weight) should be entered, so that a conversion factor from the basic unit to one unit of product can be determined. This value is used for scaling the results of the inventory results to one unit of product (the functional unit of the product system). Read more about scaling the results of the life cycle model calculation to one unit of product in section 12.1.

For the material type choose one of the three options: Good (green), Neutral (yellow), or Bad (red). The material type plays an important role in whether a flow of this material is considered an expense, or revenue. Generally speaking, all raw materials and energy should be set to green (Good). These are goods you are purchasing to run a process, to produce a good. Wastes and emissions of a process should be set to red (Bad). The revenue of a process, the intended output, must be set to green (Good) too. In multi-output processes the material type will also be used to determine the products and call for the allocation settings between the products of a process (main product, co-product).

The material type plays an important role in identifying the reference flow. Please read the section on 'Functional Unit and Reference Flow'. Read more about allocation in section 13.6

A colour is automatically set for the material. This colour is used to display a flow of this material in the Sankey diagram. You can edit the colour by double-clicking on the colour field, or using the 'Select Color' button.

When calculating the product life cycle model, all material expenses (raw materials, energy, components) in the life cycle inventory are considered with their quantities, and their characterization factors for impact assessment. For newly defined intermediate exchanges, typically no such characterization factors exist, and the intermediate exchanges will most likely not appear in the life cycle impact assessment as contributing to environmental impacts. Read more about characterization factors and LCIA in section 6.5.

In the 'Material Properties' panel the first field is labelled "Market Price" for materials that have a green material type ('Goods') and "Disposal Costs" for materials that have a red material type ('Bad'). A value can be entered in the unit of currency defined for the project (see Options), and per one display unit. Examples: 2,80 EUR/kg of material, 0,00012 USD/MJ of energy. There is no conversion of currencies. In the LCA domain, the market price is primarily used for allocation by cost (Economic Allocation, see section 8.3) or if you use the Life cycle models to do life cycle costing (LCC) projects.

For more details on the cost property of a material entry please see section 16.1.

Edit Exchange Properties: To edit an existing intermediate exchange (material) in the project, mark it in the 'Project Materials' folder. Then edit its properties, such as name, description, or material type in the Property Editor.

Move Exchange: If you wish to insert an intermediate exchange (material) into another group in the material hierarchy, just drag&drop it from one folder onto another material group folder.

Search Exchange: To be able to detect a specific exchange (material), use the search bar at the top of the Project Explorer.

- Full Text Search
- Incremental Search
- Filter

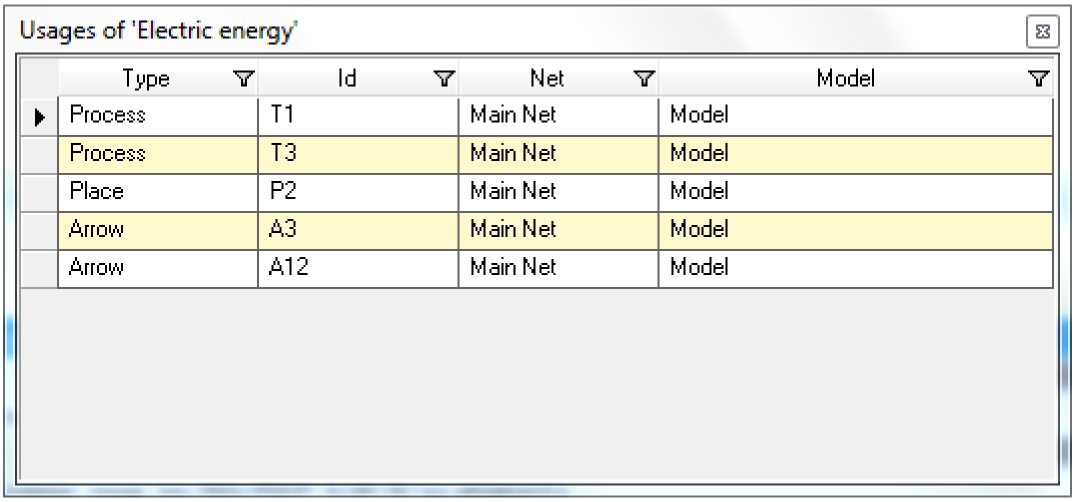
To search for materials or parts of the material name, select 'Incremental Search' and additionally 'Filter'. Only the exchanges (materials) containing the text string that is typed in the search field are shown.

The search runs over the 'Project Material' folder and over all enabled master databases (Activities and Exchanges).

Read more about temporarily enabling/disabling master databases below in section 9.2

Mind that when you have a filter set and a specific search string filters the entries in the Project Explorer, the material list may appear to be fully empty. In this case switch off the filter or remove the search string text.

Show Usage of Exchange: To find out in which element of a model a specific exchange (material) is being used, right mouse-click the entry in the material list in the Project Explorer and choose the command 'Show Usage' from the context menu. A table is prompted with a list of network elements.



Usages of 'Electric energy'

Type	Id	Net	Model
Process	T1	Main Net	Model
Process	T3	Main Net	Model
Place	P2	Main Net	Model
Arrow	A3	Main Net	Model
Arrow	A12	Main Net	Model

Figure 20: The 'Find Usage' command will yield a list of network elements where the exchange (material) is being used.

Delete Exchange: To delete an exchange (material), right mouse-click the entry in the material list in the Project Explorer and choose the 'Delete' command from the context menu. Please note that it is not possible to delete a material, if it is already in use in the specification of a process or a flow within any of the models in the project.

Using ecoinvent as the master data, intermediate exchanges can be used to expand the process chain, and choose a process that delivers a certain material into a process. This feature can be used when building up the life cycle model, but also when in the impact assessment step or for doing scenario analysis. Read more about this feature in section 9.3.

6.4 Elementary Exchanges

What are Elementary Exchanges? Elementary Exchanges are the flows that cross the system boundary, i.e. the border between technosphere (man-made environment) and the natural environment (biosphere). Typically they are emissions to air, soil, and water (on the output side) or resources taken from nature (on the input side). Elementary exchanges play a central role in impact assessment as they do have characterization factors assigned, for which the contribution to an environmental impact is calculated. Typically elementary exchanges are not defined by the practitioner as individual flows, but are predefined in the master material databases.

Learn about how to define elementary exchanges and supplement them with characterization factors in the advanced features section 13.8

Other names for elementary exchanges are "elementary flows", "substances", or simply "material".

Elementary exchanges are signaled with a check box in the Properties window of the material entry.

The group structure (classification) depends on the LCI database. In the ecoinvent v2.2 LCI database there is an individual two-level structure. The ecoinvent v3 LCI database uses the ISIC v4 classification for activities, where the actual activity entries can typically be found on the fourth hierarchy level only.

The ecoinvent v3 LCI database shipped in Umberto LCA+ has the following group structure of elementary exchanges.

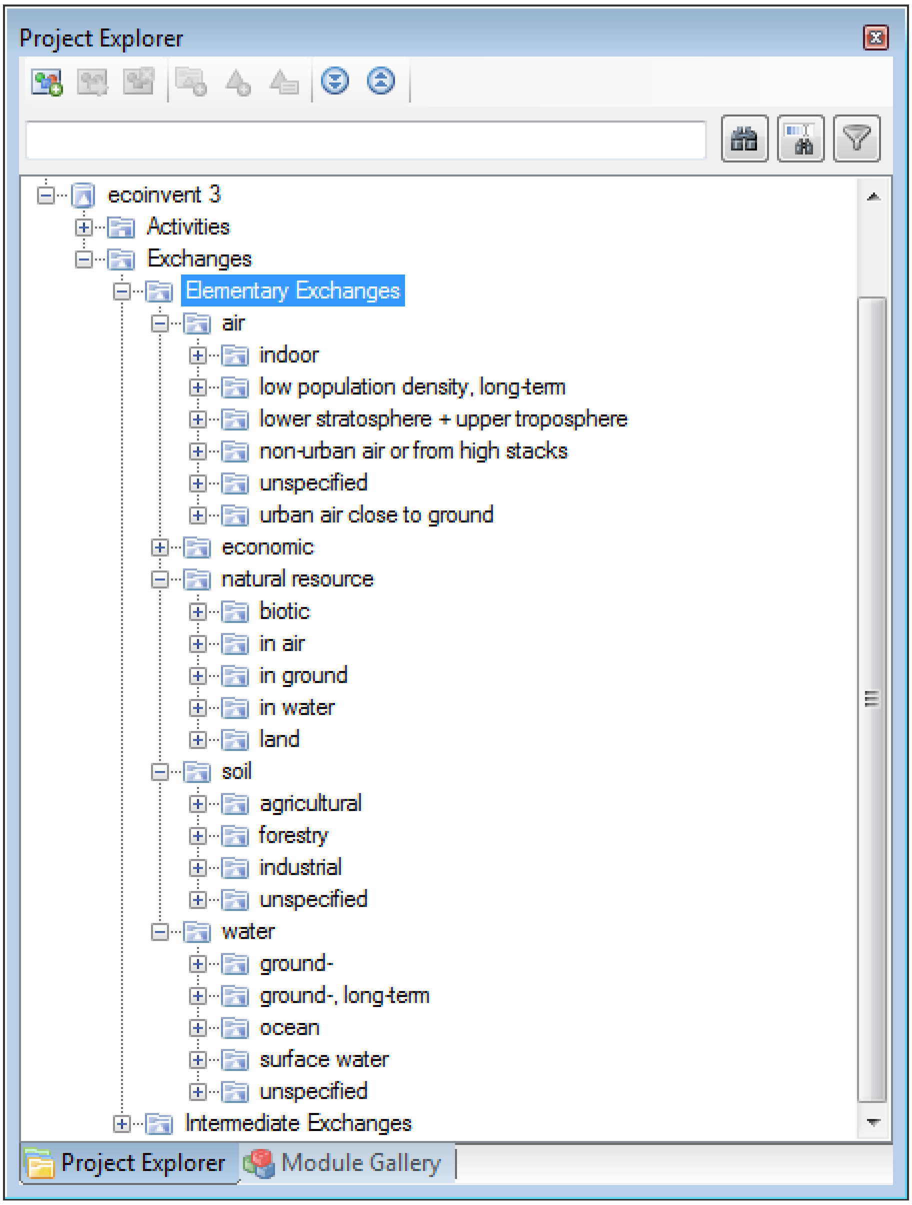


Figure 21: Project Explorer with Elementary Exchanges group structure in ecoinvent v3 LCI database

Other master material databases might have a different taxonomy and structure for elementary exchanges. These differences in nomenclature make it difficult to work with activity datasets from different sources. For example, the substance 'trichlorofluoro methane' is named 'Methane, trichlorofluoro-, CFC-11' in the ecoinvent database, but only 'CFC-11' in the ILCD database. A comprehensive matching between elements from different namespaces would be needed. Umberto LCA+ accepts the fact that there is pluralism in material naming and one can use the same substance with different name in one project, with the consequence that on the inventory (LCI) level one will see duplicates. The elementary flows, however, as long as they have the correct characterization factors will be accounted for correctly in the life cycle impact assessment step.

In the GaBi databases "...the flow hierarchy is structured according to technical aspects (for non-elementary flows and resources) and according to emission compartments air, water and soil." (Gabi Databases and Modelling Principles 2013).

Note that elementary exchanges and intermediate exchanges are not grouped separately. Rather are intermediate exchanges distinguished from elementary exchanges by the 'LCI Method' and 'IO Type' properties. This is specific to exchanges in the GaBi Databases.

The 'LCI Method' is a base type of the flow (as used in ILCD):

- Product flow: Exchange of goods or services within technosphere, with a positive economic/market value.
- Elementary flow: Exchange between nature (ecosphere) and technosphere, e.g. an emission, resource.
- Waste flow: Exchange of matters within the technosphere, with a economic/market value equal or below "0".
- Other flow: Exchange of other type, e.g. dummy or modelling support flows.

Additionally the 'IO Type' describes the type of flow within a process specification:

- Valuable
- Waste
- None

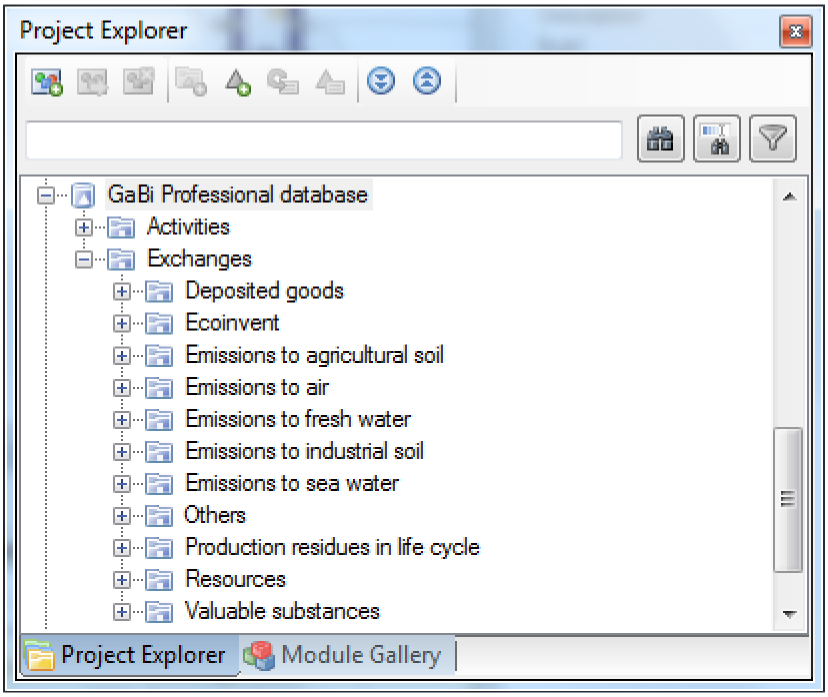


Figure 22: Project Explorer with group structure of exchanges in GaBi LCI database. Elementary exchanges to be found in the 'Resources' and 'Emissions' groups

It is strongly recommended to stick to one taxonomy in your LCA, hence only use one nomenclature (data from one master database) only in your project. Only advanced LCA practitioners, who are aware of the consequences of "mixing" datasets from different databases, and who are capable of managing this pluralism should use datasets from different data sources in one LCA model.

6.5 Impact Assessment Factors

Use of Impact Assessment Methods: The LCA practitioner typically selects one or more life cycle impact assessment methods (LCIA methods) that are used in the LCA study for assessing the potential environmental impacts. For background information see section 3.5.

In Umberto LCA+ several impact assessment methods – as provided by ecoinvent and by GaBi (see list in the annex) - are shipped.

To use one of these methods, it should be marked as active in the 'LCIA Factors' dialog accessible via the entry 'LCIA Factors' in the Tools menu.

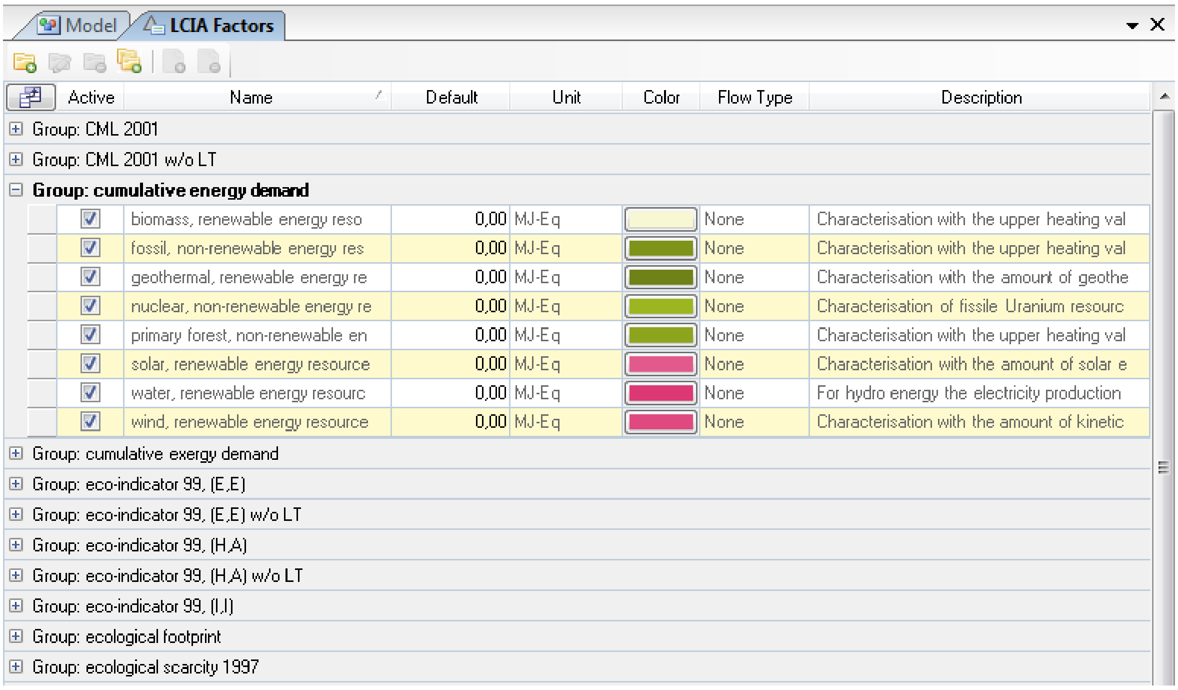


Figure 23: LCIA methods and LCIA factors provided in the master database ecoinvent 3

The 'LCIA Factors' dialog shows all available LCIA methods. Click on the plus sign to expand the group and see all available impact assessment factors available in that method. Collapse the expanded group by clicking on the minus sign in front of the LCIA method name.

Select an LCIA method that you wish to use in the project by choosing "Activate Group" from the context menu of the group header. Unselect an LCIA method by choosing "Deactivate Group" from the context menu.

Individual LCIA factor entries within a group can be selected or deselected by setting/removing the tick mark in front of the impact assessment factor name. Groups that contain activated LCIA factors are shown in bold font.

LCIA methods typically contain more than the impact assessment factors needed for an LCA study. These can be different time perspectives of the same impact assessment factor (e.g. GWP 20-year perspective, GWP 100-year perspective, and GWP 500-year perspective). It can also be the case that the same impact assessment factor impact assessment factor is used in different variations. The user of Umberto LCA+ is free to activate exactly the set of indicators he/she wishes to use. It could also be meaningful to work with a small set of impact assessment factors in the beginning, and activate additional ones e.g. in the interpretation phase of the study.

By default the impact assessment method "ReCiPe Midpoint (H) w/o LT" (without long-term effects) is chosen, however, you can choose any of the more than 30 impact methods shipped in the ecoinvent database, or – when using GaBi background datasets – the LCIA methods provided from the GaBi database. For a complete list see Annex B.

User Defined Impact Assessment Methods: It is also possible to define new Impact Assessment Methods and Factors in the LCIA Factors Dialog. All necessary functions can be found in the toolbar in the upper area of the dialog or in the context menu appearing on right-click on specific entries of the list. First you need to add a new method and specify a name and optionally a description. A first default indicator will be created automatically.

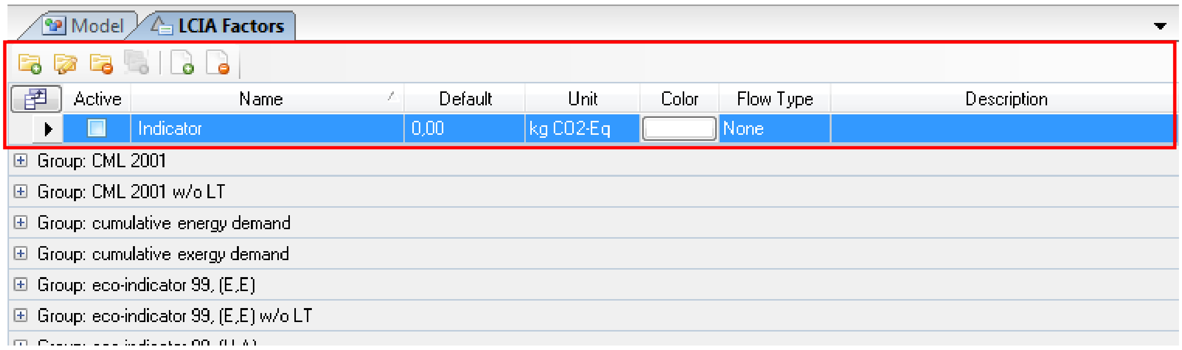


Figure 24: Elementary Exchanges with active Impact Assessment Factors

Edit: The name and description of a method can be edited by clicking the toolbar button “Edit Impact Assessment Method”. Values of indicators (name, default value, unit, color and flow type) can be edited inline within the grid by clicking in the respective cell.

Delete: User defined entries can be deleted by choosing “Delete Impact Assessment Factor”. If a method is deleted, all containing indicators are deleted as well.

Add: User defined factors can be added to all materials in the project. Their specific values can be edited in the dialog “View Impact Assessment Factors” of a material for user defined materials as well as for master materials (e.g. ecoinvent materials). On copy & paste, the factors are copied and will be added to the project in which the copied part is pasted.

Duplicate: Existing Impact Assessment Methods can be duplicated. As a result, a new method is created, named like the original but marked as copy, containing all factors and their values of the original and all current project materials will have the factors of this method and their values, too.

Note that it is recommended to use this command at a late stage of the modelling process, since the duplicated factors are only added to current project materials. Values of duplicated factors will not be added dynamically to added master materials after duplication.

Impact Assessment Factors (Characterization Factors) of Exchanges: To view characterization factors defined for an elementary exchange, right mouse click on the elementary exchange entry in the Project Explorer and select 'View Impact Assessment Factors' from the context menu. This can be done for elementary exchanges in the master material data, or for elementary exchanges in the 'Project Materials' group. The factors defined and active for the selected exchange are listed in a tab in the main area (on a tab behind the model open)

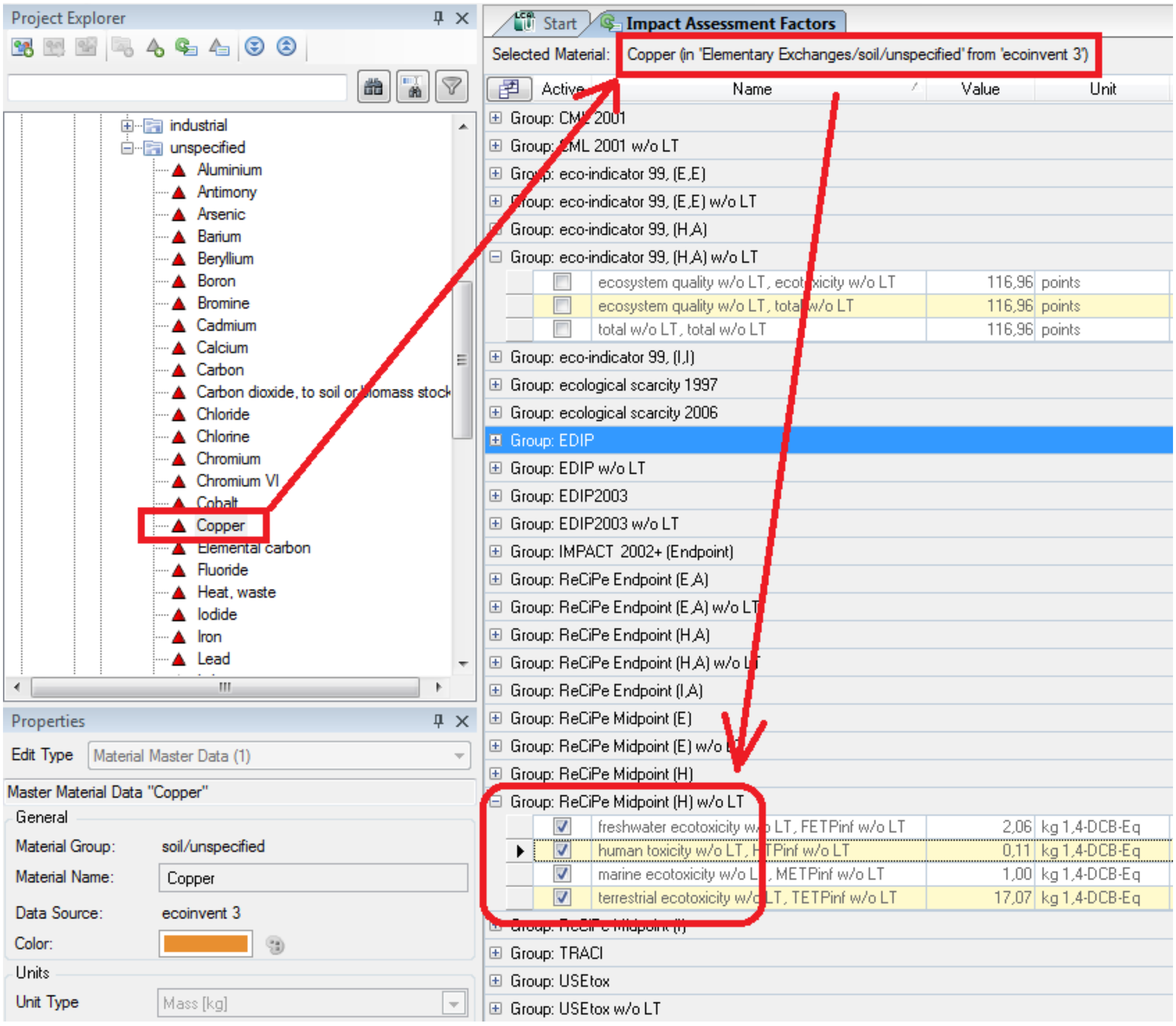


Figure 25: Elementary Exchanges with active Impact Assessment Factors

The 'Impact Assessment Factors' tab can remain open while exchanges are being browsed in the Project Explorer. The list of characterization factors is shown for the selected exchange. Note that not all elementary exchanges do have characterization factors defined for them. Check the original elementary exchange of the ecoinvent database (db.ecoinvent.org, use your login) to verify, if in doubt.

A filter setting is available at the top of the tab, which allows filtering the list of characterization factors:

- Filter "Show Only Activated": Only the characterization factors which have been set to 'Active' in the 'LCIA Factors' dialog are displayed. If the check mark for this filter is removed, all characterization factors available are shown.
- Filter "Show Only With Values": Only the characterization factors that do have a value defined are displayed. If unchecked (mark for this filter is removed), all characterization factors available are shown, even those for which no value is defined ("not defined").

The default setting for these filters is "Show Only Activated" set on, and "Show Only With Values" is off. Hence only the actually existing and activated characterization factor entries are shown for the selected elementary exchange. These are also the exchanges that are then used to calculate the impact assessment.

Intermediate Exchanges could theoretically also have characterization factors defined – this idea is implemented in 'Umberto for Carbon Footprint'. This characterization factor then includes the "rucksack" of the environmental impact accrued along the supply chain up to the provision of the intermediate material (product). In that case the upstream supply chain does not have to be modelled in detail anymore and the intermediate exchange flow which is defined on an arrow from an input place into the model with the respective characterization factor is included in the impact assessment. This is a shortcut procedure for impact assessment, and does not allow tracing the specific process of the supply chain where the elementary exchange leading to the environmental impact occurs.

6.6 Material Properties

In addition to the LCIA factors (characterization factors) described above in section 6.5 there are also "regular" material properties. These material properties are characteristics of the material for which they have been defined. Material properties can be technical or physical (e.g. e.g. density, metal content, wet mass, dry mass, ...), they can be economic (such as the market price), or they can be environmental (e.g. toxic/non-toxic, cancerogenic, C-content, ...). Also, additional tags for the material that carry information can be stored as material property (e.g. CAS number, Smiles code, NACE code, article number, ...).

Available Material Properties: To view the material properties that have been defined in a project, open the dialog 'Material Properties' accessible via the entry 'Material Properties' in the Tools menu.

This dialog is built-up similarly to the 'LCIA Factors' dialog described above

At present, it is not possible to define own material properties in the project. Currently the market price, and possibly material properties contained in the master material data can be viewed in this dialog.

Select a material property you wish to use in the project by clicking the check box "Activate" in front of the entry. Unselect by removing the tick mark in front of the material property entry.

Material Properties for Exchanges:
To view material properties defined for a material, right mouse click on the elementary exchange entry in the Project Explorer and select 'View Material Properties' from the context menu. This can be done for exchanges in the master material data, or for exchanges in the 'Project Materials' group. The material properties defined and active for the selected exchange are listed in a tab in the main area (on a tab behind the model open)

Note that in Umberto LCA+ the definition of individual material properties is not yet possible in the current version. Only the market price can be set, so that cost allocation is possible.

A filter setting is again available at the top of the tab:

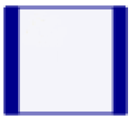
- Filter "Show Only Activated": Only the material properties which have been set to 'Active' in the 'Material Properties' dialog are displayed. If the check mark for this filter is removed, all available material properties are shown.
- Filter "Show Only With Values": Only material properties that do have a value defined are displayed. If unchecked (mark for this filter is removed), all material properties available are shown, even those for which no value is defined ("not defined").

7 Graphical Life Cycle Model

The Modelling Editor covers the main area of the application. It serves to graphically build the life cycle model of the product, and to specify the processes, in order to determine the environmental impacts along the product life cycle.

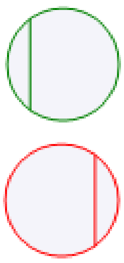
Get a practical idea how to build the LCA models in the tutorials (in separate PDF documents).

The life cycle model is made up from the following three elements:



Process:
A square or rectangle with a blue borderline. The process is the most important element in the model. It is used to specify the activity, in which an input flow is converted into an output flow.

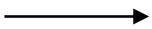
→ read about specific process element related information in section 7.2
→ for details on defining the process see chapter 8 'Process Specification'



Place:

- a circle in green for an input to a process or to the system (input place)
- a circle in red for an output from a process or from the system (output place)
- a circle in yellow that connects to processes within the system (connection place)

→ read about specific place element related functions in section 7.3
→ for special characteristics of place elements in subnets please read the hints in section 13.4



Arrow:
A directed line from a process to a place or from a place to a process. Several flows can run along an arrow. Arrows can also be represented as Sankey arrows.

→ read about arrow related information in section 7.4

7.1 General Element Related

Insert Elements (Process, Place, or Graphical Elements): To insert a process, place or graphical element in the life cycle model, click on the respective button in the toolbar, then click at the desired position in the modelling editor where the element is to be inserted.

When double-clicking on an element button, it is pinned (locked insert mode) so that several elements of the selected type can be inserted one after another, until the insert mode is terminated by a right-click of the mouse, pressing the ESC key, or clicking on the button 'Select and Edit Elements' in the toolbar.

Move Elements (Process or Place): Move process or place elements to any position in the modelling editor by pointing the mouse cursor on the element and dragging it. Connected arrows will move along with the element.

Display/Hide Elements: To hide a process symbol or place, unmark the "Display Shape" option in the Property Editor window (element must be marked in the modelling editor). Hidden elements can be displayed anew by setting the check mark again.

Note that when a process or place symbol is hidden, it can still be clicked, and used to connect arrows to it. The element will become temporarily visible in a transparent mode, when either a connected area is clicked, or when the area where the hidden element is located is selected by dragging a selection frame.

Resize Elements: To change the size of a process symbol or place, click it, then pick one of the marker points and drag them. Hint: if you resize while holding the SHIFT key pressed, the aspect ratio will be maintained.

Adapt Process Size To Connected Arrow's Magnitude: With this command the size of one or more processes or places can be adapted, so that their height, or width or both match the magnitude of the arrows that connect to them. From the context menu of the process choose the entry 'Adapt Process Size' and one of the commands from the cascading menu: 'Height to Arrow', 'Width to Arrow', or 'Height/Width to Arrow'. The process height or width will be set to the largest arrow magnitude connecting to the respective side of the process.

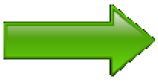
Adapt Element Size To Master: Several elements (processes, places) can be adapted to match the size of one selected master element: Choose one element that has the size to which the others should be matched, if required adjust its size to your needs. From the context menu of this element choose 'Set Size to this Element'.

Align Elements: Several elements (processes, shapes, labels) can be aligned with one command. Select the elements that should be aligned, then open the context menu for the element to which the other elements shall be aligned. Choose the entry 'Align to this Element' and one of the alignment commands from the cascading menu. All elements selected are aligned in relation to the master element from whose context menu the command is being called.

Since arrows are always connected to the middle of the process side, this command does not necessarily lead to fully horizontal/vertical arrows. The size of the connected processes must be the same to have strictly horizontal/vertical arrows. Also, fully horizontal/vertical arrows are not always achievable automatically when using stacked arrows. Manually change the process place size to get fully horizontal/vertical arrows.

Copy Elements: To copy a process symbol or place, mark it and choose 'Copy' from the context menu. Alternatively use the shortcut 'CTRL+C'. Of course it is also possible to mark several elements at the same time.

Note that when copying processes, the connected arrows and neighbouring places will be copied along with the process. You are thus actually copying a small network structure.



Hint on how a process or a section of the carbon footprint model or the whole carbon footprint model can be copied to the module gallery for future use can be found in the chapter 'Module Gallery' below.

Delete Elements: To delete a process symbol or place, mark it and choose 'Delete' from the context menu. Alternatively use the shortcut 'CTRL+X'. Of course it is also possible to mark and delete several elements at the same time.

Warning: Mind that process specifications are lost, if a specified process symbol is deleted. If the process is linked with one or more arrows, these arrows are also removed. If the process symbol represents a subnet, the whole net model below the subnet process is deleted.

Edit Element Properties: When an element in the modelling editor is selected, its properties can be edited in the Property Editor window. The context menu of each element or the keyboard shortcut 'CTRL+E' also allows calling the property editor window. For information about individual properties see Process Properties, Place Properties, or Arrow Properties. Among the properties are its name, a description, and an overlay image.

Editing Multiple Elements (Multi Element Edit): Changing the property of several graphical elements of the same type is possible using multi element edit: Mark several elements of the same type in the model by keeping the SHIFT or CTRL key pressed when selecting the element, or mark a section of the graphical model by pulling up a selection frame around it. In the properties dialog, choose the element type for which you wish to perform the editing option from the dropdown-list 'Edit Type' below the caption. The number of elements affected is shown in brackets.

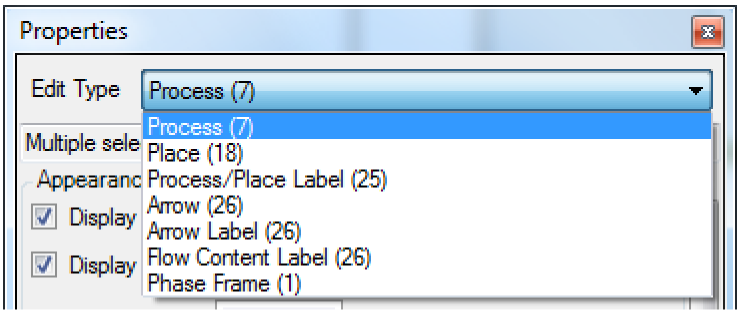


Figure 26: Multi Element Edit in Properties dialog

The properties of the selected elements of the same type can then be changed. Note that some elements might have different existing property values. This is indicated with the entry "<...>" in text boxes or a filled check-box.

Naming Elements: To give a name to a process or place, use the element properties panel (mark element, bring Property Editor to front). Alternatively click the label of the element, and type the name directly (inline editing) in the modelling editor.

Element IDs (e.g. T1, P2) can be hidden by unmarking the 'Display ID' option in the Property Editor window (element must be marked in the modelling editor). In the same way an element name can be hidden by removing the check mark for the 'Display Name' option.

Use Image for Elements: To replace the default process or place symbol by an image, icon or clipart, mark the element in the model, bring the Property Editor to front, and click on the 'Load Image' button. Brows the image files on your hard disk for the image.

Layer Order of Elements: Just like in other drawing programs, elements (arrows, places, processes) can superimpose each other on different layers of the drawing area. To individually control the layer order of the elements, use the commands from the cascading menu of the 'Order' command in the context menu:

- Bring to Front (=to topmost layer)
- Send to Back (=to last layer)
- Bring Forward (=up one layer)
- Send Backward (=down one layer)

Search Elements: Use keyboard shortcut 'CTRL+F' to open a search field in the top right corner of the editor area. In the search field type a text string, then hit the 'RETURN' key to start the search. The hit list will show all elements that have an id or label containing the searched text. Skip through the drop down list that contains the matching elements and select one entry (arrow, place, process, text), to bring this element into focus and select it in the editor.
You can use the keyboard shortcut 'F3' to jump to the next diagram element from the search results.

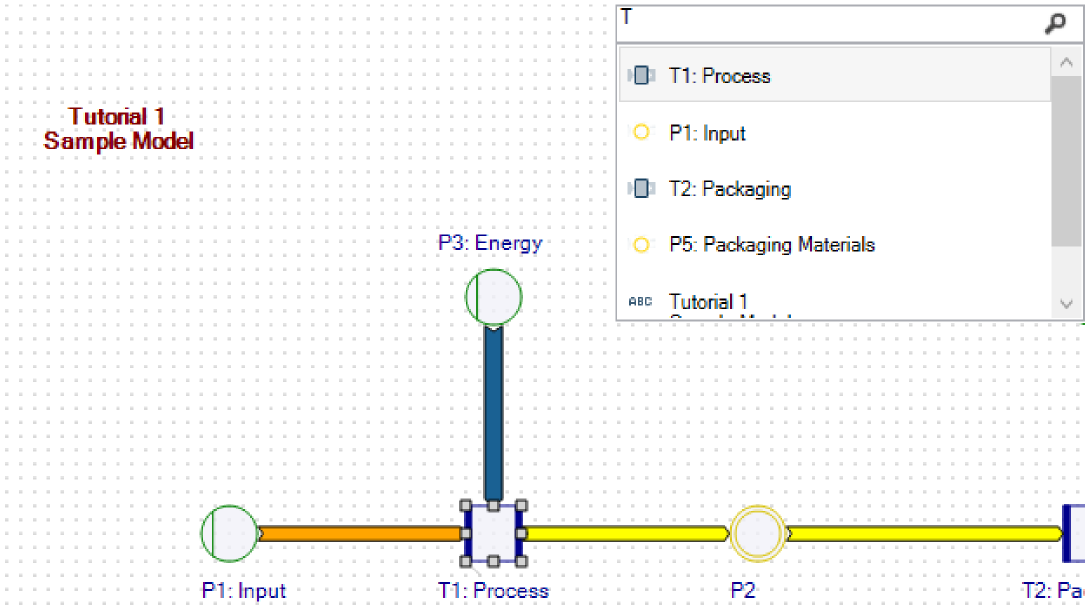


Figure 27: Search Elements in the Modelling Editor

7.2 Process

In this section you can find hints on functions that relate specifically to the graphical handling of processes in an LCA model. Process symbols are also known as node, or transition. For general functions of elements in the modelling editor, see above. Information on how to define a process can be found below in section 8.

Set Process: To draw a process click the 'Add Process' button from the toolbar, then click at the desired position in the modelling editor. A single process element will be drawn (square), and the insert mode will be ended.

By double-clicking the 'Add Process' button you can pin it (lock the insert mode) to insert several process symbols, until you actively end the insert mode (right mouse-click or ESC or clicking on the button 'Select and Edit Elements' in the toolbar).

For advanced users there is a quick draw option for processes pre-linked with arrows and a connection place between them: When in arrow drawing mode the user clicks and drags over an empty area of the editor, the arrows drawn will have connected process symbols already. Likewise, when wishing to draw a process and link it to an existing process, users can start drawing the arrow in an empty area of the editor, and drag the cursor onto the target element. See below in section 'Arrow'.

Process Properties: The properties of a process can be edited in the Property window when the process symbol is clicked. Several options are available.

Process Label: The process when being set in the model will receive an automatic ID (such as T1, T2, T3). This ID is used to identify the process. It can be modified in the 'Label and Description' panel. Use the option 'Display Id' to show or hide the identifier for each process individually.

The process label text itself can be edited in the 'Label and Description' panel of the Process Properties window. Click the process label itself to edit its options (font, alignment, colour, …) and selectively hide or display flow name, quantity and unit. The option 'Display Text Label' can be used to show or hide the text label for each process.
Note: you can hide all element IDs and labels jointly using the Visibility command of the model (right mouse-click on an empty area in the editor area).

Show/Hide Process: To hide a process, remove the tick mark for the option 'Display Shape' in the Process Properties dialog. The fill color for the process shape is a light blue by default. Choose another fill color for the process by clicking on the 'Select Color' button.

Instead of showing the process with a regular square shape an icon or image can be loaded. Click on the button 'Load Image' in the 'Appearance' pane of the Process Properties dialog, and load an image file. Several cliparts for processes (.umf graphics format) are provided in a directory of the Umberto LCA+ installation.

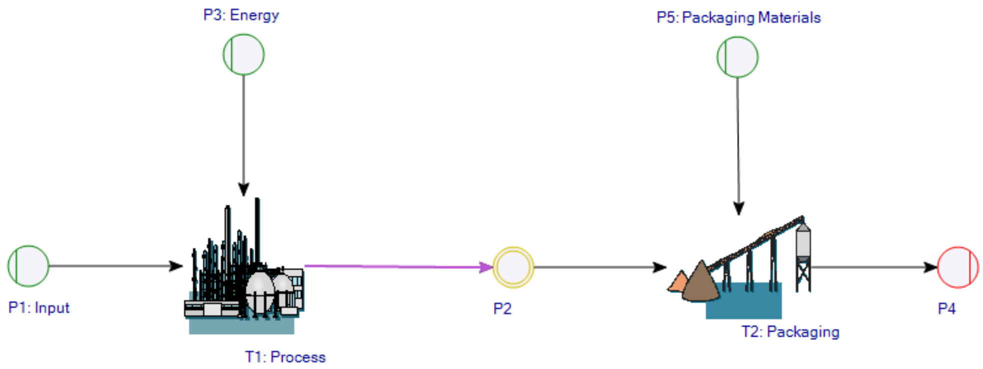


Figure 28: The default process symbols have been replaced with an icon from the clipart gallery

A descriptive text for the process can be entered for the process in the "Description" field. Note that when an activity from a material database is inserted directly, there is typically some description of the activity to be found in the "Description" already.

List of Processes: A list o processes that have been defined in the models of a project can be called using the button 'Process List' from the main toolbar, or by calling the command 'Process List' from the Tools menu.

Process Options: Several options are available for the arrow: rounded curves, curviness, and orthogonal routing. Some options (such as connectivity, padding and stacking) refer to the behaviour of Sankey arrows connecting to the process. These options are explained in chapter 11.2 on Sankey diagrams.

For information on the specification (i.e. definition) of processes please read in chapter 8 and 9.

7.3 Place

In this section, find hints on functions that relate specifically to the graphical handling of places (input place, output place, connection) in an LCA model.

Set Place (Input or Output): To set an input or output element in the model click the 'Add Input' or 'Add Output' button from the toolbar, then click at the desired position in the modelling editor. A single instance of the respective place symbol is drawn (circle) and the insert mode is terminated.

By double-clicking on a place button you can pin it (lock the insert mode) to insert several symbols of the same type until, you actively end the insert mode (right mouse-click or 'ESC' or clicking on the button 'Select and Edit Elements' in the toolbar).

Place Properties: The properties of a place can be edited in the Property window when the place symbol is clicked. Several options are available. A description can be entered.

Place Type: The place type can be set as "Input", "Output" or "Connection". The place type "Storage" is mainly used for material flow analysis and has less or no relevance for Life Cycle Assessment calculations.

Place Options: Several options are available for the place: rounded curves, curviness, and orthogonal routing. Some options (such as connectivity, padding and stacking) refer to the behaviour of Sankey arrows connecting to the place. These options are explained below in the chapter on Sankey diagrams.

Place Label: The label of a place can be edited in the Place Properties window. Click the place label itself to edit its options (font, alignment, colour). The option 'Display Text Label' can be used to show or hide the text label for each place individually.

Note: you can hide all element IDs and labels jointly using the 'Visibility' command of the model (right mouse-click on an empty area in the editor area).

Merge Places: Two places can be merged by dragging them onto another. By this, network sections can be linked, and duplicates of places can be merged again. Note that when merging two places of different types, they will most likely become a connection type place.

Merging of places is also required when a process with connected places or a life cycle model section which has places as connectors is inserted from the Module Gallery by drag&drop.

Duplicate Places: If you wish to "reuse" an input or output place in the model, you can duplicate it by marking the symbol and selecting the command 'Duplicate' from the context menu. Duplicated places are useful for avoiding long, and crossing arrow lines all linked to one single copy of the place. The place type can be changed afterwards (see Arrow Properties).

Places can also be specified, that is, a begin quantity or stock in the place can be defined. This feature is typically not required in LCA calculation, but rather for corporate material and energy flow accounting that also has a period-related accounting.

Note that on a subnet level of a model, the subnet connects to the level above via input or output places that have a special marker, a colored dot in the middle of the place. These so-called "Port" places hand over the flows to the parent level of the hierarchical model. No input or output places that are not port places at the same time may exist in subnets, since all flows are received from the parent level, and are handed back to the parent level again. This is to ensure the consistency of the input and output flows on the top level that comprises all flows of the model. For more details on subnets see section 13.4.

Figure 29: Port Places in a subnet

7.4 Arrow

In this section you can find information that relates specifically to arrows.

Draw Arrow: To draw a directed arrow between to processes, click on the button 'Draw Arrow between Net Elements' in the toolbar. This will allow drawing one arrow between elements, and the arrow drawing mode will terminate automatically. By double-clicking the button 'Draw Arrow between Net Elements' it can be pinned (locked in the arrow drawing mode) to draw several arrows between the elements until this mode is actively ended (with a right mouse-click, by pressing the ESC key, or by clicking on the button 'Select and Edit Elements' in the toolbar).

In the drawing mode, move the mouse pointer onto the first process symbol (start node). A gray marker will be visible. Then drag to the other element (destination node). When over the centre of the symbol (a gray marker will be visible again) release the left mouse button. An arrow will be drawn, if permitted, between the two elements. The arrow will also snap to the process, if you drag it very close to the destination process - almost like with a magnet.

Arrows can be drawn:

- from an input place or a connection place to a process
- from a process to a connection place or to an output place
- from one process to another (a connection places will be set automatically)

An advanced drawing mode allows drawing arrows without having to set a process first. When in the drawing mode just click on an empty area in the editor and drag to the position where the next process shall be created. Two process symbols, as well as the arrows and the connection place will be drawn.
In the same way, when the drawing starts on a process symbol and end on an empty area a new process symbol connected to the starting process will be drawn. When beginning on an empty area and drawing an arrow to an existing process, a process with arrow and connection place is drawn. The advanced drawing mode can speed up enormously the graphical modelling for the advanced user.

Arrow Routing using Arrow Points: An arrow between two elements has a number of points that are important for its routing. These points become visible when the arrow is clicked.

The yellow points (lug points or hook points) are created by default at the end of the first segment after at a horizontal or vertical offset from the node, and at the beginning of the last segment of an arrow that is linked to the node. Yellow points can only be moved horizontally or vertically, depending on the orientation of the base segment or head segment of the arrow to the node. They cannot be removed!

Note: When two elements are located to close to each other, the yellow points of these neighbouring elements might collide, and cause crooked arrows. Pull the elements apart to avoid weird looking arrow routings, or reduce the segment length by sliding the yellow points closer to the element.

The gray points (bending point or waypoint) appear in the middle of an arrow segment (except the first horizontal or vertical segment) or can be created using the 'Add Point' command from the context menu. Several gray points on one arrow are possible. These points can be moved freely in X and Y directions and allow to insert bends/curves in an arrow. They also serve to create new arrow segments since when being dragged to a new position, an arrow bend is introduced and new movable gray points appear on each segment. Remember that they cannot be located between the element border line and the yellow point (first and last arrow segment that hooks to the place or process element).

Inserting a gray point leads to a check of the routing and possible rerouting/redrawing of the arrow. Instead of using the angle of the imaginary line between the centers of the process node to determine whether the exit must be horizontally or vertically, it will use the new gray point and the angle of its imaginary line to the center of the process symbol to recalculate and re-determine the exit direction.

Remove a gray arrow point by choosing the command 'Delete Arrow Point' from the context menu. All gray arrow points can be removed with the 'Delete All Arrow Points'.

Arrow routing is important for the Sankey diagram mode, where the flows are shown with widths representing the flow quantity. Read more about Sankey arrows below.

Reconnect Arrow to Another Element: Arrows can be unattached from the process or place they are connected to, and can be connected to another element. This feature is helpful when expanding an existing model, when using model sections from the Module Gallery, or when an arrow has been connected accidentally to the wrong element- The red points at the base and at the tip of an arrow can be used to reconnect the arrow. Simply drag the red point to unattach the arrow and drag it onto another element. The arrow will snap to the new element, if it is a valid element it can connect to.

Arrow Properties: The properties of an arrow can be edited in the Property window when the arrow is clicked. A description for the arrow can be entered.

Arrow Options: Several options are available for the arrow: rounded curves, curviness, and orthogonal routing. Additional options (such as arrow head/tail, and borderline style and colour) are available for arrows when shown in the Sankey diagram mode. These options are explained below in the chapter on Sankey diagrams.

Arrow Labels: An arrow has two labels: The 'Arrow Flow Label' is created automatically from the flow in the arrow, the flow quantity, and the unit. The arrow flow label is not shown by default, and can be displayed by setting a tick mark in the checkbox 'Display Flow Label' in the Arrow Properties window. Click the arrow flow label to edit its options (font, alignment, colour) and selectively hide or display flow name, quantity and unit.

The 'Arrow Text Label' is an additional text that is hooked to the arrow, and can be edited freely in the "Text Label" entry field. It is used to give more information on the flow. The arrow text label is also not shown by default, and can be displayed by activating the checkbox 'Display Text Label' in the Arrow Properties window. Click the arrow flow label to edit its options (font, alignment, colour).

A flow can be specified in an arrow. This so-called manual flow that is used to launch the calculation of all the other flows of the model. Typically this flow will be (although not required) the product flow. Please see below in chapter 10.2 about specifying a manual flow in an arrow.

7.5 Text Labels, Images and Other Graphical Elements

Apart from the labels created automatically for each element, additional text elements can be created to add more information to the graphical model.

Use the button 'Add Text' from the toolbar, then click at the desired position in the modelling editor. Return to the normal edit mode by using the button 'Select and Edit Elements' from the toolbar, or with a right-click of the mouse. Type the text directly in the text element (inline editing), or mark the text element and enter the text in the properties panel. In the Property window of the text element, you also find a number of options, such as font size, color, wrapping, or alignment.

Use the image element to add photos, cliparts or maps to the graphical model. Click the button 'Add Image' from the toolbar, then click at the desired position in the modelling editor to create an image area. In the Properties dialog of the image element use the 'Load Image' button, then choose an image file from your hard disk. The following graphics file formats are supported: .BMP, .EMF, .WMF, .JPG, .PNG, .TIF, .EXIF, .ICO and the proprietary Umberto .UMF format (set for clipart icons).

Several additional graphical elements are available: rectangle, rounded rectangle, ellipse, and line. Use the corresponding button from the toolbar to set a graphical element in the modelling editor area. Edit the graphical element directly, e.g. move and resize it. The properties of the graphical element (e.g. color, line style, etc.) can be administered in the Property window when an element is marked.

Note that the graphical element 'ellipse' when drawn as a circle is not the same as a place, which has certain significance in the modelling logic. A simple line, even when a line head is added, is not the same as the arrow element described above. Ellipse and line are mere graphical elements.

7.6 Module Gallery

Umberto LCA+ contains a module gallery that can be used to store individual processes with connected input and output places, model sections, and whole models.

The 'Module Gallery' can be found by default on a tab behind the 'Project Explorer'. If it has been closed and is not visible any more, it can be called again using the 'Tools' menu.

The modules are stored as files on your hard disk. The default directory is "C:\Users\<USERNAME>\Documents\Umberto LCA+\Gallery". The directory path can be set by clicking on the button 'Open Root Location for Modules' in the 'Module Gallery'.

The modules contained in a folder are shown in the bottom section as thumbnails when the folder is marked.

Folder Structure of Module Gallery: The Module Gallery has a hierarchical structure. New folders can be created by clicking on the button 'Create Module Group' from the toolbar. Alternatively use the same command from the context menu of a folder. The default name given to a newly created folder can be edited by clicking on the button 'Rename Module Group'. To delete a module group click on the button 'Delete Module Group' from the toolbar. Alternatively use the command 'Delete' from the context menu of a folder.

Inserting a Module in the Module Gallery: To insert a module (a single process, a process with neighbouring places, several network elements linked with arrows, model structures that contain one or more hierarchical subnet levels) in the Module Gallery proceed as follows: In the model, select the process or several processes (e.g. by dragging a frame around them with the mouse pointer). Copy these elements to clipboard using the keyboard shortcut CTRL+C or the 'Copy' command from the context menu. The neighbouring places that serve as connecting points are automatically included in the selection. Next, copy the clipboard content into one module group folder by choosing the command 'Paste to Module Gallery' from its context menu. Alternatively mark the folder and use the command 'Paste clipboard data to module gallery' from the toolbar of the Module Gallery.

The module will be given a default name made up from the label of the first process. Rename the module according to your requirements by clicking on the thumbnail and choosing 'Rename' from its context menu. Alternatively, mark the thumbnail and click on the button 'Rename selected module' in the toolbar.

Copying a Module from the Module Gallery into the Model: To copy a module from the Module Gallery into a life cycle model, make sure the target model is open and visible. This can be a new empty model too. Then browse for the module in the gallery. Choose the command 'Copy to Net' from its context menu, or, mark it and click on the button 'Copy module to net' in the toolbar. Alternatively just drag&drop the module from the Module Gallery onto the Model Editor.

The process, or the model structure made up from processes with neighbouring places, and any other graphical elements will be inserted. You might have to merge places after inserting a module, to connect it to an existing structure in the model.

Note that flows manually specified in any arrow of the model or model section stored in the Module Gallery are removed and may have to be entered again, if required for calculation.

Deleting a Module: To delete a module from the Module Gallery click its thumbnail and choose the command 'Delete' from the context menu. Alternatively use the button 'Delete selected module' in the toolbar.

Properties of a Module: The properties of each module can be edited in the bottom section of the Module Gallery when the thumbnail is clicked. The name of the model can be edited and a description can be entered.

To see a larger version of the thumbnail, undock the 'Properties' window, and resize it to see a larger preview image.

Using the module gallery, it is also a possibility to exchange models or model sections with other users of Umberto LCA+. The files (four files belong to one module, they have the file extensions .txt, .png, .ume, and .ums) can be copied from, sent, and pasted into the folder of the module gallery on file level.

Content of the Module Gallery: Some pre-defined modules may be provided in the Module Gallery as samples.

Users may build a collection of ready-to-use building blocks (model sections) in the Module Gallery which they can include in their life cycle models by just dragging them onto the editor.

8 Specifying Activities (Process Definition w/ Primary Data)

Processes (ecoinvent refers to processes as 'activities'), represented by squares, are the most important element in the life cycle model. The processes have to be specified, that is, the relationship between input and output flows has to be defined. It is a prerequisite for a successful calculation of all material and energy flows of the system, and subsequently for the LCIA results, that all processes are specified.

8.1 Input/Output Flows and Coefficients

A process specification can be made by entering materials on the input and output side of the process, and specifying a coefficient for each entry. These coefficients don't have to be absolute values. Rather do they represent the size of flows on the input and on the output side in relation to each other.

To specify a process, click on the process symbol in the model editor. The specification window appears in the section below the drawing area. If the window has been closed, open it again with the command 'Specification Editor' from the Tools menu.

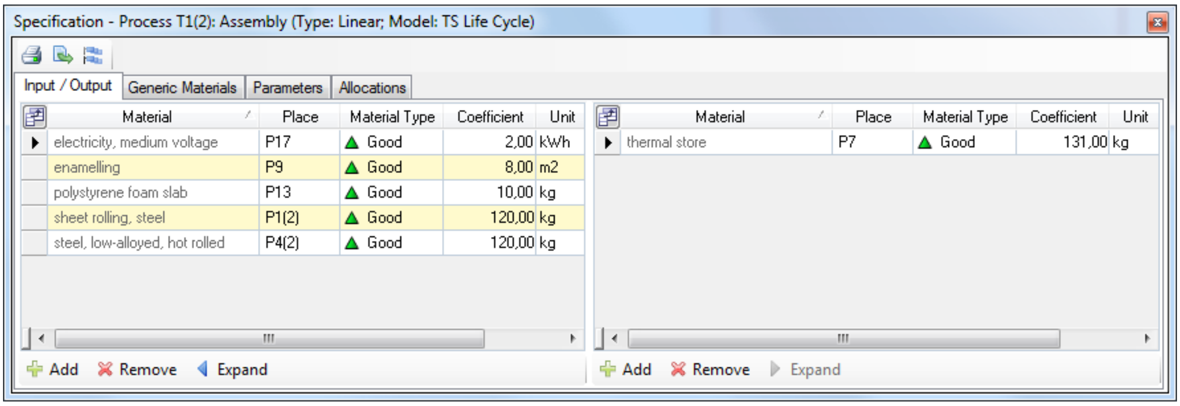


Figure 30: Specification Editor window for a process, 'Input/Output' tab

The window has several tabs. The specification of input and output flows and their coefficients is done on the 'Input/Output' tab.

Adding Flow Entries: To add a flow entry on either the input or output side of the process specification, first make sure the correct process is marked in the model editor. Then browse for the element in the material explorer, and drag&drop it onto the respective side of the 'Input/Output' tab of the Specification Editor. Materials can be chosen the 'Project Materials' group (if they have been previously used in the model), or from a master database.

Alternatively click on the button 'Add' for the input or the output side and select a material entry from a search list. The 'Search Material' dialog allows to searching materials from the project materials group (material already in use in the model) and from the master database. Type a search string into the search field in the column "Name" to search for a specific material. Multi-select of entries from the list is possible.

Other search filter criteria (e.g. "Starts With" or "Does not contain") can be set in the menu that opens when clicking on the button with the blue square dot at the left of the search field.

Note that if you defined own project materials (flows), these are typically found in the "Project Materials" group. If you intend to link to a process dataset from one of the installed master databases (e.g. ecoinvent, see section 9.1) that yields or consumes a certain material, you should select that intermediate exchange as a flow entry in the specification. If the flow is a direct input from nature (and not from a technosphere process) or a direct output to the environment, you would choose an elementary flows from the master material database.

A third option for adding exchanges on the input or output side of a process is dragging one or more entries directly onto the process element in the editor. A selection menu will pop up, where you can choose to insert the flow on the 'Input' or 'Output' side.

Assigning Place Identifiers: If only one place connects with an arrow to the process on the input or output side, it can be automatically determined, and will be set in the column "Place". If more than one place is connected on the input or output side, then the place assignment cannot be done automatically. Three question marks ("???") will be shown, to indicate that the correct place must be assigned. Select the appropriate places from which a material flows into the process, or to which a material flows from a process, from the dropdown lists in the "Place" columns. To make a process specification complete, all places must be assigned on the input and output side.

You can assign the same place to a number of input or output entries by marking several entries (see paragraph "Multi-Selection in Grids" in chapter 4.1) and using the cascading menu from the "Assign Places" command in the context menu.

Note that two identical flow entries (the same material) must not flow on the same arrow (i.e. have the same place assigned). Either join them, or assign different input/output places, or use two different materials.

Adding Flow Coefficient: In the column "Coefficient" enter a numerical value as coefficient. The coefficients represent the relation between the flows entering and leaving the process, as well as among the flows among each other on the same side. They do not have to be scaled to "1,00" kg or to "100 %". Nil (zero, 0.00) is a permitted coefficient value.

The decimal separator used for numerical values, depends on the regional settings of your machine.

Removing Flow Entries: To remove a flow entry from a process specification, mark the entry on the input or output side, and click on the associated 'Remove' button.

Importing Linear Process Specifications: A complete process specification can also be imported from an Excel spreadsheet file.

To import a process specification choose the command 'Import Linear Specification…' from the context menu of a process in the net editor.

Should the process already contain a process specification, a warning will be prompted. Importing a process specification from an Excel file into a specified process will overwrite the existing process specification.

The process data in the Excel table needs to have the correct format setup for the import of inventory data. This is the format that is also used for the export of inventory data:

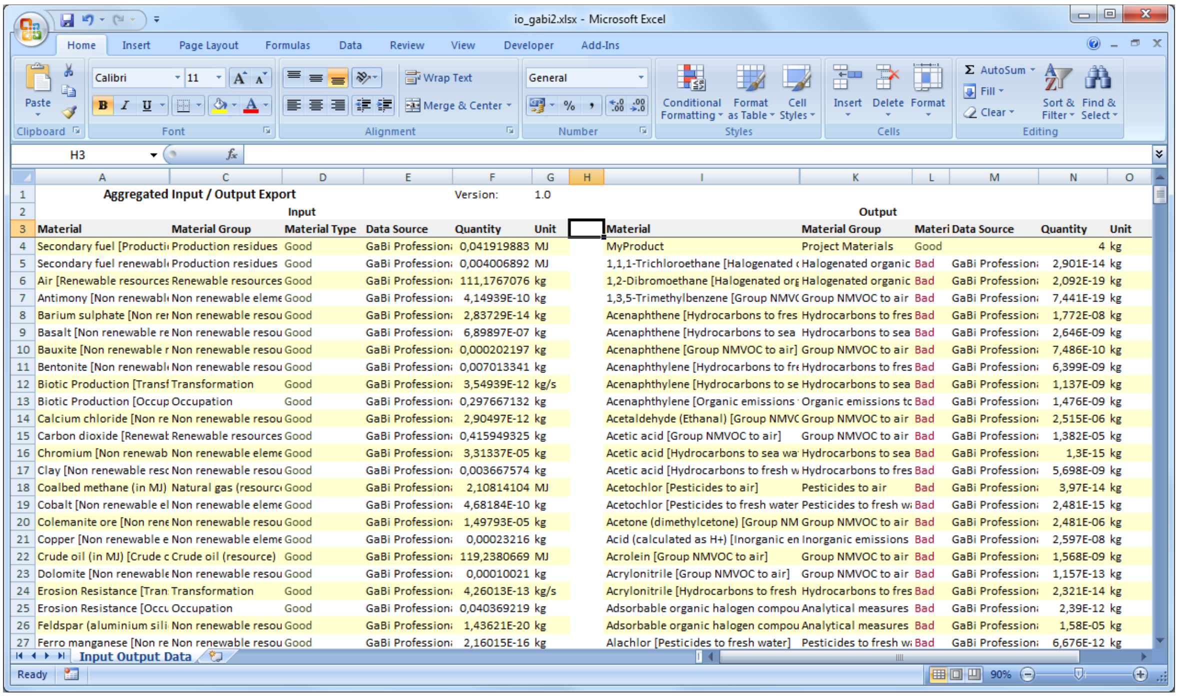


Figure 31: Excel table containing a process specification

It is recommended to use the template Excel file that can be obtained by exporting inventory data to Excel. This template has the correct format and is well-formed for the import of a process specification. Read more about exporting inventories in chapter 11.3

The Excel table requires the following format so that the import of the process specification can run smoothly: Row 1 may contain free text. Lines 2 and 3 contain header information and should have exactly the following content in the cells A2 to G3 for the input side, repeated in cells A2 to G3 for the input side:

	A	C	D	E	F	G
1	free header text				Version:	1.0
2			Input			
3	Material	Material Group	Material Type	Data Source	Quantity	Unit

Figure 32: Header cells A2 to G3 of Excel table, input side of a process specification

	I	K	L	M	N	O
1						
2			Output			
3	Material	Material Group	Material Type	Data Source	Quantity	Unit
4	Scrap, biopolymer	Residues	Bad		197,530864	kg

Figure 33: Header cells I2 to O3 of Excel table, output side of a process specification

The actual content starts in row 4.

For the input side of the process:

Column A	Material	Name of a material entry. Should have exactly the same spelling as an existing item to be matched.
Column B (hidden)	Material GUID	This is a unique GUID for the material. Do not modify. It is recommended to keep this column hidden.
Column C	Material Group	Name of a material group. Should have exactly the same spelling as the group in the project.
Column D	Material Type	"Good", "Bad" or "Neutral" for materials
Column E	Data Source	The data source, if the material entry is from a master material database
Column F	Quantity	Use decimal point as defined in Excel
Column G	Unit	One of the existing basic units or one of the display units defined. See annex D for a list of units.

Column H is used for visual separation only and remains empty.

For the output side of the process:

Column I	Material	Name of a material entry. Should have exactly the same spelling as an existing item to be matched.
Column J (hidden)	Material GUID	This is a unique GUID for the material. Do not modify. It is recommended to keep this column hidden.
Column K	Material Group	Name of a material group. Should have exactly the same spelling as the group in the project.
Column L	Material Type	"Good", "Bad" or "Neutral" for materials
Column M	Data Source	The data source, if the material entry is from a master material database
Column N	Quantity	Use decimal point as defined in Excel
Column O	Unit	One of the existing basic units or one of the display units defined. See annex D for a list of units .

Material entries (columns A and I) in the Excel files will be matched with existing project materials. Newly identified material entries will be added to the project material list. If a correct material group name is given (columns C and K) for the material, the imported material will be inserted there. Otherwise it will be inserted into a group "Imported Materials". After importing check the group "Imported Materials" in the Project Explorer and identify any new items.

The "Material Type" column requires "Good", "Bad" or "Neutral" for material entries. If a material with the same name exists already in the project materials, the same material with a different material type can not be imported.

Material entries in the Excel file can have either one of the defined basic units, or any display unit defined for a basic unit. A full list of units is available in Annex D. Mind the exact name of the unit, including upper- and lowercase! For example "KG" and "Kg" are incorrect spellings for the mass unit "kg".

New materials will be added to the project materials in the 'Imported Materials' group with the properties. It is not possible to define new groups by simple having a group as entry in the Excel list. Instead it is recommended to define a material group (see section 6.2) before running the import, so that the material can be inserted

If the import of the process specification from Excel fails or conflicts (e.g. unit mismatch) occur, a rollback will be performed and the previous specifications in the process re-established. A log file with the conflicts/error will be written to the working directory (typically C:\Users\<USER>\Documents\Umberto LCA+).

Functions for Flow Coefficients: Instead of entering a coefficient, it is also possible to use a function that is evaluated to determine the coefficient value. These functions can contain parameters (see below).

Enter a function or term to be evaluated in the field 'Function' on either input or output side for any of the entries. The button with the three periods in the field can be used to open the 'Edit Coefficient Function' dialog box.

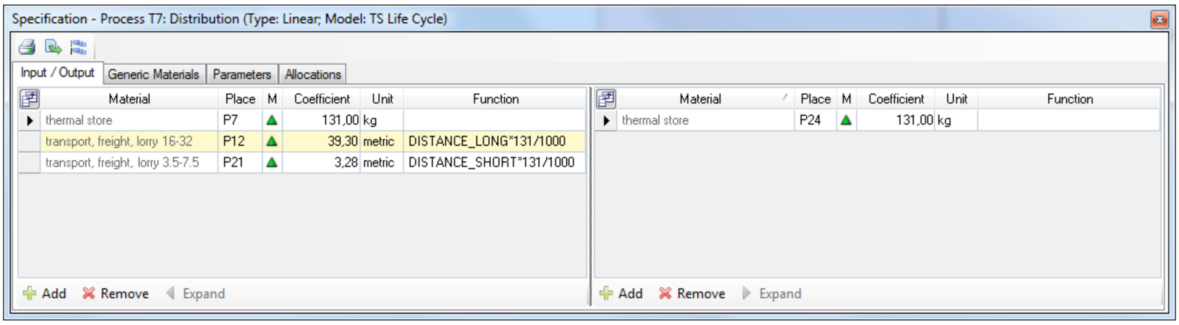


Figure 34: Specification Editor window for a process, 'Input/Output' tab, use of a function with parameters DISTANCE_LONG and DISTANCE_SHORT to determine coefficient values

You can use names of parameters, mathematical operators, and a set of pre-defined functions within the term entered in the "Function" field.

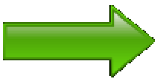
Examples for functions are:

- `((EMPKMOUT*DISTOUT+EMPKMRET*DISTRET*(EMPTYRET/100))/CARGOTRIP)/1000`
- `EMDAY*DAYS*PKPTO/CPPAL`
- `MIN(HEATA,HEATB)`

The expressions DISTOUT or CARGOTRIP are parameters. Parameters are described in the next section.

The term MIN(expr1,expr2) is a function that delivers the minimum of two values. A complete list can be found in the annex at the end of this user manual.

After you typed the first letter of a reserved function name, you can use the keyboard combination CTRL+SPACE to bring up code completion for pre-defined function and parameter names.



Note that the complete process specifications can also be defined as "User Defined Functions" to describe more complex, e.g. non-linear process relationships. This feature is described in chapter 13.1

Live Links to Flow Coefficients: Flow coefficient values on the input and output side of a process specification can also be fed from an external data source (an Excel spreadsheet file) via a so-called Live Link. In this case, a reference to cell in an Excel spreadsheet file is created and linked to the coefficient. An update of the value in the source file leads to an update of the value in the process specification.

To establish a Live Link, copy the value of a cell and paste it on the specific line of the table on the input or output side. A coloured icon signals that this value is fed via a Live Link. In case the icon is shown in grey the data source file is closed and values will only be updated when it is next opened, or when the update is triggered manually.

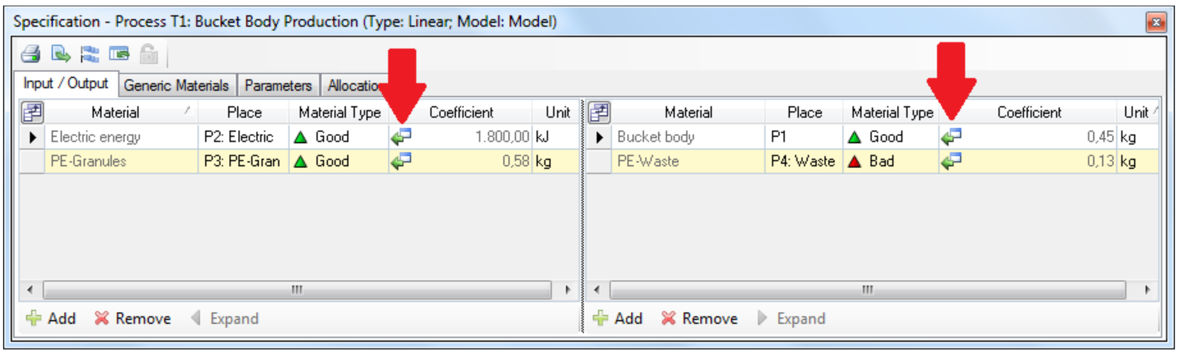


Figure 35: Live Link references of four coefficient values in a process specification indicated by an icon

Note that entering a coefficient value manually or adding a function will overwrite an existing Live Link reference.

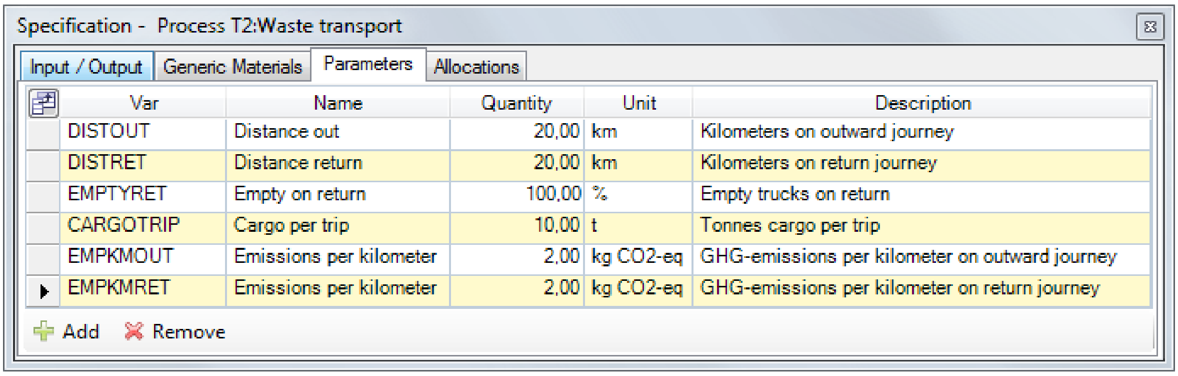
To paste a Live Link use the command 'Paste Live Link' from the context menu of the process specification. Make sure you are on the correct line and correct side of the table on the 'Input/Output' page.

To delete a Live Link mark an entry on the input or output side of the process specification, then use the command 'Remove Live Link' from the context menu.

A more comprehensive description of how the Live Links can be created and managed in Umberto can be found in section 14 of this user manual.

8.2 Parameters in Process Specification

Parameters can be used to calculate the process. They are defined on the 'Parameters' tab of the Specification Editor. Parameters can be used in functions for calculation of coefficients on the 'Input/Output' tab.



Var	Name	Quantity	Unit	Description
DISTOUT	Distance out	20,00	km	Kilometers on outward journey
DISTRET	Distance return	20,00	km	Kilometers on return journey
EMPTYRET	Empty on return	100,00	%	Empty trucks on return
CARGOTRIP	Cargo per trip	10,00	t	Tonnes cargo per trip
EMPKMOUT	Emissions per kilometer	2,00	kg CO2-eq	GHG-emissions per kilometer on outward journey
EMPKMRET	Emissions per kilometer	2,00	kg CO2-eq	GHG-emissions per kilometer on return journey

Figure 36: Specification Editor window for a process, 'Parameters' tab

Defining Parameters: To define a flow parameter in a process specification, click on the button 'Add'. A default entry will be created in the table on the 'Parameters' tab, which can subsequently be edited: enter a name and a unit, and set a value for the parameters. The default variable name (C00, C01, …) can be edited as well, to allow for a better identification of a parameter.

The parameters are referenced in the functions with the variable name given for an entry in the column 'Var'. In the above example, the default parameter names have been replaced with DISTOUT, DISTRET, EMPTRET and the like for better understanding.

These parameter names can be used in the functions for coefficients (see above) and in the user defined functions for the process specifications (see section 13.1).

Apart from process parameters, valid locally in one specific process, there are also net parameters that are available globally (see section 13.5).

Removing Parameters: To remove a parameter entry from a process specification, mark the entry and click on the 'Remove' button. Mind that the deletion of a parameter may result in different coefficient values, if the parameter has been used for the calculation of a coefficient value on the Input/Output tab, or for the calculation of another parameter.

Functions for Parameters: Instead of entering a parameter value explicitly, it is also possible to use a function that is evaluated to determine the parameter value. These functions can themselves contain other parameter names.

Enter a function or term to be evaluated in the field 'Function' for a parameter. The button with the three periods in the field can be used to open the 'Edit Coefficient Function' dialog box.

You can use names of parameters, mathematical operators, and a set of pre-defined functions within the term entered in the "Function" field. For examples see the description of function term for coefficients in process specification (above section 8.1 and 13.1). A list of valid expressions can be found in Annex E.

Live Links to Parameter Values: Parameter values can also be fed from an external data source via a Live Link. A reference to a cell in an Excel spreadsheet file is created and linked to the coefficient. An update of the value in the source file leads to an update of the parameter value.

To establish a Live Link, copy the value of a cell and paste it on the line of the parameter table. A coloured icon signals that this value is fed via a Live Link. In case the icon is shown in grey the data source file is closed and values will only be updated when it is next opened, or when the update is triggered manually.

Note that entering a parameter value manually or adding a function for the calculation of the parameter will overwrite an existing Live Link reference.

To paste a Live Link use the command 'Paste Live Link' from the context menu of the parameter. To delete a Live Link that has been created for a parameter mark the entry on the 'Parameter' page, then use the command 'Remove Live Link' from the context menu.

A more comprehensive description of how the Live Links can be created and managed in Umberto can be found in section 14 of this user manual.

8.3 Allocation in Multi Product Processes

Allocation is an important topic in Life Cycle Assessment. Choosing allocation factors may have significant impact on the results of an LCA. For further details please refer to publications on the topic of allocation.

The question how allocation is handled on the system level is implicitly determined by the choice of system model (see section 13.7) since the background datasets used make use of one specific method for allocation. It is good practice to also handle allocation on the process level in line with the chosen system model, as recommended by the LCA methods and guidelines, unless there are explicit reasons why a certain process should use different ways of doing the allocation on the process level

This section describes how allocation on the process level can be done in Umberto LCA+.

Allocation is not required in processes that yield but one product. Hence, if a process specification has only one reference flow (one entry with material type 'Green' on the output side or one entry with material type 'Red' on the input side) then no allocation settings are required. All expenses of the process are linked to the one reference flow. Consequently, when there is only one reference flow in a process then the 'Allocations' tab is not visible.

Should a process specification have more than one reference flow, then allocation factors need to be set. This is done on the 'Allocations' tab of a process specification that becomes visible in that case. There are several possibilities for default allocation on the process level.

Remember that reference flows are automatically identified by checking whether a flow on the output side of a process has the material type 'Good' and/or whether a flow on the input side of a process has the material type 'Bad'.

The default setting for allocation when creating a process specification that has more than one reference flow is "Physical", if the reference flows are of the same unit type.

A "mixed" allocation is also possible when the 'Display' is set to "Expenses": Leaving the entry "Default" in the dropdown list in the column "Allocation Method' will use the default allocation method chosen above in the 'Default Allocation Method' dropdown list, but individual expenses might be allocated differently. To this end, choose another allocation method for individual expenses.

In the screenshot below there is a simple process that has a raw material as input (expenses), waste and emissions as additional expenses on the output side. The process yields two products (Product 1 and Product 2) in different quantities.

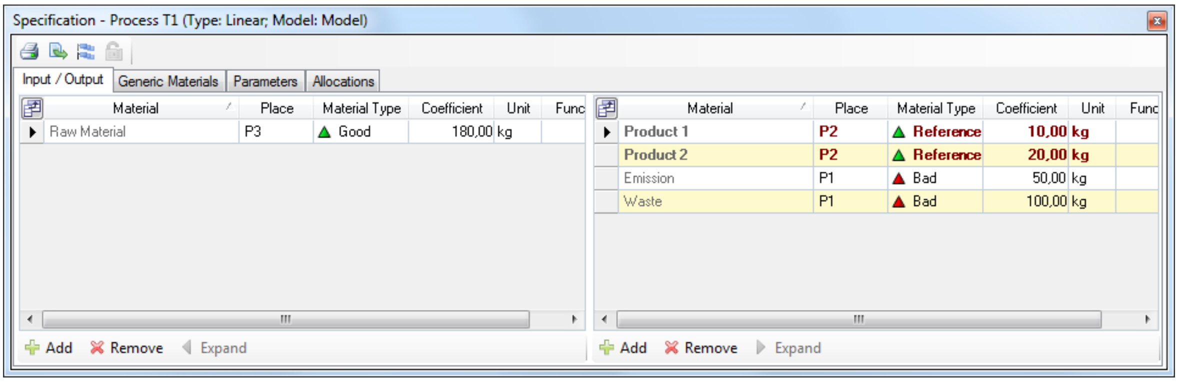


Figure 37: Specification window, 'Input/Output' tab, two reference flows

User Defined Allocation Factors: In this case the allocation of the expenses on the 'Allocations' tab of the process specification is set to 'User Defined'. The user has the possibility to enter the allocation factors manually. In the screenshot below, an equal allocation of the expenses (50:50) has been set, despite the fact that the products are not produced in the same quantitative proportion.

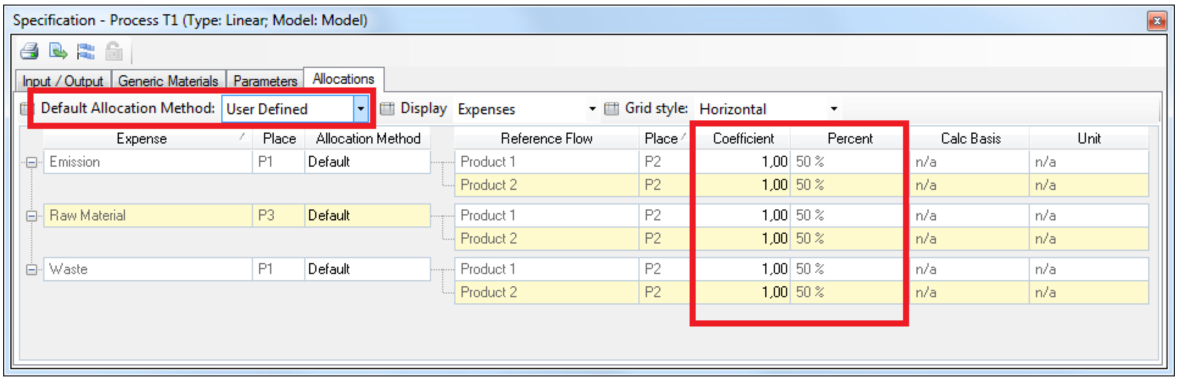


Figure 38: Specification Editor, 'Allocations' tab, 'User Defined' allocation

Different user defined allocation factors could be set. They do not necessarily have to be the same for every expense, but can vary in each allocation set of an expense to the two or more products. The percentage values will automatically be determined depending on the values entered in the 'Coefficient' column

Physical Allocation: This is the default allocation setting for newly created processes that have two or more reference flows of the same unit type (e.g. mass). Physical allocation assesses the mass of the reference flows and uses their physical proportionality as the allocation factor. The values are determined in the first part of the calculation process and are entered in the 'Coefficient' fields on the 'Allocations' tab automatically when the 'Default Allocation Method' is set to 'Physical'.

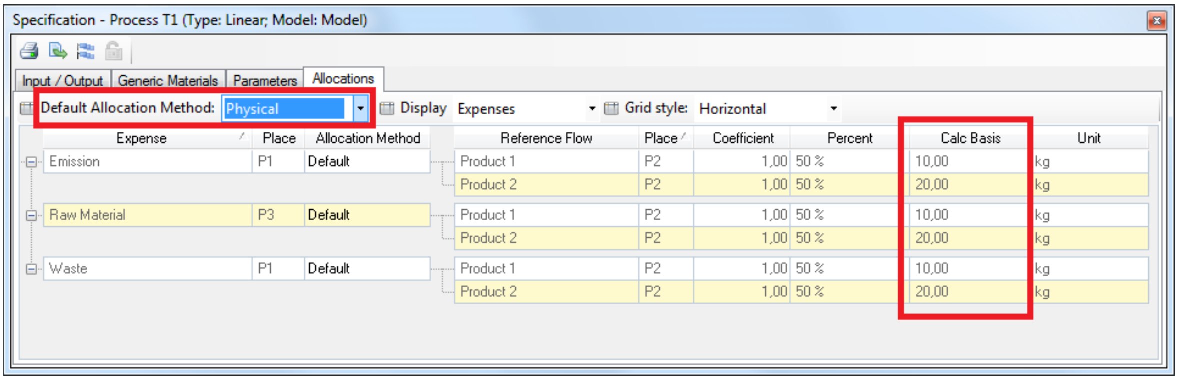


Figure 39: Specification Editor, 'Allocations' tab, 'Physical' allocation

The dropdown lists 'Display' and 'Grid Style' can be used to adapt the display of the allocation, either the products by their expenses, or the expenses by the products.

In the example above, the 'Default Allocation Method' is set to 'Physical' and the coefficients entered for the two reference flows are "10" and "20". These values are shown in the 'Calc Basis' column for orientation. The values in the 'Coefficient' and 'Percent' columns still show the previous values. The valid allocation factors are only determined in the first part of the calculation (see section 10.2):

```
Product 1  10 kg      10 / (10+20) = 33,33%
Product 2  20 kg      20 / (10+20) = 66,66%
```

The 'Coefficient' and 'Percent' values can be viewed after the first calculation.

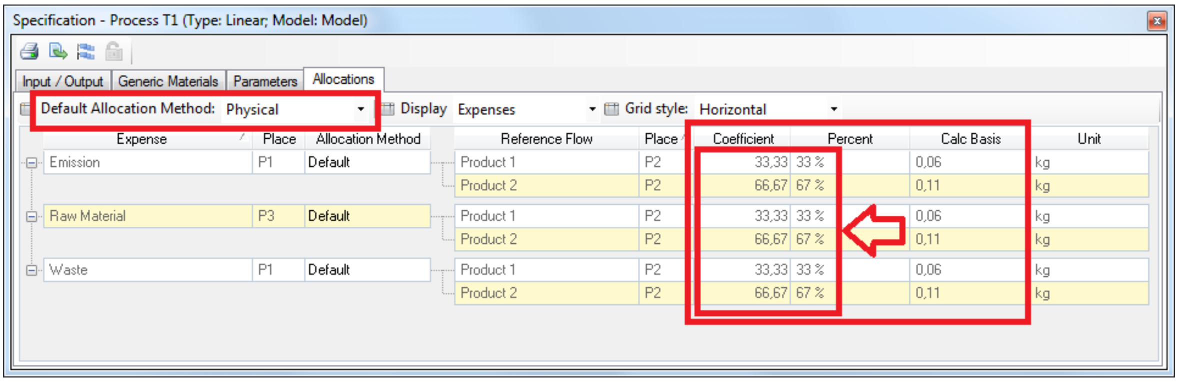


Figure 40: 'Allocations' tab, 'Physical' allocation. After the first calculation the allocation factors were determined and can be viewed in "Calc Basis" and "Coefficient" column

Mind that this type of allocation is only meaningful, if the reference flows have the same unit type (e.g. Mass). 'Physical' allocation is not possible, if the reference flows are from different unit types (e.g. main product is mass, co-product is energy). A warning will be shown and the user will be asked to change the allocation method setting.

Economic Allocation: To set economic allocation choose "Economic" from the dropdown list "Default Allocation Method". For all expense entries set to "Economic" or "Default" the allocation between the reference flows is determined via the flow quantity multiplied with the market price of the material.

The dropdown list 'Grid Style' should be set to 'Horizontal' so that the two additional columns 'Calc Base' and 'Unit' can be seen. In the 'Calc Base' field it can be checked, whether the allocation calculation will be what is expected. Especially, it should be checked whether a market price has been defined for the material identified as reference flow. Economic allocation to a reference flow with market price 0.00 is disallowed.

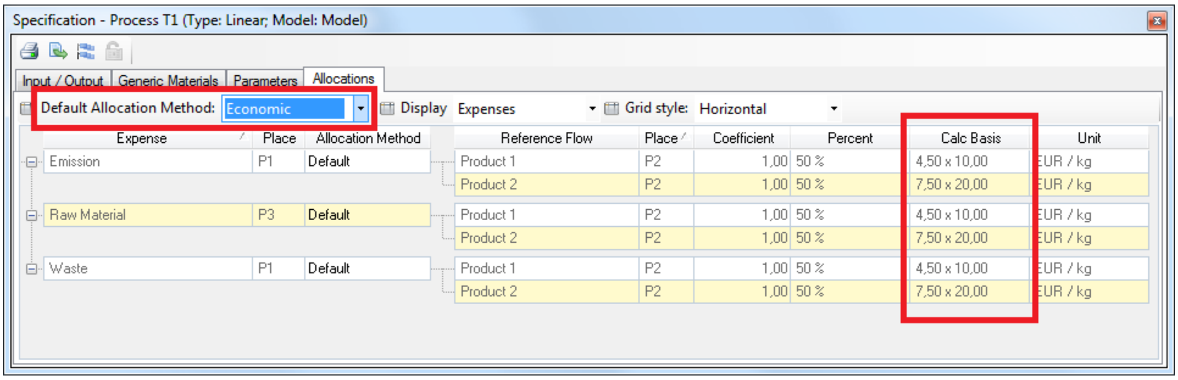


Figure 41: Specification Editor, 'Allocations' tab, Economic Allocation

In the example above, the 'Default Allocation Method' is set to 'Economic' and the coefficients entered for the two reference flows are "10" and "20". Both reference flows have a market price defined (4,50 EUR/kg and 7,50 EUR/kg). These values are shown in the 'Calc Basis' column for orientation. The values in the 'Coefficient' and 'Percent' columns still show the previous values. The valid allocation factors are only determined in the first part of the calculation:

```
Product 1  10 kg      4,50 € * (10/(10+20)) >> 23,0769 %
Product 2  20 kg      7,50 € * (20/(10+20)) >> 96,9231 %
```

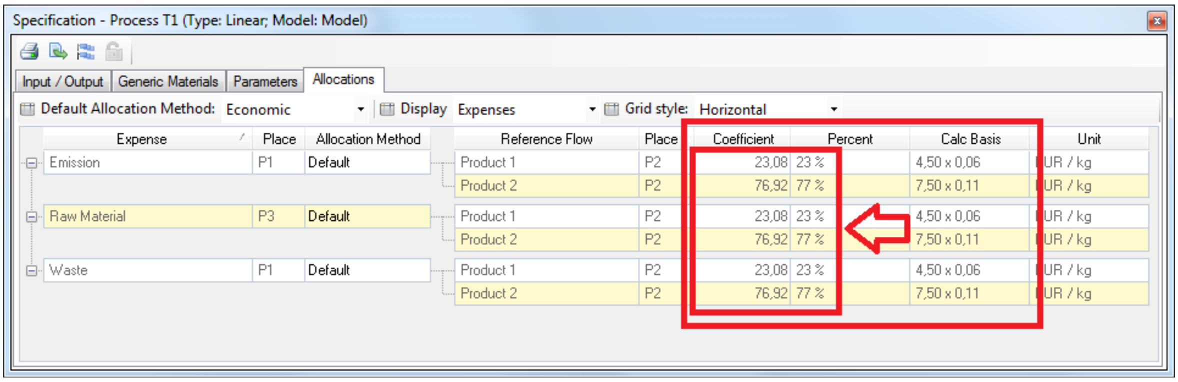


Figure 42: 'Allocations' tab, 'Economic' allocation. After the first calculation the allocation factors were determined and can be viewed in "Calc Basis" and "Coefficient" column

To view allocation factors that are being used, run the two calculation steps separately: Execute 'Calculate Total Flows' (SHIFT+F9) first to determine the allocation factors. To complete, launch 'Calculate Product Flows and LCIA' (CTRL+F9).

Allocation based on Material Properties: Allocation based on individual material properties is at present not supported in Umberto LCA+. Please check the next version for a better and more comfortable support of this allocation type. In the meantime the user can use the 'User Defined' option described above and enter the allocation factors for self-defined multi-output processes manually.

8.4 Further Process-Related Features

List of Processes: A list o processes (activities) that have been defined in the models can be called using the button 'Process List' from the main toolbar, or by calling the command 'Process List' from the Tools menu.

For more advanced features related to process specification, such as the use of generic materials, allocation in processes that have more than one product, process specification using mathematical formulas and operators, and hierarchical modelling using subnets, please refer to chapter 13.

Apart from the functions used for the definition of parameter values, it is also possible that process specifications are made using mathematical formulas (functions). These give a much higher degree of flexibility for process specification than with simple linear input/output coefficients.

A complete list of functions and operators used can be found in the annex at the end of this user manual.

Hierarchical modelling with subnets is possible and explained in section 13.4.

9 Using Background Datasets (Process Specification with Secondary Data)

9.1 LCI databases as Master Databases

Several LCI databases are available for use in Umberto LCA+. Individual licenses might be required for using an additional LCI database. Each database can be installed separately (see chapter 2.4).

Specific information relating to the activity datasets in the individual LCI databases are made available by the data producers. For questions regarding the content of the databases or individual datasets, please contact the original provider of the database.

When LCI data providers update their LCI databases, they are made available to Umberto users as new installation files. When a new master database version is released, the update notification in the software will show a hint on the start page. Users can then download and install the new databases. After installing the new master databases and upon opening project files the user has the option to update the activity datasets within the project files (see section 9.2)

ecoinvent v2.2
The ecoinvent database (www.ecoinvent.org) is published and maintained by the ecoinvent Centre in Switzerland. It is the most renowned database for life cycle inventory (LCI) datasets. It contains approximately 4500-5000 harmonized, reviewed and validated datasets for use in Life Cycle Assessments (LCA). These datasets are all fully documented.

The version 2.2 was released in May 2010, and is the last version of the database built on the EcoSpold v1 data format. Version v2.2 is available as legacy data, but no more updates are being made to the database. The successor to this version is ecoinvent v3 (current subversion is v3.2, as of January 2016).

For further details on the ecoinvent database v2.2 please refer to the official reports available to registered users as PDF downloads on the ecoinvent website.

ecoinvent v3 (version v3.4)
This is the successor to the ecoinvent v2.2 database described above. It contains even more reviewed datasets for use in Life Cycle Assessments (LCA) models. The datasets are available in three different system models in Umberto LCA+: 'Allocation, cut-off', 'Allocation, at point of substitution' (short 'Allocation, apos') and 'Consequential'. For more information on system models please see section 13.7.

The ecoinvent v3 database is based on the EcoSpold v2 data format. For more information please refer to the official ecoinvent documentation:

- Weidema B P, Bauer C, Hischier R, Mutel C, Nemecek T, Reinhard J, Vadenbo C O, Wernet G. (2013). Overview and methodology. Data

quality guideline for the ecoinvent database version 3. Ecoinvent Report 1 (v3). St. Gallen: The ecoinvent Centre

- Moreno Ruiz E, Weidema B P, Bauer C, Nemecek T, Vadenbo C O, Treyer K, Wernet G. (2013). Documentation of changes implemented in ecoinvent Data 3.0. Ecoinvent Report 5 (v3). St. Gallen: The ecoinvent Centre.
- Moreno Ruiz E, Lévová T, Bourgault T, Wernet G. (2014). Documentation of changes implemented in ecoinvent version 3.1. Zurich: ecoinvent.
- Moreno Ruiz E, Lévová T, Bourgault T, Wernet G. (2015). Documentation of changes implemented in ecoinvent version 3.2. Zurich: ecoinvent.
- Moreno Ruiz E., Lévová T., Reinhard J., Valsasina L., Bourgault G., Wernet G., (2016). Documentation of changes implemented in ecoinvent database v3.3. ecoinvent, Zürich, Switzerland
- Moreno Ruiz E., Valsasina L., Fitzgerald D., Brunner F., Vadenbo C., Bauer C., Bourgault G., Symeonidis A., Wernet G. , (2017). Documentation of changes implemented in the ecoinvent database v3.4. ecoinvent, Zürich, Switzerland.

For further details on the ecoinvent database v3 please refer to the official online documentation of the ecoinvent LCI database. As a registered user you can logon and access the ecoinvent database at http://www.ecoinvent.org/login-databases.html.

GaBi Professional Database

The GaBi Professional database is published and maintained by PE International (http://www.gabi-software.com). It contains approximately 7500 LCI datasets from publicly available and industry sources that can be used in Life Cycle Assessments (LCA). These datasets are all fully documented.

For further details on the GaBi databases please visit http://www.umberto.de/en/gabi-databases/

GaBi Extension Databases

There are 21 additional GaBi Extension databases that contain LCI data from specific industrial sectors. These are labelled with Roman numerals (I to XX).

- Extension database Ia: Intermediates organic
- Extension database Ib: Intermediates inorganic
- Extension database II: Energy
- Extension database III: Steel
- Extension database IV: Aluminium
- Extension database V: Non-ferrous metals
- Extension database VI: Precious metals
- Extension database VII: Plastics
- Extension database VIII: Coatings
- Extension database IX: End of life
- Extension database X: Manufacturing
- Extension database XI: Electronics

- Extension database XII: Renewable raw materials
- Extension database XIII: ecoinvent 2.2 integrated
- Extension database XIIIb: ecoinvent 3.1 integrated
- Extension database XIV: Construction materials
- Extension database XV: Textile finishing
- Extension database XVI: Seat covers
- Extension database XVII: Full U.S. database
- Extension database XVIII: NREL U.S. LCI integrated
- Extension database XIX: Bioplastics
- Extension database XX: Food & Feed
- Extension database XXI: India

For more information on the content and sources of these data please check http://www.gabi-software.com

For further details on the GaBi database please refer to the official documentation provided on the GaBi website. You can browse all datasets at http://www.umberto.de/en/lca-data/search/ and also access their documentation.

Tutorial Example
A master database with some sample datasets using fictitious activity data is provided, so that the user of the trial version and those users who don't hold a license of ecoinvent or any other additional master database can still use the software with their own activity datasets.

Warning: Do not use the activity datasets for real-life LCA studies. Data is fictitious!

The 'Tutorial Example' master database uses the same elementary exchanges as the ecoinvent v3 database (see above), so that the impact assessment methods delivered by ecoinvent can be used.

Advanced users who do not use the tutorial example any more are recommended to disable the database so that these dataset are ignored in searches.

9.2 Using Activity Datasets from LCI Databases

Several master databases might be installed in Umberto LCA+, depending on the LCI database licenses acquired jointly with the purchase of the software. Each installed master database is shown with a separate node in the 'Project Explorer'.

Most databases contain activities (processes) and exchanges (flows). In this section the use of activities from master databases for process specification in the life cycle model is explained.

The group structure (classification) depends on the LCI database. In the ecoinvent v2.2 LCI database there is an individual two-level structure. The ecoinvent v3 LCI database uses the ISIC v4 classification for activities, where the actual activity entries can typically be found on the fourth hierarchy level only.

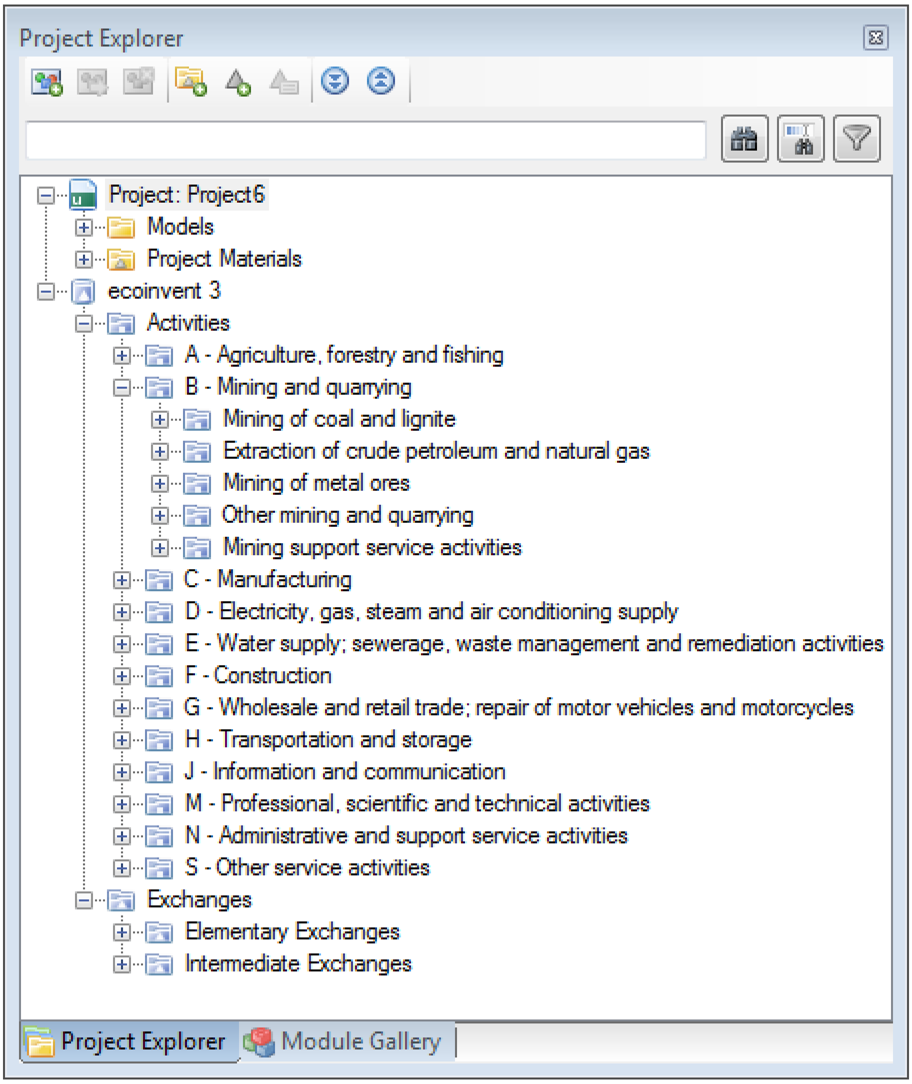
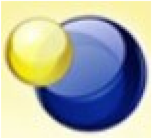


Figure 43: Project Explorer with ecoinvent 3 LCI database activities group structure



In the GaBi LCI databases there is a different grouping with most of the production activities under the group "Production" and "Industry Data".

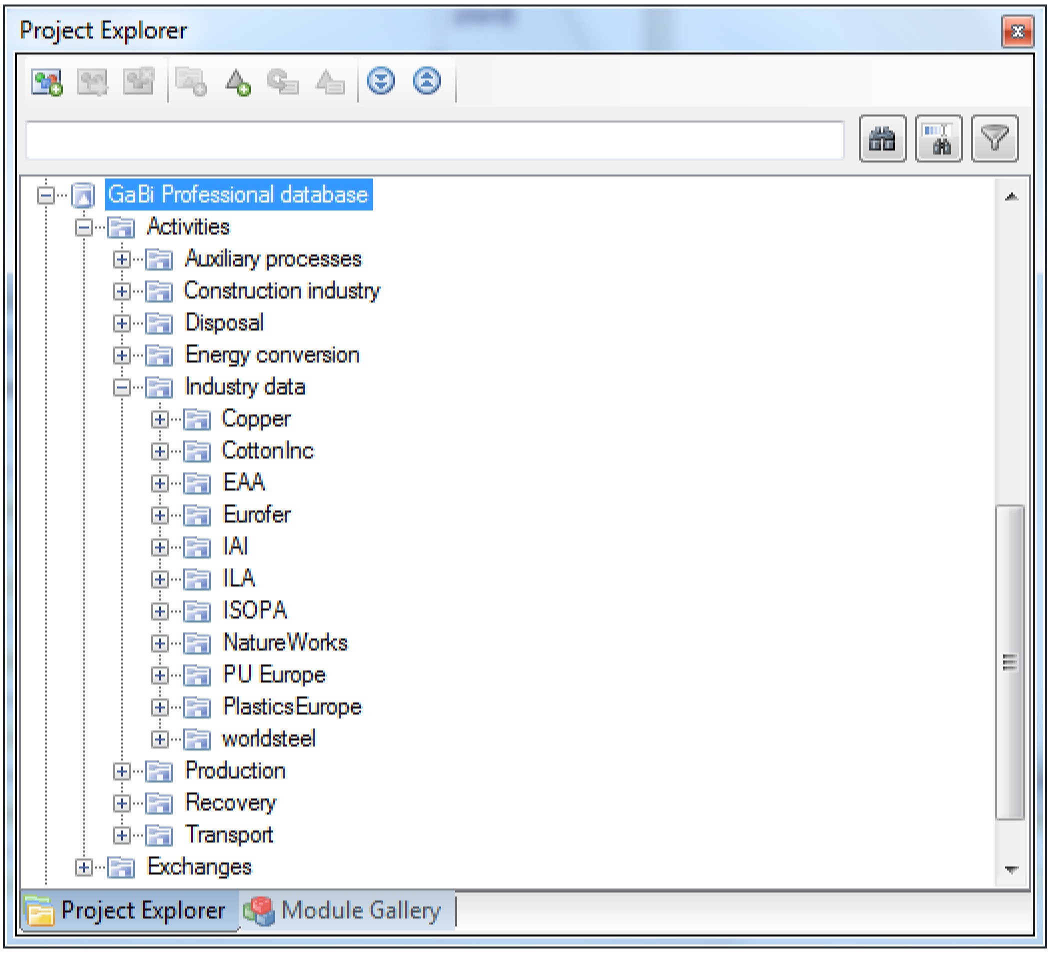


Figure 44: Project Explorer with GaBi LCI database activities group structure

Enabling/Disabling Master Databases: In case you have several LCI master databases installed, but do not need the datasets from a specific database for your project, the database can be temporarily disabled.

To temporarily disable a database, right mouse-click on the root folder of the master database and choose the command 'Disable Master Data Library'. Disabled databases are shown with a greyed folder symbol.

To enable a temporarily disabled master database choose the command 'Disable Master Data Library' from the context menu.
A disabled database will not be uninstalled, but it won't be included in dataset searches, and the expand function will not offer any activity datasets from this database.

The enabled and disabled master database settings will be remembered for the project. When opening the project again, the enablement status of the LCI databases is maintained.

Browse Activity by Classification: To search for a specific activity, you can browse the classification of activities by unfolding the hierarchical groups with a click on the plus sign in front of the group. A click on the minus sign in front of an activity will collapse the expanded group. The buttons 'Expand All' and 'Collapse All' are available in the toolbar at the top of the Project Explorer.

Search Activity by Full Text: To search for a specific activity, use the search bar at the top of the Project Explorer.

- Full Text Search
- Incremental Search
- Filter

To search for an activity by name of part of its name, select 'Incremental Search' and 'Filter'. Only the materials containing the text string that is typed in the search field are shown.

Mind that only enabled master databases will be searched. No results will be yielded from databases that are temporarily disabled. Read above how to enable/disable LCI databases for use in your project.

Examples: To search for all activities that are related to Brasil, type "Brasil" and click on 'Incremental Search' and 'Filter'. To search for all activity datasets that have to do with polypropylene, type the string "polyprop". The search will yield not only production datasets, but also activities covering the end-of-life of the plastic.

Versioning and Update: Due to the fact that these LCI datasets are delivered as master data, they cannot be fully modified. On the other hand, official updates of the LCI database will allow updating the existing master data in Umberto LCA+. New datasets and activities can be added to the master data in your local installation.

Before updating master data in Umberto LCA+, the new master data will have to be installed. The update mechanism is not silent. This means that the practitioner will receive a warning, and will be offered the possibility to update (or decline this option).

Activity Properties: When an activity dataset is selected in the master data hierarchy, the 'Properties' dialog shows the most important dataset information, such as geographic reference, time period, the available system models and types of this activity that are available, along with the general comment and the version number of the dataset.

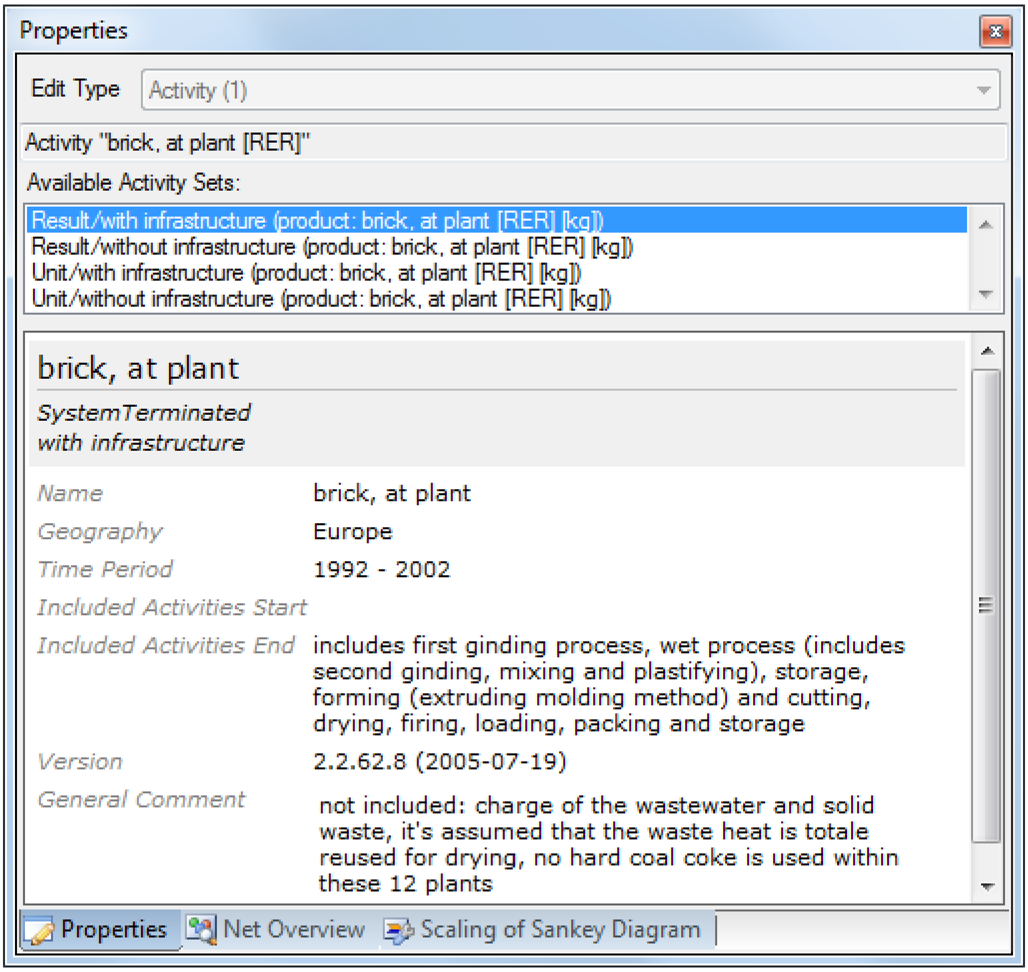


Figure 45: Properties dialog for an ecoinvent activity dataset. Only the most important meta information is presented. For details the practitioner should access the full documentation online

When the activity dataset has been added to a life cycle model, you can view the properties by selecting the command 'View Activity Meta Data' in the specification of the process. The activity dataset in the master data is selected in the Project Explorer and the associated properties are shown in the 'Properties' dialog.

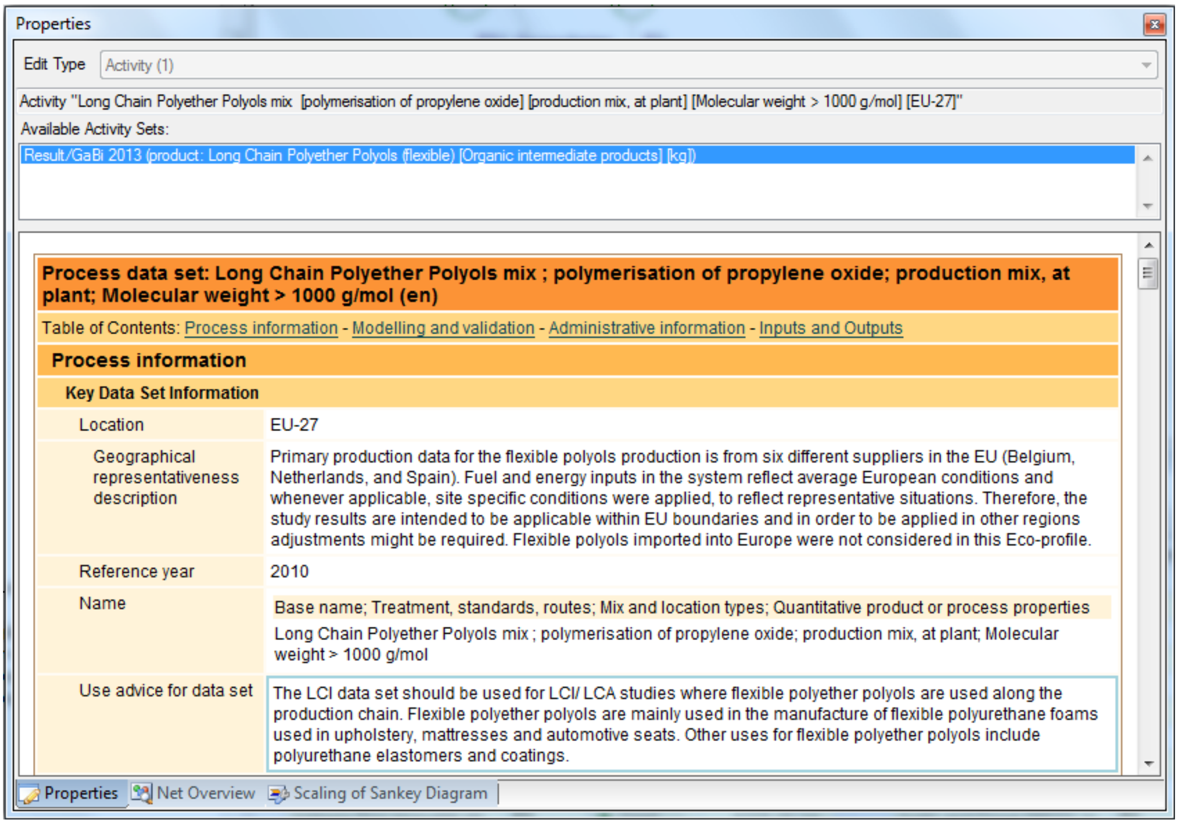


Figure 46: Properties dialog for a GaBi activity dataset. Only the most important meta information is presented. For details the practitioner should access the full documentation online

Access to Additional Information: To get access to the full documentation of the activity dataset the LCA practitioner should access the web page of the LCI database supplier. Login credentials might be required to access the information.

For ecoinvent v2.2 and ecoinvent v3 databases the dataset information can be found on the website of the ecoinvent Centre at http://www.ecoinvent.org

You can click on the hyperlink 'View Online at ecoinvent' to go to the dataset information. Be prepared to enter your login credentials when first visiting the ecoinvent website.

For GaBi databases the dataset information can be found on the website http://www.gabi-software.com or via http://www.umberto.de/en/lca-data/search/

Inserting Activity Dataset in Model: To use an activity dataset in your life cycle model simply drag the selected dataset (activity name with blue process icon in front) to an empty area in the editor.

Note that activity datasets from the master databases are "locked" to protect their original status. This is shown with a lock icon. To modify or adapt the process specification, the lock must be removed. Read below for more information.

The activity dataset typically is available in different types (or "versions") and you will be prompted to choose the type you wish to insert into the model. This can be the unit process or one or more result (system terminated) processes which yield the product. If the ecoinvent master database contains more than one system model the same activity may be offered with coefficients that were determined by different system models for allocation.

Choose the activity type with the appropriate system model and product to be inserted from the selection list in the 'Select Activity Type' dialog.

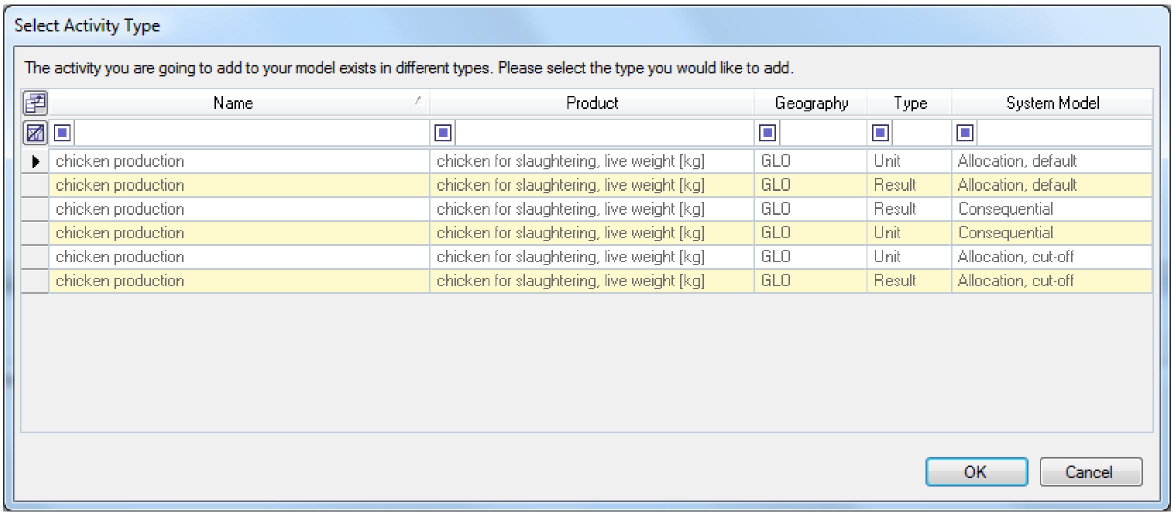


Figure 47: Select activity type: choose between unit or system terminated (result) version of the activity and one of the system models

Ecoinvent activities typically are available as both 'Unit' and 'System terminated' ('Result') type.
They can in most cases be chosen from one of the three system models: 'Allocation, default', 'Allocation, cut-off' or from the 'Consequential'. Note that the actual underlying coefficients in the activity vary significantly depending on the system model chosen.

Note that some activities may yield different products (multi-product activity). In this case the list offers several single-output entries, each of which is available as unit or result process.

In GaBi databases the activities are available as 'Unit' or 'LCI Result' types. The 'Partly Terminated' activity type is not labelled separately and listed as 'Unit'.

If an activity yields more than one product, there are no individual processes, but rather the activities contain multiple outputs. The practitioner must take care of the by-products in the model.

Typically each activity is present in the master database as unit process and system terminated (result) process. However, in some cases, where the provision of disaggregated unit datasets has been limited by the data provider, only the system terminated (result) process may be available.

Depending on the selection, a model section will be inserted at the position where the activity dropped in the editor area.

For a unit process this model stub has one input and an output place, to which elementary exchanges (should they exist in the unit process) will be assigned, and two connection places: one for the intermediate exchanges on the input side, and one for the intermediate exchange(s) on the output side (typically the reference flow).

Note that depending on the number of intermediate exchanges on the input side, and how the activity is integrated into the life cycle model, it might be required to add additional connection places and assign the place IDs for each of the exchanges.

Below are figures of model stubs for 'Unit' and 'System Terminated' ('Result') activities from the ecoinvent LCI database. 'System Terminated' ('Result') activities have no remaining intermediate exchanges.

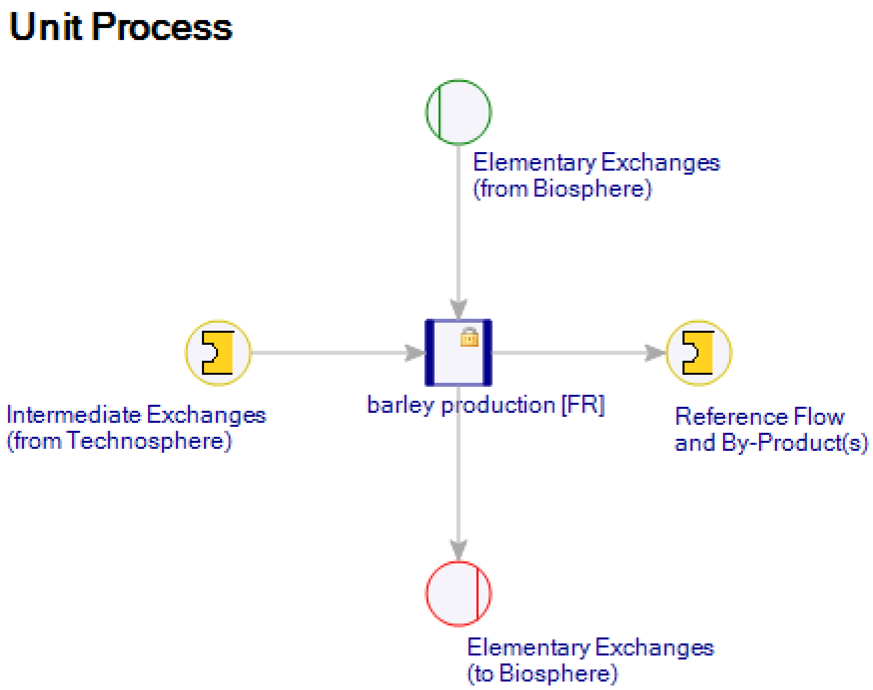


Figure 48: Model stub for a unit process from ecoinvent LCI database

For a result (system terminated) process the model stub has one input and an output place, to which all elementary exchanges are assigned, and one output-sided connection place for the reference flow.

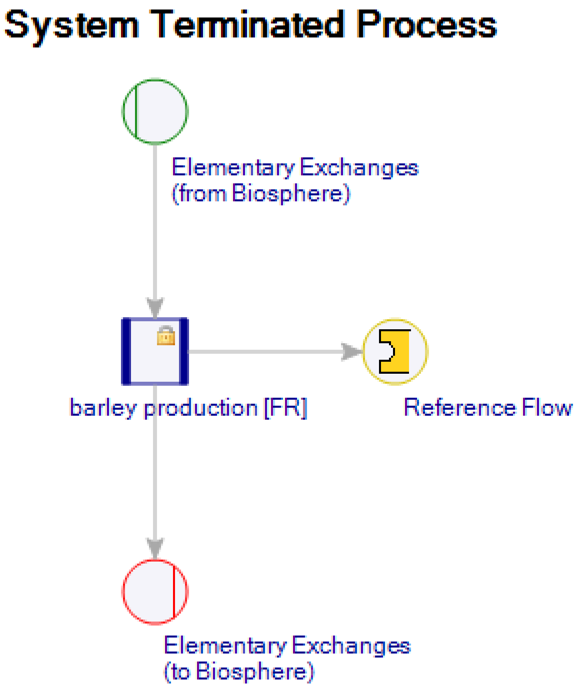
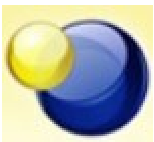


Figure 49: Model stub for a system terminated (=result) process from ecoinvent LCI database

The processes in these model stubs are fully specified. Inserting them by simple drag&drop facilitates building of life cycle models enormously. The model stubs can of course be adapted, e.g. by adding additional places for intermediate exchanges as input to unit processes, or by removing the input/output places, should a unit process not contain any elementary exchanges.



Below are sample figures of model stubs for 'Unit', and 'LCI Result' activities from the GaBi LCI databases.
Mind that the GaBi database features additional activity types, such as 'Unit process, black box', 'Avoided Product System' and 'Partly Terminated'. These are at present all grouped as unit processes, although they are not unit processes in the strict sense.

Mind that some activities from the ecoinvent and the GaBi databases can have very long names. To shorten the name in the process label, the activity needs to be unlocked (see below).

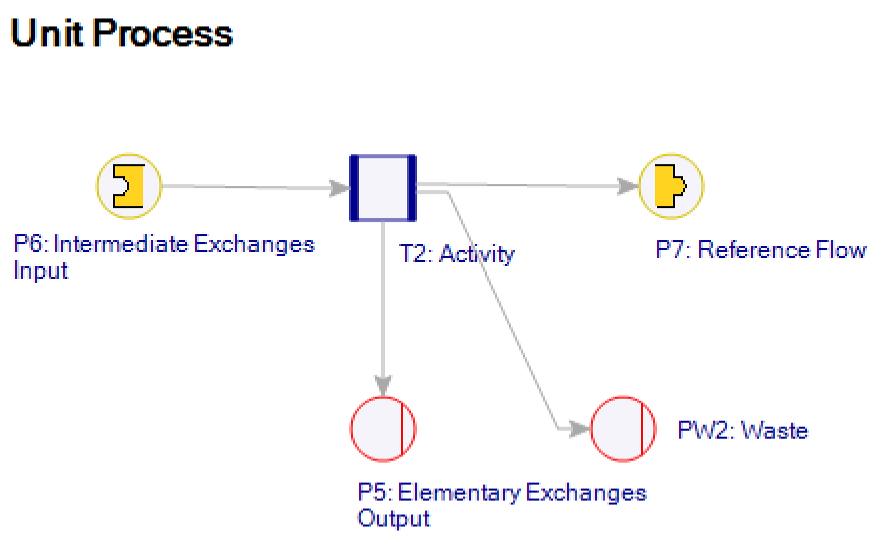


Figure 50: Model stub for a unit process activity from a GaBi LCI database.

The structure is different to the one shown above for an ecoinvent activity since it additionally has a "Waste" output for the non-elementary exchanges. This is because the stubs are created from the values set for the 'LCI Method' and 'IO type' properties. A model stub may have up to four input places next and up to four output places.

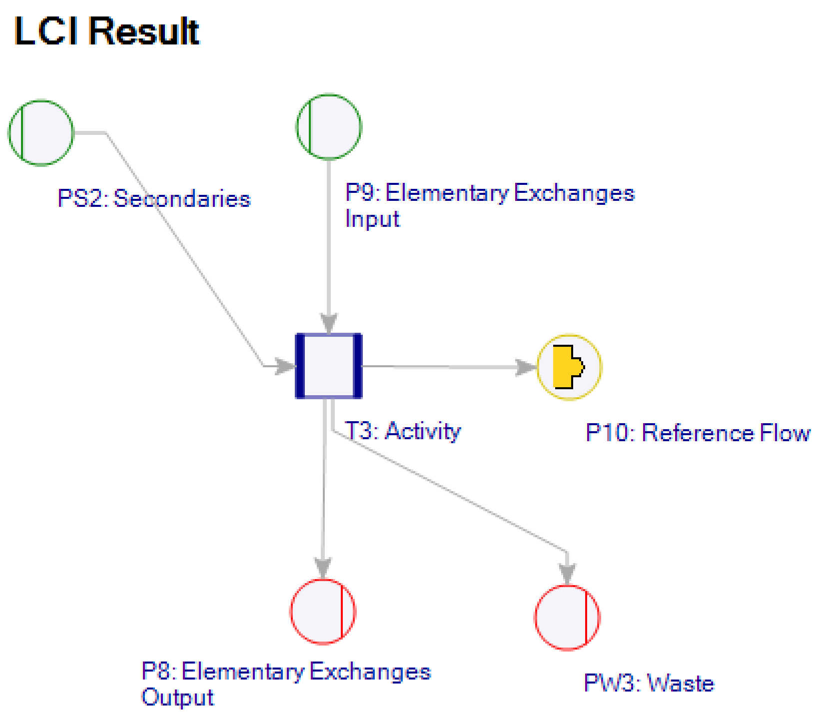


Figure 51: Model stub for a 'LCI Result' activity from a GaBi LCI database.

The structure is different to the one shown above for a 'System Terminated* ('Result') ecoinvent activity since it additionally has a "Secondaries" input and "Waste" output for non-elementary exchanges.

Use the feature to merge places (see section 7.3) to quickly connect the model stub to any existing models structure. The arrows can also be reconnected (see section 7.4), either by dragging the arrow foot or the arrow head.

Replacing Activity Dataset in Model: If the activity is dropped directly onto a process symbol in the editor, then the activity will be inserted without drawing a new model stub. The intermediate exchanges on the input and output side will be assigned to the first available connection place on each side. Elementary exchanges on the input and output side are assigned to the first available input and output place respectively. Should there be no places available, they will be supplemented.

If the activity is dropped directly onto a process in the life cycle model that is already specified, it will replace the activity. The place assignments should be checked and might have to be adjusted.

Updating of Activity Datasets in Models: When updates of LCI databases are released by providers (see section 9.1) and the updated master databases have been installed, a dialog is prompted informing about the availability of new activities when a project is opened.

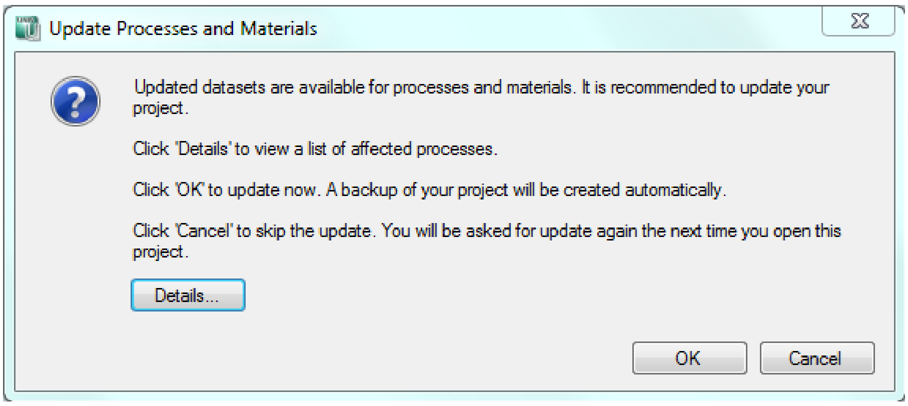


Figure 52: Warning that master material data has been updated and that datasets in the model being opened can be replaced.

Click 'OK' to replace the activities with new versions of the dataset available in the model. A backup copy of the original model will be created an stored in the backup directory 'C:\Users\<USER>\Documents\Umberto LCA+\Backup'. A report on the updated will also be produced.

If you prefer to manually produce a copy of the model with the old activity datasets for backup purposes it is recommended to not run the update process at that stage ('Cancel') and make a backup copy of the .umberto project file first.

The list of affected activities in all models within the project is shown when clicking on the button 'Details...'.

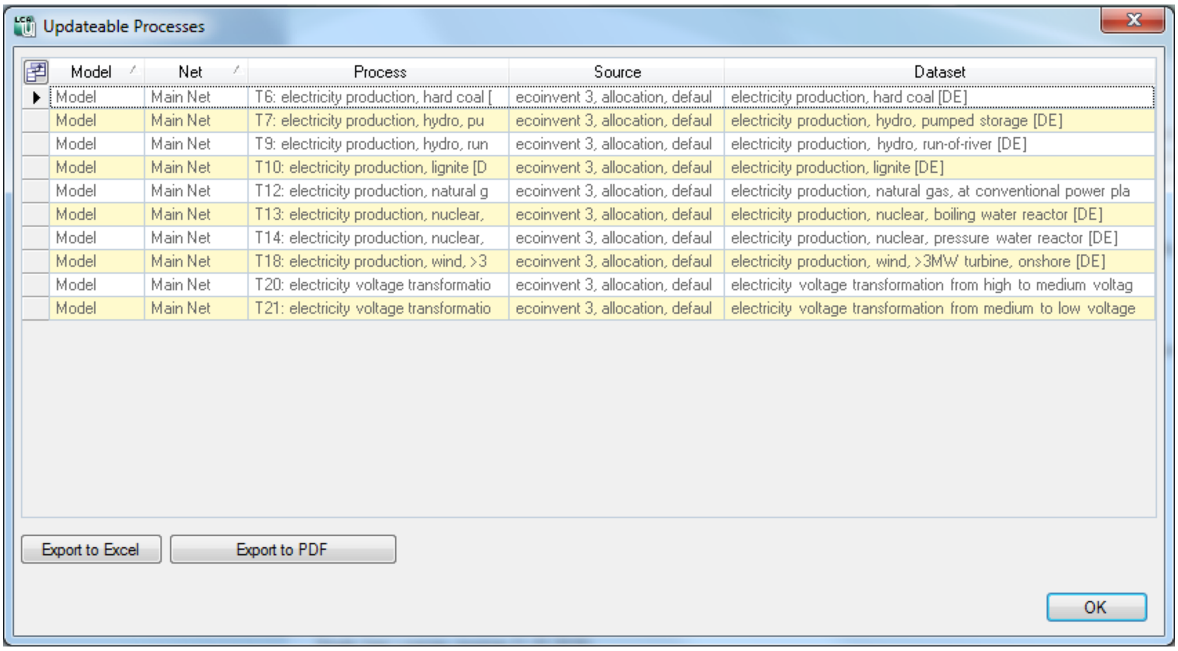


Figure 53: List of 'Updateable Processes'

All original (unmodified, showing a lock icon, see next section) processes that are affected and that can be updated will be listed. The list can be exported to Excel or printed as PDF file for documentation purposes.

Updating an activity will be successful when the data provider maintains the unique process identifier (GUID) and only modifies the flow entries, coefficients, description text, etc. (1:1 replacements).

If a former activity dataset has no corresponding dataset in the updated LCI database (abandoned or discontinued dataset), the update mechanism will keep the existing activity dataset in the model, since it has not replacement process available. This is also the case when several processes are to be replaced with the same new activity (n:1 replacements) or when the data provider offers two or more different new processes as a possible replacement for an activity (1:n replacements) all of them with new GUIDs. The user can replace these activity datasets in the models manually, by dragging the activity from the master database in the Project Explorer onto the process symbol in the Net Editor.

Note that the automatic update of activities is not possible for projects that have been migrated from Umberto 5. The processes in the models from the previous program version did not have the unique identifier (GUID) required.

A hint will be written to the log file. The log file of the update can be viewed after the update of the models in the C:\Users\<USER>\Documents\Umberto LCA+\ directory.

9.3 Modifying Activities

The activity datasets created by LCI database suppliers cannot be directly modified. You can, however create a private copy of the activity dataset and modify it according to your requirements.

To protect activity datasets inserted from the LCI databases from unwanted modification, and to maintain their status of originality, the datasets are locked when inserted. To modify a locked dataset, it must first be unlocked. Even the change of the original name of the activity requires unlocking.

To unlock an activity, click on the button "Unlock Activity" (showing a lock symbol) in the process specification.

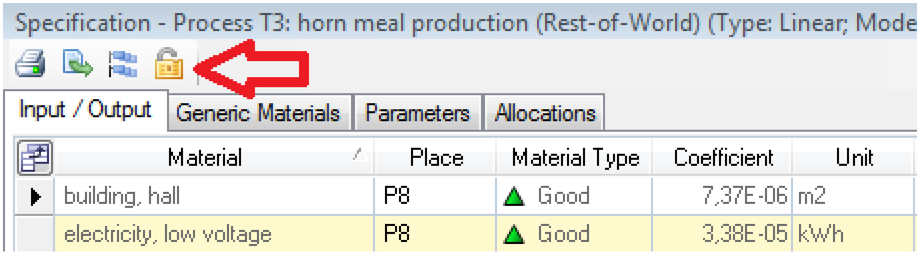


Figure 54: Locked process specification. Entries on the 'Input/Output' table are in grey (read-only). Button must be clicked before dataset can be modified.

A warning message will be prompted. Experienced users can disable the warning message, so that it won't show again. This setting is also accessible in the application options (see section 4.3).

After unlocking the process dataset can be modified (e.g. flow coefficients modified, flow entries deleted, material types modified, original process names changed, etc.). The fact that the dataset is not the original activity dataset is signalled with the removed lock icon on the process symbol and with a hint (e.g. "Modified, based on ecoinvent v3") shown in the process properties.

Note that for the purpose of auditing and review of the LCA model, changes made to an original ecoinvent or GaBi dataset that has been unlocked and modified should be well documented. Unlocked activities will signal to the reviewer that it is not the original dataset any more.

Some LCI datasets from the ecoinvent and GaBi databases come with function terms on the 'Input/Output' page of the process specification that contain variables. These variables are defined as parameters on the 'Parameters' page. They have a preset for their value, but the parameter values can be modified without unlocking the activity. Switch to the 'Parameter' page of the activity after inserting it into an LCA model, then change the parameter value. Observe the description of each parameter for the allowed value range.

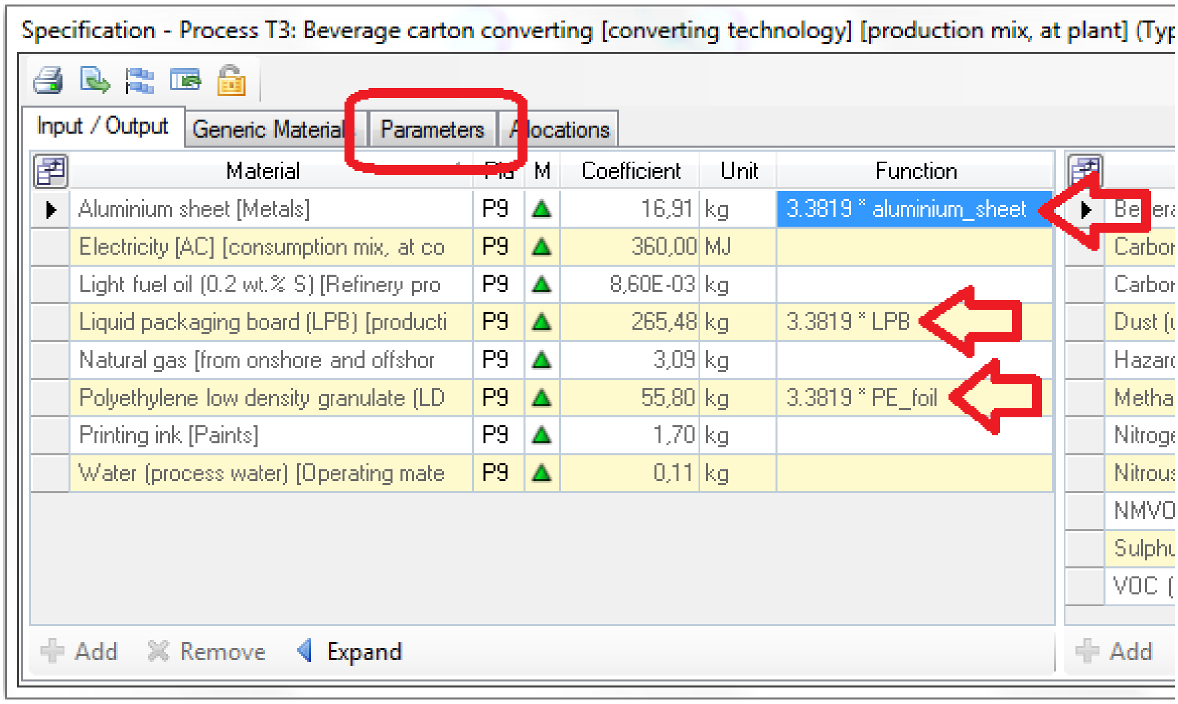


Figure 55: A process specification that contains parameters. The values can be modified on the 'Parameters' page. The process doesn't need to be unlocked to change the value.

To re-establish the original dataset you can either replace it again with the original dataset from the master database. Simply drag&drop the process symbol on top of the modified process. You can also use the command "Replace Unit Process with Result Process" or "Replace Result Process with Unit Process" (see below) from the context menu. This command will search for the original activity dataset in the master database.

To save the modified dataset, copy it to the Module Gallery (see section 7.6).

A modified ecoinvent dataset should be marked as modified, both by giving it a different name or adding an appendix to the name, as well as by documenting any modifications in the description of the activity dataset.
When your Life Cycle Assessment study is reviewed, it might be of importance to the reviewer to understand modifications made based on an original dataset from the master database.

Note that when the ecoinvent database is updated (see section 9.2), and a new version of the activity dataset is released, the modified private copies of the activity in the models and in the Module Gallery will not be updated automatically.

9.4 Expanding Upstream and Downstream Process Chains

Exchanging Result Process with Corresponding Unit Process: It is common practice to close-off an upstream chain by adding a system terminated (result) process from the LCI database. However, it might become necessary to analyse the individual process steps that are encapsulated in the result process. To do so, it is first required to replace the existing result process by the corresponding unit process, so that the inputs of this process show the intermediate exchanges. The next step can then be to follow one or more upstream or downstream chains process by process (see below).

To exchange an existing result process, right mouse click on the process symbol and choose the command 'Replace Result Process with Unit Process' from the context menu.

Exchanging Unit Process with Corresponding Result Process: To replace an existing unit process with the corresponding system terminated (result) process, right mouse click on the process symbol and choose the command 'Replace Unit Process with Result Process' from the context menu.

The exchange feature is only available for ecoinvent LCI datasets, for which on most cases a 'Unit' and a 'System Terminated' ('Result') version of the activity is available. Other databases might not provide corresponding activity versions.

Expand Upstream Supply Chain: This feature supports the step-by-step unfolding of the upstream supply chain.

For any of the intermediate exchanges on the input side of an ecoinvent unit process an activity that delivers this flow as output can be set: From the context menu of the intermediate exchange in the specification of the process choose the command 'Set Delivering Activity' or use the button 'Expand' below the input table of the process specification. A dialog box 'Select Activity' will pop up allowing choosing the activity (process) that should be connected as the delivering process in front of the current process in the life cycle model.

If only one specific activity in the database (indicated in the process specification in the 'Activity Link' column) delivers this flow as a product, then the only choice in this list is between the unit and the system terminated version of the activity, possibly available from the 'Consequential', 'Allocation, cut-off' and the 'Allocation, default' system models. These entries are the default activities linked to this intermediate flow. They are shown in bold. Typically they are the so-called market processes, recommended to be used in case there is no information about the specific originating process.

If several activities in the database can deliver this flow and hence are candidates that could be connected as a delivering dataset the selection list is populated with several activities, each of which typically have a unit and a system terminated version. This is the case when the intermediate exchange has no activity link, but has been inserted by the user.

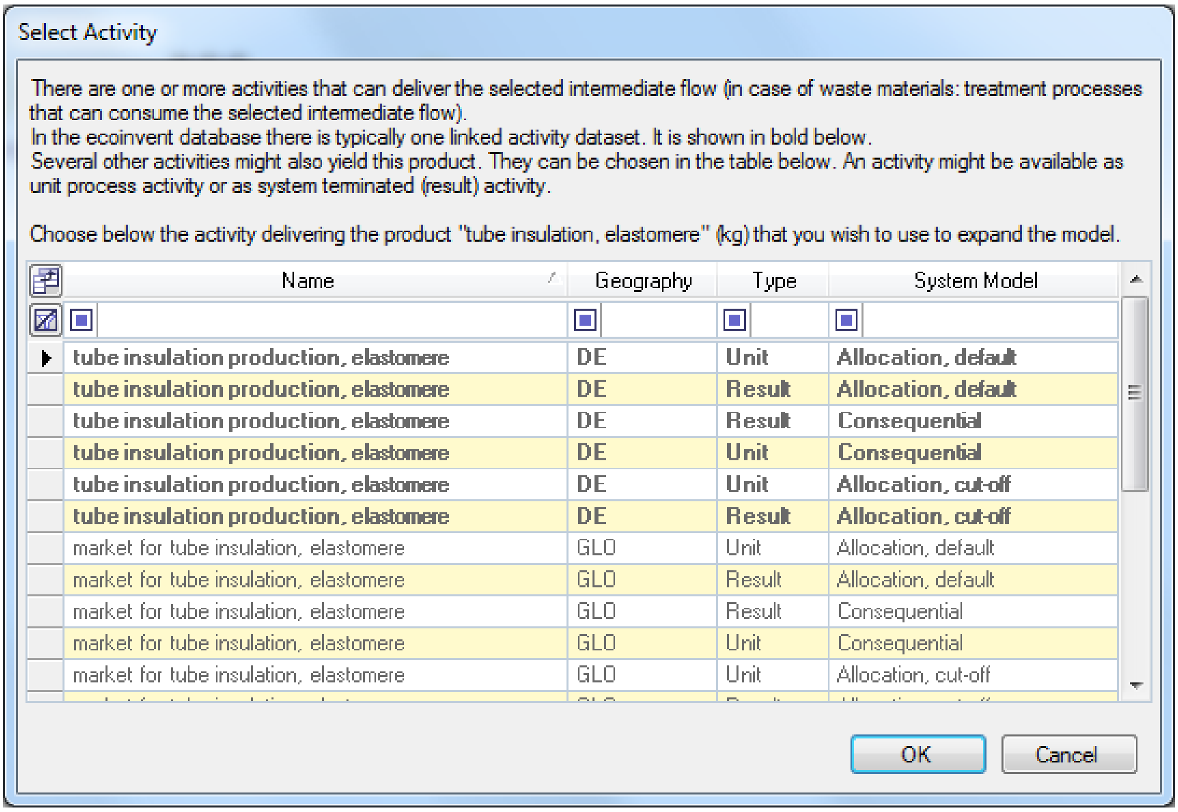


Figure 56: Expanding the input intermediate exchange of a unit process by choosing the delivering activity. For some exchanges there are several processes that could deliver the flow.

Choose the activity you wish to connect. The model will be expanded to the left. This process can be repeated to explore the next tier of the supply chain. If there are several processes already connected the newly drawn model section will be added with a certain offset. The practitioner can of course manually arrange the life cycle model in such a way that there are no superimposed network elements or crossing arrows.

Note that the datasets from different system models should not be used together. Depending from the modelling approach chosen by the practitioner for the LCA study, one should either use "Allocation, default", "Allocation, cut-off" or "Consequential".

Note that the Expand feature is available for processes from the ecoinvent master database. Other LCI databases that don't have the activity linking concept do not support the automatic expansion of upstream or downstream process chains.

The Expand feature is available for upstream supply chains for many of the intermediate inputs into unit process activities. It is not available for 'Secondaries' input flows of LCI result activities or of partly terminated activities.

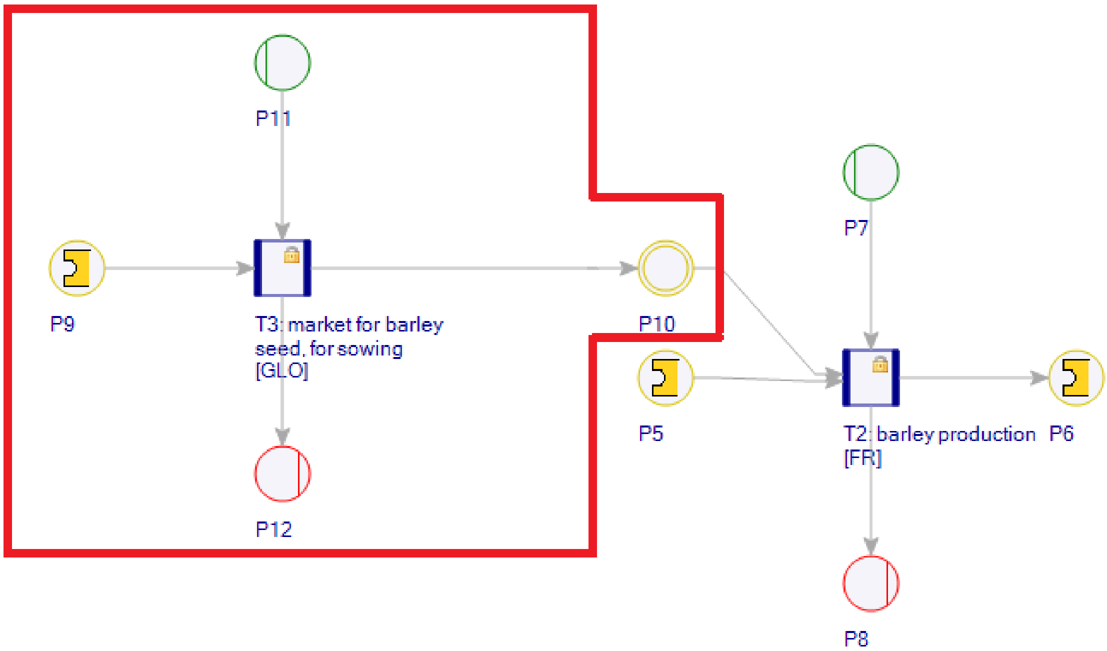


Figure 57: The unit process 'barley production [FR]' has been expanded upstream with the delivering activity 'market for barley seed, for sowing [GLO]'. This expansion can be repeated over several steps.

This feature is useful both for building and 'exploring' the upstream chain process by process when modelling the life cycle, but also in the life cycle impact assessment and interpretation phase of an LCA where the materials that contribute the largest part to an impact category can be traced through the system to identify in which process step the emissions or resource consumption that are responsible for the impact actually occur (material tracing).

Typically each activity is present in the master database as unit process and system terminated (result) process. However, in some cases, where the provision of disaggregated unit datasets has been limited by the data provider, only the system terminated (result) process may be available. These result processes cannot be disaggregated and the upstream supply chain cannot be expanded due to reservations by the dataset owner.

Expand Downstream Waste Treatment Process Chain: The same feature also can be used for a step-by-step unfolding of the downstream waste treatment process chains (when using ecoinvent activities). For any of the intermediate exchanges on the output side of an ecoinvent unit process a treatment activity that delivers this flow as output can be set: From the context menu of the intermediate exchange in the specification of the process choose the command 'Set Consuming Activity'. A selection list will pop up that allows choosing the treatment activity.

The downstream direction is less common in LCA models specified with ecoinvent data. However, since in the flow-oriented process modules in

Umberto, treatment processes and markets for waste materials are modelled in a downstream direction.

The Expand feature is not available for downstream waste treatment chains of the activities from the GaBi databases.

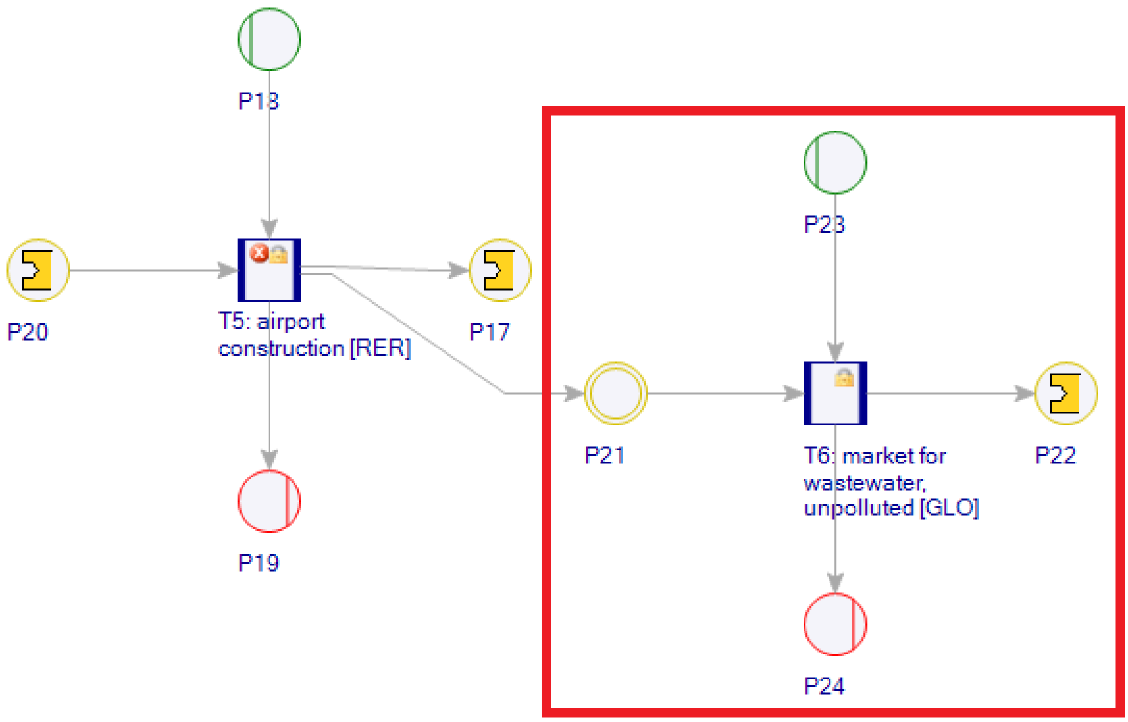


Figure 58: The unit process 'airport construction [RER]' has been expanded downstream with the consuming activity 'market for wastewater, unpolluted [GLO]'. This expansion can be repeated over several steps.

The downstream expansion feature is not available for unit processes from the ecoinvent v2.2 database. In ecoinvent v2.2 waste treatment processes are modelled as an input service.

9.5 Aggregated LCIA Results in ecoinvent 3.2

The intermediate materials in the ecoinvent 3.2 database contain aggregated LCIA results for all impact indicators. This allows for a quick estimation of the ecological impact related to their production (in case of a product) or disposal (in case of a material for treatment) without having to expand pre- or post-chains. The ecological impact of ecoinvent materials at the system boundaries will always be assessed and no delivering activity datasets are necessary. Using aggregated LCIA results, you can build slim and performant LCA models where only the most relevant supply chains are expanded.

The aggregated ecological impacts of each intermediate are taken from a preferably 'general' process from the ecoinvent 3.2 database that produces (or treats) this material. These are mostly global market processes from the system model ‘Allocation, cutoff’ that ecoinvent recommends as a default (see Section 13.7). Details about the selection of default processes can be found in the FAQ section of the Umberto web site.

To achieve more specific LCIA results (e.g. with respect to a certain geography), the intermediate's supply chain can still be expanded to individual producers or treatment processes as described in Section 9.4.

The source process of an intermediate material's impact can be browsed in Umberto as follows:

- Click on an ecoinvent intermediate material in the Project Explorer
- In the Properties Editor below, hover over the small 'Information' (i) icon next to the field 'CO2 footprint' with the mouse pointer. The source process of the ecological impact for the indicator 'IPCC 2013, climate change, GWP100a' will be shown in a tooltip.
- To browse the values and sources of all indicators, right click on the material and select 'View Impact Assessment Factors'.

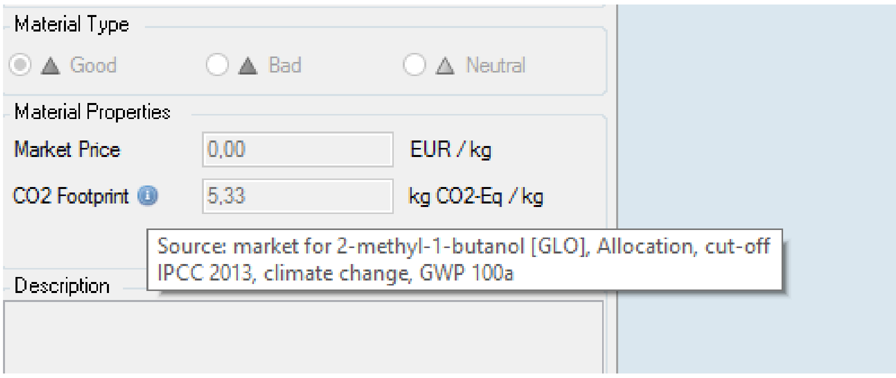


Figure 59: Display of source process and indicator for aggregated LCIA results of an ecoinvent 3 intermediate exchange in the Properties Editor.

10 Calculating the Life Cycle Model

10.1 Reference Flow and Functional Unit

The life cycle model is typically calculated for one unit of product. This is the so-called functional unit, which describes the delivery of the function of the product. It is also used in comparisons between products, to allow for a comparison based on the same function.

The product for which the life cycle model is built is represented by the reference flow of the system. In most cases there will be just one reference flow ("single product system"), but the models in Umberto LCA+ are also capable of handling several reference flows ("multi product systems"). This is the case, for example, when besides the main product there are also one or more co-products. In this case allocation must be made to properly assign process expenditures to the individual products.

The topics 'multi-product system' and 'allocation' are addressed further below in section 10.3.

The system will try to automatically identify the system reference flow i.e. the product or service ("function") of the modelled system, and allocate expenditures (materials and energy consumed, emissions or waste released, etc.) to it. To this end, two pre-requisites are checked:

- the reference flow must have the material type "Good" (green)
- the reference flow has to be located on an arrow that leads to an output place (i.e. it is a system output)

There is a second, less common, case that qualifies for identification of a system reference flow. It is described below in the section on 'Waste Input'.

Material Type: The material type of the materials play an important role in this mechanism and deserve additional explanation for better understanding.

When defining a new intermediate exchange (see section 6.3) it is required to set a material type (colored triangle): Good (green triangle), Neutral (yellow triangle), or Bad (red triangle). This concept is from production theory. The material type in combination with the side of the process where it appears (input or output) indicates whether an exchange is considered a required expense, or whether it constitutes a revenue.

- **Good (green):** Goods are required inputs of a process (and to the overall system). They are considered expenses needed to produce a product or deliver a service. Typically all raw materials, energy inputs, auxiliaries, service inputs and inputs that have a cost have this material type.
  Additionally the product itself is a good (green material type) that has a value, and that can be sold to a market. In this case it is on the output side of a process and is a revenue. Co-product that have a value (and are not disposed of) are also "Goods".

- **Bad (red):** "Bad" is the opposite of a good. Bads (red material type) are produced as an undesired side-effect of producing a product. They are undesired since they cause expenses that must be borne by the product. Emissions and waste are typically of the red material type.
- **Neutral (yellow):** The yellow material type is "neutral" and is neither considered an expense, nor revenue. Materials with a yellow material type do not contribute to the LCIA calculation, and they are excluded from the inventories.

The following two tables visualize the four possibilities made up from the material type and the side of the process (or the inventory) where the materials occur.

	Input	**Output**
Good	Expense	Revenue
Bad	Revenue	Expense

Figure 60: Table showing relation between the material type and the occurrence of the material as expense or revenue

	Input	**Output**
Good	Resources, Raw Materials	Product
Bad	Waste Reduction, Recycling	Waste, Emissions

Figure 61: Table showing relation between the material type and the occurrence of the material with typical role of flow

Identification of System Reference Flows (Products of a Process and of the System): Umberto LCA+ will automatically identify the products of the system, by checking the material type, the side of the process where they occur, and whether the material is led to an output place.

This is done for the processes (process reference flow) as well as for the overall system (system reference flow). Local reference flows are outputs of a process that are led to another process via a connection place. In the subsequent process they are used as an input. One could say that these are intermediate products, since they do not cross the system boundaries.

Processes that do not have any reference flow show a warning marker and prevent the calculation from being successful. Make sure every process either has an entry with green material type on the output side, or an entry with red material type on the input side (the latter case described below as "waste input").

Global reference flows are flows that are led to an output place, hence they leave the system. These are typically the products for which the system has been modelled. Both products as well as co-products are considered as global reference flows, and expenses to create these products are allocated to the products so that LCIA results can be calculated for them.

In cradle-to-gate or cradle-to-market models we typically find this situation as the product produced and shipped to the market is an output of the model.

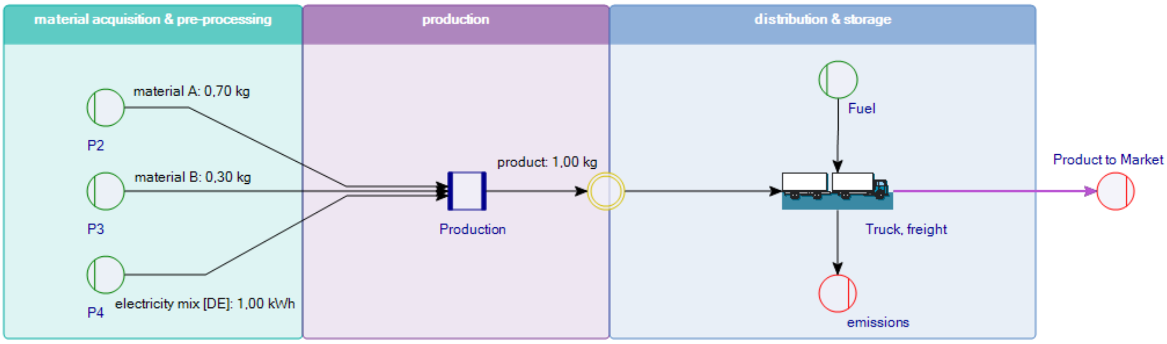


Figure 62: Cradle-to-Gate model with system reference flow at the right "end" of the process chain. Symbolic model for explanation only.

As an indication whether a system reference flow can be identified, you can check the inventory after the first calculation ('Calculate Total Flows'): If there is a flow with a green material type on the output side of the table, this is the system reference flow.

Virtual Reference Flows: In some cases, - and most commonly in 'cradle-to-grave' LCA models that also comprise the End-of-Life phase - the actual product does not appear as an output of the system anymore, but rather has turned into a waste. This product waste is being treated and causes additional expenses after the product has delivered its function. This is the case e.g. for a consumer good that has turned to waste after use (an old toy that is being disposed of, transported to an incinerator, and incinerated), or for a product has fulfilled its function (it has delivered its service), and is in another indirect way being disposed of (e.g. a hair shampoo that has been applied, and the wastewater has to be treated).

In this case Umberto uses a "virtual" flow that exits the model to an output place and takes the role as the system reference flow. This is the case in the modelling situation shown in the figure below.

The product itself has been used, but its packaging or remaining parts is being treated downstream in a waste treatment. The waste treatment has additional inputs, and emissions (both considered expenses) that are assigned to the product, even though it has completed its useful life and has fulfilled its function. In this situation, the product is modelled as a virtual reference flow:

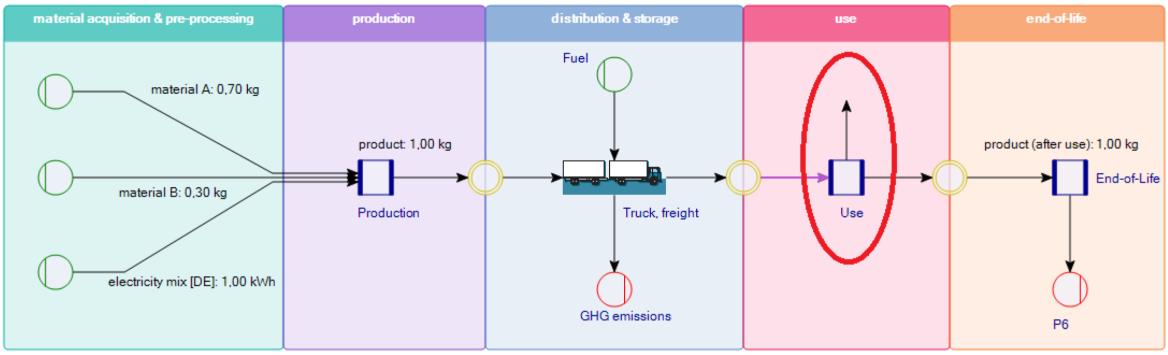


Figure 63: Process with input of product (green), the product waste leading to a waste treatment or output place (red), and the virtual reference flow in the use phase (circled in red) leading to an invisible output place. Symbolic model for explanation only.

To set a flow as a virtual reference flow in a process specification, right mouse click the entry on the output side, and choose 'Set Virtual Reference Flow Property' from the context menu. The entry will also be shown in bold red, additionally in the 'Material Type' column there is an indication that shows that this has been set as a virtual reference flow of the process and by this for the whole system.

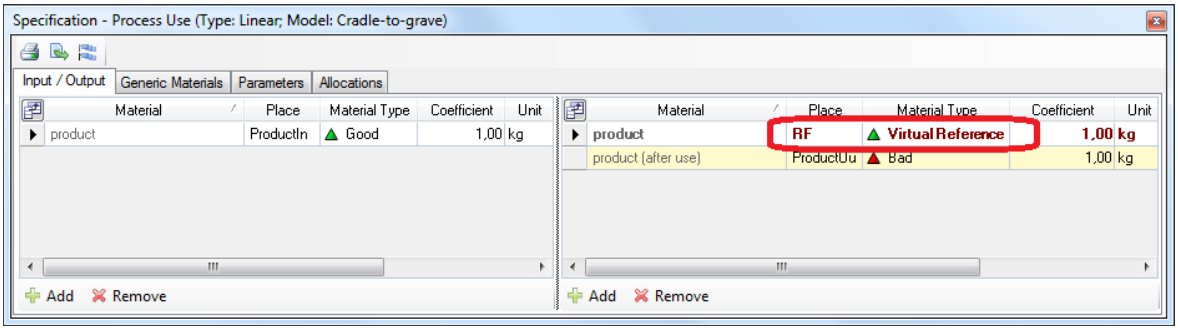


Figure 64: Virtual reference flow in a process is shown in bold.

When a virtual reference flow is set, an arrow and an invisible (hidden) output place is drawn and the virtual flow is led to this place. If several virtual reference flows are set in the process, they will all be led to the invisible output place.

Virtual reference flows are not shown in the inventories, as this would lead to a double-counting on the mass level: The product input has been transformed to a waste.

The virtual reference flow in the hidden arrow and hidden output place is also not displayed in the Sankey diagrams for total flows, and product related flows. It is shown in the LCIA Sankey diagrams where the flow quantities are shown as weighted arrows representing the impact in a LCIA category (see section 12.2).

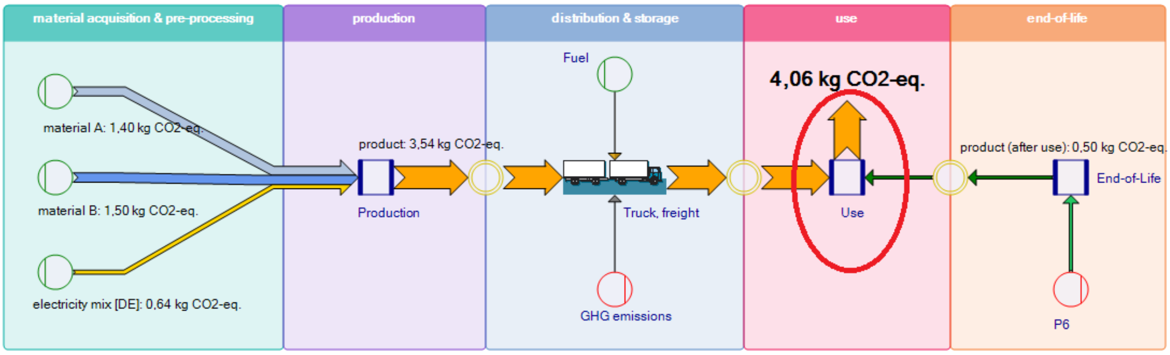


Figure 65: The LCA model from the figure above in the LCIA Sankey view for the impact Category 'climate change' (GWP). The virtual reference flow (circled in red) is in the use phase. It sums up the environmental impacts loads from the upstream supply chain and the downstream end-of-life treatment processes. Symbolic model for explanation only.

Waste Input: In addition to the situation described above for the reference flows that constitute products of the system, there is another situation that is handled in the same way.

If a flow has a red material type, but can be found on an arrow from an input place, this is also considered a product or a service of the process (or of the system). This is an input-sided system reference flow. Real world examples of this modelling situation are waste management systems, or processes that use materials otherwise considered and handled as waste as input (e.g. incineration of used tyres in a cement plant, burning of waste to create energy).

This second case is somewhat less common, but also qualifies for identification of a system reference flow. It is handled in the same way as for production systems.

Hence, in addition to the more common case of production systems (see above) this second case of waste treatment systems allows identifying the system reference flow i.e. the service of disposing waste is handled by the calculation algorithm in the same way.

Here the two pre-requisites are:

- the reference flow must have the material type "Bad" (red)
- the reference flow has to be located on an arrow that leads from an output place (i.e. it is a system input)

The case where there is a product output (system reference flow 1) and, in addition, a waste treatment (system reference flow 2) qualifies as a multi-output system. Such systems are described below in section 10.3.

Remember that the detection of reference flows (products of a process and of the overall system) is done by interpreting the material type of a flow, and whether it is an output or an input of a process. Hence, the material "aluminium scrap" (regardless of the fact that the word "scrap" insinuates that it is a waste material) is considered a product, if it has the material type

"Good" (green) and is found on the output side. The same material "aluminium scrap" is considered a waste, if it has the material type "Bad" (red) and is found on the output side. Within the same logic the material "aluminium scrap" is considered a good (raw material) and hence an expense needed for producing the product of this process, if it has the material type "Good" (green) and is found on the input side. The same material "aluminium scrap" is considered a waste being recycled and hence constitutes a service or product of the process, if it has the material type "Bad" (red) and is found on the input side.

The yellow material type is "neutral" and is neither considered an expense, nor revenue. Materials with a yellow material type do not contribute to a carbon footprint, and they are excluded from the inventories.

10.2 LCA Model Calculation

After a model has been built up and all processes have been properly specified, it can be calculated. As a prerequisite to launch the calculation, it is required to enter at least one flow manually. This start flow, or trigger flow, can be located anywhere in the model, but it typically is the flow of one unit of product for which the model is calculated. As a result of the model calculation, ideally, all other flows will be determined.

Specifying a Manual Flow: To specify a manual flow, click on the correct arrow in the net, where this flow runs (e.g. at the output of the last process in the production phase, or at the entry into the use phase). The specification window for the arrow is brought to front. Choose a material from the material list, and drag&drop it into the Specification Editor. You can also drag it directly from the Project Explorer onto the arrow.

Alternatively, use the button 'Add' and search for the material in the Search dialog. Note that this should be the material that is defined in the process connected to the arrow. Enter a quantity for the flow. This can be the quantity of the annual production or the weight of one unit of product.

A second time-saving alternative is to create the manual flow directly from a linear Input/Output process specification. Browse the output entry from a process that shall be used as the manual flow, then use the 'Use Entry as Manual Flow' command from the context menu. This also works for an input entry in the process that can be used to create a manual flow on the incoming arrow. Note that the value of the coefficient is inserted by default as the manual flow quantity, and might have to be adapted to the actual quantity.

A manually inserted flow is signalled by the arrow being colored in purple. This is to indicate the arrow that contains the start flow for the calculation.

Note that flows manually specified in an arrow are removed when the model or model section is copied/pasted.

A manual flow coefficient can also be specified via a Live Link, as has been described for process flow coefficients in section 8.1 too. By establishing a reference to a cell in an Excel sheet, the manual flow value can be fed into the model from an external source.

Start Calculation: To start the calculation of all the material and energy flows in the life cycle model, and of the product-related flows as well as the associated environmental impacts, click on the button 'Calculate' in the toolbar of the Model Editor. Alternatively choose the command 'Calculate' from the Calculation menu, or press F9.

In the first part, the algorithm determines all material and energy flows from the trigger flow and by assessing the process specifications. This first calculation must be successful, before in a second part the product related flows and the associated LCIA result values can be determined. If the first calculation produces errors, the second calculation will not start, but the log file will be shown instead.

The second calculation is for determining the flows per product (in a multi-product system) and the LCIA values. The product flows calculation is based on the allocation factors made for multi-product processes.

Upon a successful calculation of the second part of the calculation, where the overall flows are allocated to the products (reference flows) identified in the system, two new tabs open in the Specification Editor area: 'Inventories' and 'Results'.

The LCIA calculation results (tab 'Results') are explained in the next chapter.

The advanced user can launch both calculations separately by using the commands 'Calculate Total Flows' (Shift+F9) and 'Calculate Product Flows and LCIA' (Ctrl+F9) from the Calculation menu.

The arrows that were grey in the uncalculated model should now be colored black, to indicate that flows have been calculated in the arrow. If a flow remains grey, this is a sign that no calculation has taken place for the flows in that arrow.

The calculated flows can be seen in the Specification Editor when clicking on an arrow in the model. The overall inventory of the flows that have been calculated opens in a tab 'Input/Output Flows'.

Note that as a prerequisite for calculation in hierarchical life cycle models (models that contain subnets), all input and output flows must be connected to a port place, to ensure that all flows are consistently linked to the upper level (and finally to the topmost level.
The calculation algorithm will check if this requirement is met,

and in case it detects unlinked input or output places, will offer to create default input and default output places on the top level and link these places to these places.

Calculation Logs: Should errors or warnings occur during calculation, the calculation log will be prompted on a tab on the Specification Editor area. The log shows information, warnings and errors of the calculation of the model.

The severity is represented by an icon. A description explains why the calculation produced a warning or an error. The element where the error occurred is shown in the column 'Reference'. Click on a line in the calculation log to select the element where the error occurred.

The calculation log file can be exported by clicking on the button 'Export Calculation Log'. The last calculated logs can also be opened from the Menu 'Calculation'.

Reset Calculation: To reset a calculation, i.e. to remove the last calculated flows, choose the command 'Reset Calculation' from the menu calculation. All flows in the arrows, with the exception of manually specified flows will be removed. The model can be calculated again.

Total Flows Calculation: To separately start the calculation of all the material and energy flows in the life cycle model, choose the command 'Calculate Total Flows' from the calculation menu. This feature is for the advanced user who wishes to analyse the allocation settings determined in the first calculation before proceeding with the calculation of the flows per product and the associated environmental impacts.

Product Flows and LCIA Calculation: To separately start the second calculation for determining the flows per product (in a multi-product system) and the LCIA values, choose the command 'Calculate Product Flows and LCIA' from the calculation menu. The product flows calculation is based on the allocation factors made for multi-product processes. The LCIA calculation uses characterization factors for the active LCIA factors, and multiplies them with the flows in the input/output inventory.

Calculation of Model Sections: It is possible to calculate the flows of a section of a model, and to determine the environmental impact linked to the inputs and outputs of the model section. In other words, a calculation of individual model sections with different system boundaries can be performed.

To see the flows and LCIA values of a model section mark a section by pulling up a selection frame. If the area of the model cannot be captured in a rectangle area, individual processes can be selected by clicking them with the SHIFT or CTRL key pressed. Then choose the command 'Calculate Selection' from the calculation menu. Not that the flows which leave the system defined by the selection frame which represents the temporary system boundary will become the reference flows and the LCIA results are shown for these reference flows. Mind that intermediate flows typically don't have characterization factors assigned, and that only the elementary exchanges that cross the boundary of the selected model section are included.

The input/output inventories for model sections can be exported to Excel and reused as process specifications. Read how to do this in section 11.3

10.3 Multi Product Systems and Allocation

The LCA models built with Umberto LCA+ can be either for individual products ("Single Product System") or for more than one product ("Multi Product System"). The products (or reference flows) of a model are identified automatically by searching for flows that have the material type 'Good' (green) and are found on an arrow to an output place, and by searching for flows that have the material type 'Bad' (red) and are found on an arrow from an input place (see section 10.1 above).

In case the model delivers one product only, there is no distinction between the results shown as 'Input/Output' and 'Input/Output per Product'. Also, the LCIA results calculated for the whole system are actually the same as for the one product, since all consumption of material and energy and all emissions along the product life cycle can be linked to the one product that is yielded by the system.

If there is more than one product (reference flow), we are dealing with a multi product system. Multi product systems can have two or more products that are of similar importance (all considered products of the system), or there could be a main product, and one or more co-products (such as, for example, some residues from a production process that are recovered and can be beneficial as input into another production process). A third variant of multi-product systems are those where there one product is a service delivered and at the same time products can be sold to the market. Such an example is waste incinerator whose primary purpose is to take up and treat household waste (red material type on the input side) and at the same time heat and/or energy can be sold two the market. Waste-To-Energy (WTE) facilities therefore are also considered multi-product systems.

This section deals with multi product systems and the need for allocation in processes that have more than one reference flow.

Allocation of Expenses to the Reference Flows: Umberto LCA+ will automatically identify the products of the system, by checking the material type, the side of the process where the flow occurs, and whether the material is led to an output place.

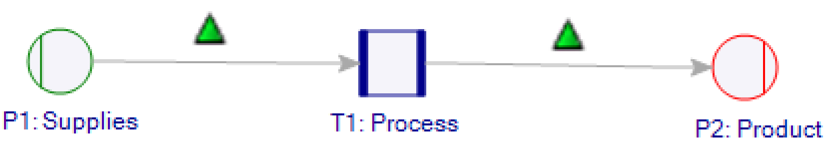


Figure 66: Process with one product output (green), and one or more goods inputs (green).

The above figure shows a single product system, where all input materials (expenses) are assigned to the only product being produced. No allocation on the process level is required and the 'Allocations' tab in the process specification isn't visible.

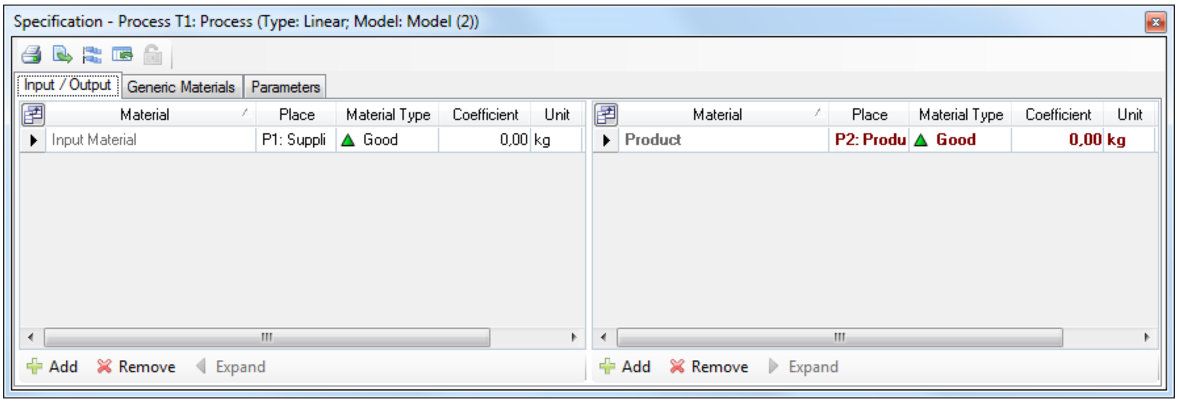


Figure 67: Process specification, 'Input/Output' tab... no allocation required

In the next figure there is a co-product (material type green, led to an output place). The expenses of the process (the input materials consumed) are shared between the two products of the system based on the allocation factors defined on the 'Allocations' tab of the process.

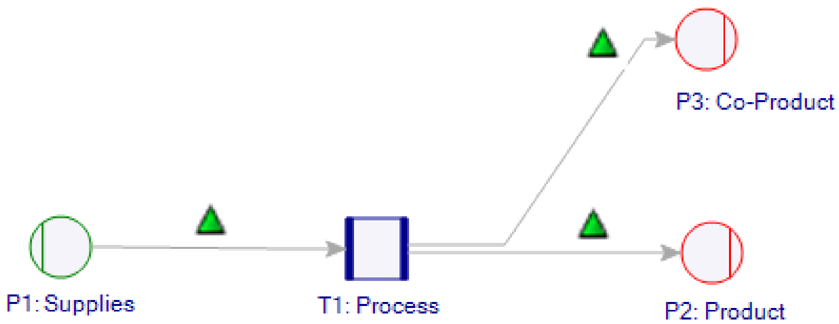


Figure 68: Typical process with one product output (green), a co-product output (green), and one or more inputs (green).

Two reference flows are identified automatically and are shown in bold red.

Note that the coefficient value of a reference flow can be set to zero ("0.00"), but at least one of the reference flows in a process must be unequal to zero.

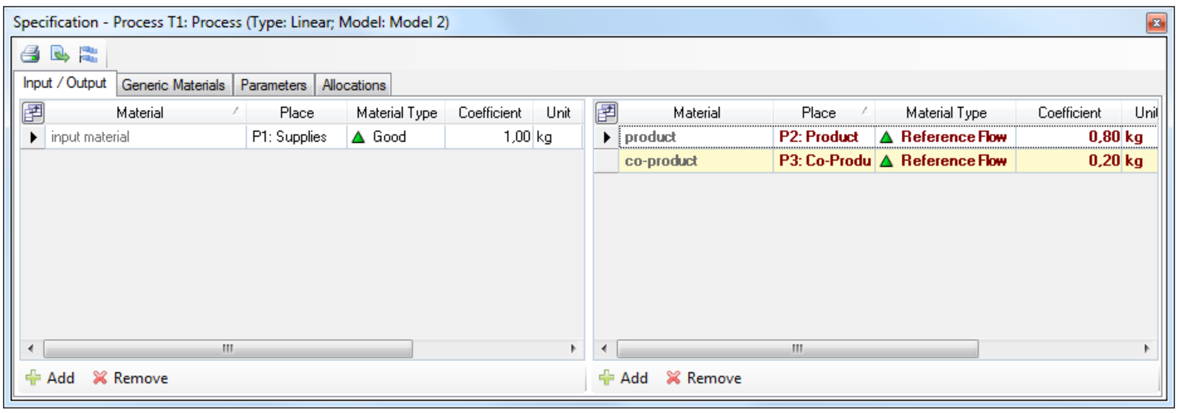


Figure 69: Process specification, 'Input/Output' tab...

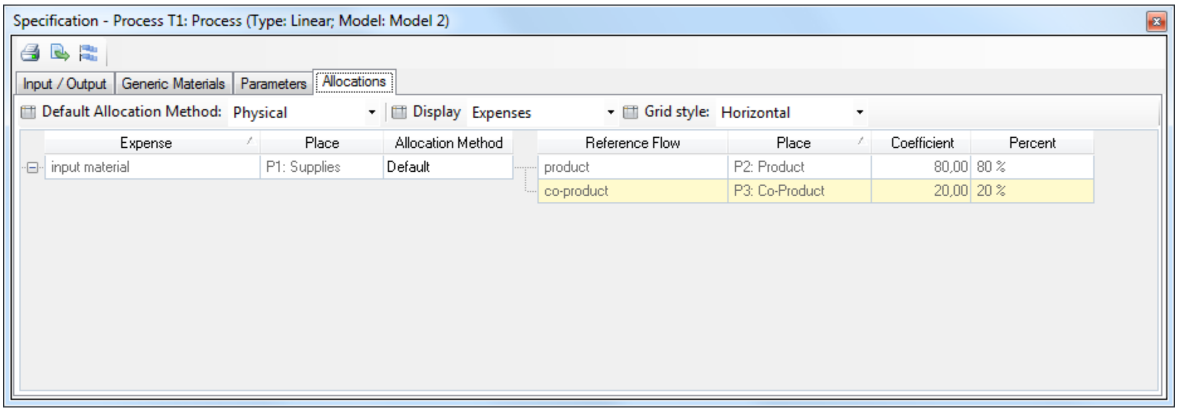


Figure 70: ... and 'Allocations' tab for the above process. In this example the allocation is set to 'Physical'.

If the process has any emissions or wastes, these are specified with a red material type, and the flow is either led to an output place, or along a downstream process chain (e.g. waste sorting, waste transport, etc.) until it is led to an output place.

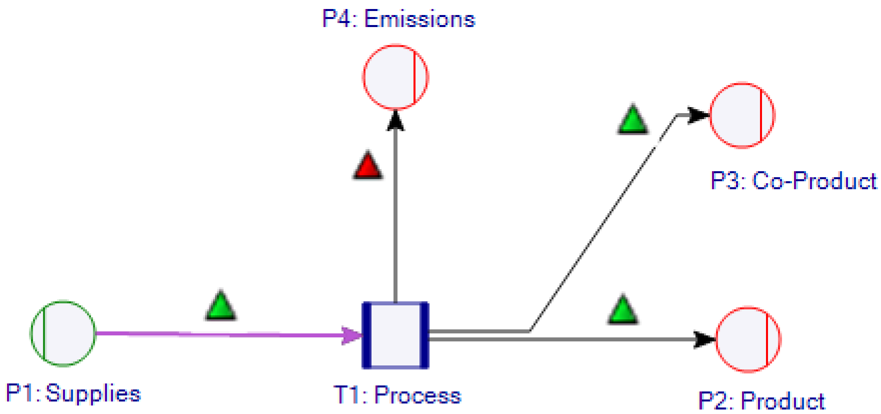


Figure 71: Process with product (green), co-product (green), and one or more inputs (green). Emissions and waste (red) are considered an expense and must be allocated.

The allocation factors defined on the 'Allocations' tab of the process are used to assign the expenses (both raw material supplies and emissions/waste) to the product and the co-product respectively.

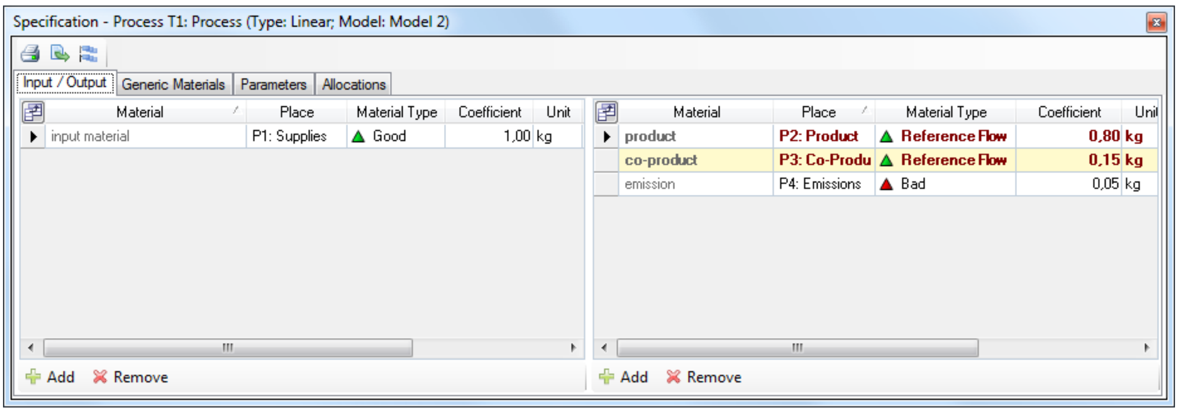


Figure 72: Process specification, 'Input/Output' tab ...

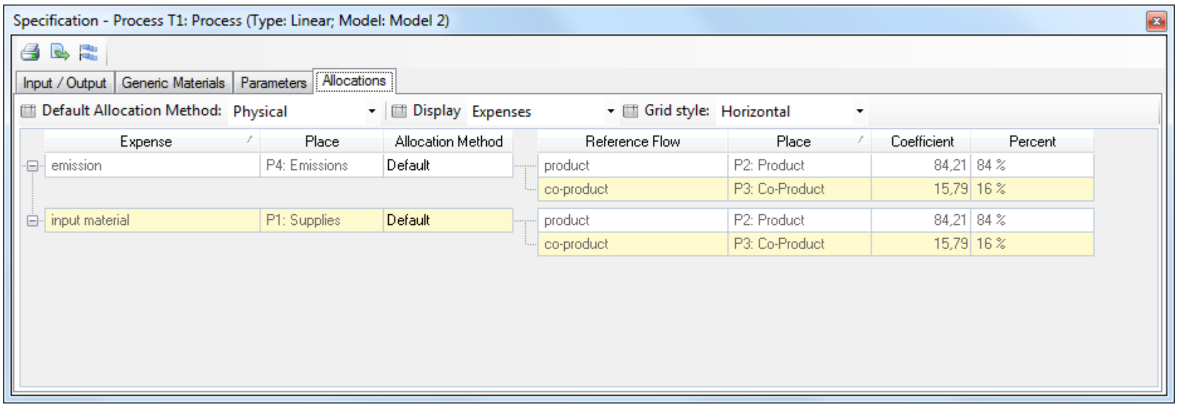


Figure 73: ... and 'Allocations' tab for the above process. In this example the allocation is set to 'Physical'. Both input material and emission are considered an expense and have to be allocated.

Allocation on the Process Level: Allocation of expenses in expenses with more than one product (reference flow) is performed on the 'Allocations' tab for each individual process.

Allocation on the process level is described in section 8.3.

Allocation on the System Level: Allocation also plays a role on the system level. When a product system yields co-products, some of the guidelines and standards recommend to expand the system to also include the function of the co-products (by redefining the unit of analysis). If you choose system expansion, rather than looking at the environmental impacts of one single product, you study the environmental impacts of the main product plus the environmental impacts of the co-product(s). In a separate step you can decide whether the co-products can possibly displace the production of another product. In this case the environmental impacts associated with the co-products can be displaced /subtracted (credit for avoided burden).

System expansion with Umberto LCA+ can be handled in two different ways. Either make two LCA models (within the same project file) or model the avoided burden within the same model for the expanded system and subtract the displaced environmental impacts with a negative coefficient from the expanded system.

Allocation on the system level and system expansion are described in section 13.6.

11 Life Cycle Inventory Results and Analysis

11.1 LCI Results (Inventory)

All flows that enter the system (on a flow from an input place to a process) and that leave the system (on a flow from a process to an output place) are shown after calculation of the model on the tab "Inventories" in the window pane below the editor area.

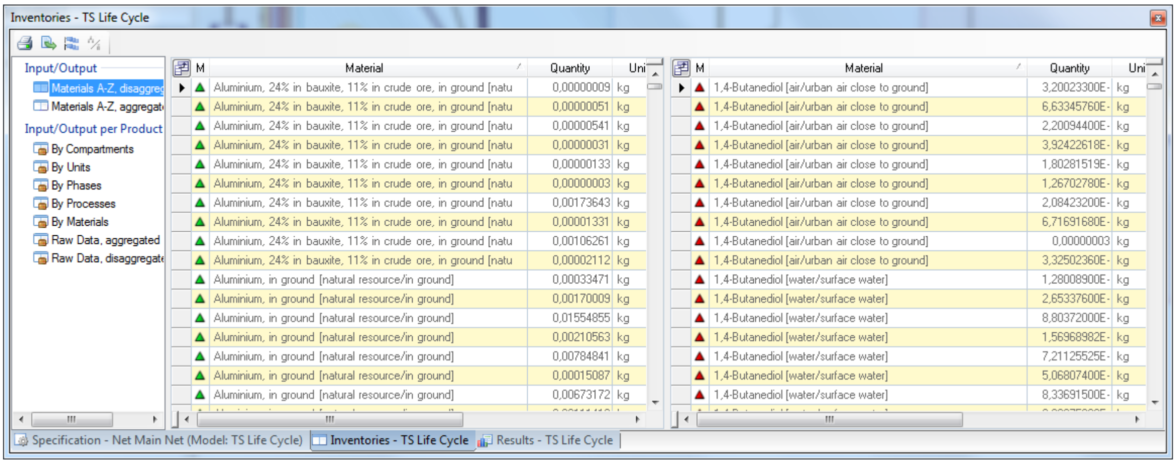


Figure 74: Default view of inventory with Input/Output Flows, materials A to Z, disaggregated

In the view 'Materials A-Z, disaggregated' every input/output flow is shown as a separate entry with the processes that take up an input and the processes that output the flow listed in the column 'Process'.

If you switch to the view 'Materials A-Z, aggregated' in the selection list on the left of the table, only one flow entry will be shown, aggregating them without showing the individual processes. The hint 'Multiple Processes' is displayed in the column field instead.

Different Views of Inventory Results: Further pre-defined views of the inventory data are available and can be selected in the list on the left.

For multi-product LCA models (LCA models that yield more than one product or have a main product and co-products) the inventories can be viewed for all products ('All Reference Flows') or for individual products. Select the product for which you want to see the inventory of input and output flows from the dropdown list 'Selected Product'.

The following inventory views are available:

- **Inventory By Compartments**: A grouped list of inputs and outputs of the model by compartment. Aggregated view with only one entry for a material, even if the material is input into or output from more than one process. Compartment groups are closed by default showing the sums of the flows in that group. If user defined material entries and intermediate exchanges exist in the inventory, they are shown at the top, and the groups are shown opened.

- **Inventory By Units**: A grouped list of inputs and outputs of the model by unit type. Aggregated view with only one entry for a material, even if the material is input into or output from more than one process. Note that flows of the unit type 'Mass' (basic unit 'kg') are by default shown at the top. Entries of other unit types (area, volume, ...) are listed below.
- **Inventory By Phases**: A grouped list of inputs and outputs of the model by life cycle phase. Within each phase the entries are grouped by process. This is an aggregated view with only one entry for a material, even if the material is input into or output from more than one process. The attributing of a flow to a certain phase depends on the location of the place. For further details please read in section 5.3 on Life Cycle Phases.
- **Inventory By Processes**: A grouped list of inputs and outputs of the model by process. This is similar to the above view "By Phase". Aggregated view with only one entry for a material, even if the material is input into or output from more than one process. This view allows analysing individual processes in regard to the input/output flows that are the basis for the potential environmental impacts. Since the processes have inputs and outputs of different unit types, the sums for each unit type are shown in the group header.
- **Inventory By Materials**: A grouped list of inputs and outputs of the model by material. Showing the processes that take up this exchange or that release this exchange.
- **Raw Data, aggregated**: This is a plain view of all LCI data. This is an aggregated view with only one entry for a material, even if the material is input into or output from more than one process.
- **Raw Data, disaggregated**: This is a plain view of all LCI data. It can be grouped individually or can be used for export of all data to Excel. In Excel the inventory data can serve as the basis for creating Pivot tables and graphs. Please read below for further information.

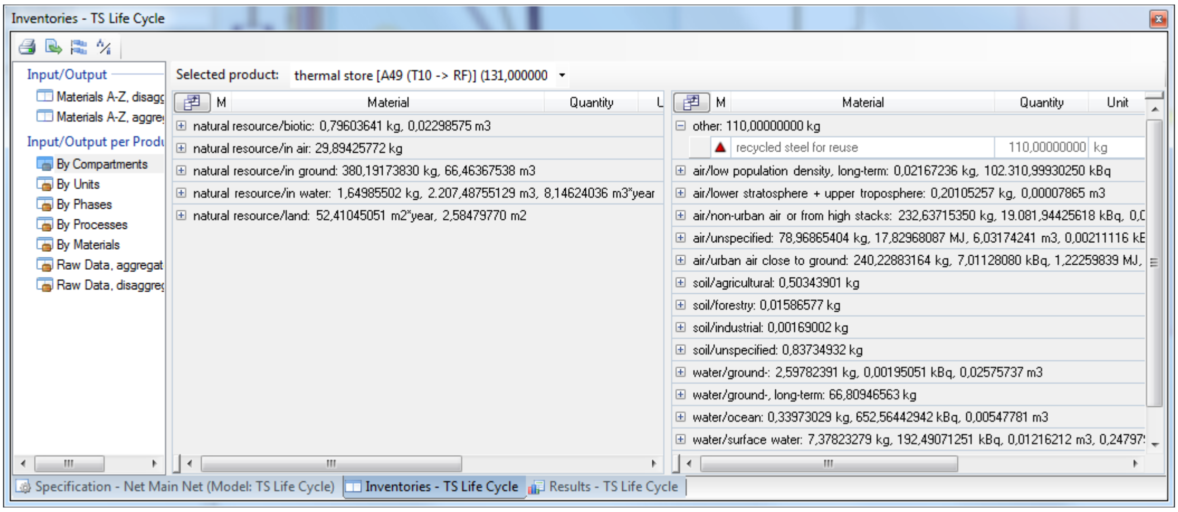


Figure 75: Inventory of input/output flows grouped by compartment, all groups closed except the ones showing other and intermediate flows

See the section on grid handling above to learn how to further sort and group the list of input/output flows.

Note that in all grouped views flows of the unit type 'Mass' (basic unit 'kg') are by default shown at the top. Entries of other unit types (area, volume, ...) are listed below.

Scaling of Results: The results displayed on the tab 'Inventories' are scaled to the functional unit that has been defined for the material that represents the product. If no functional unit has been defined results are for the quantity of the reference flow, for which the model has been calculated (e.g. the yearly production). To switch between scaled and unscaled results, toggle the button 'Show Scaled Values'.

11.2 LCI Flows Sankey Diagrams

Sankey diagrams are flow diagrams, where the width of the arrows represents the flow quantity. The Sankey diagrams are an integral part of Umberto LCA+, and the normal life cycle model view can be switched to a Sankey diagram view easily.

Numerous options exist, to adapt the Sankey diagram[5].

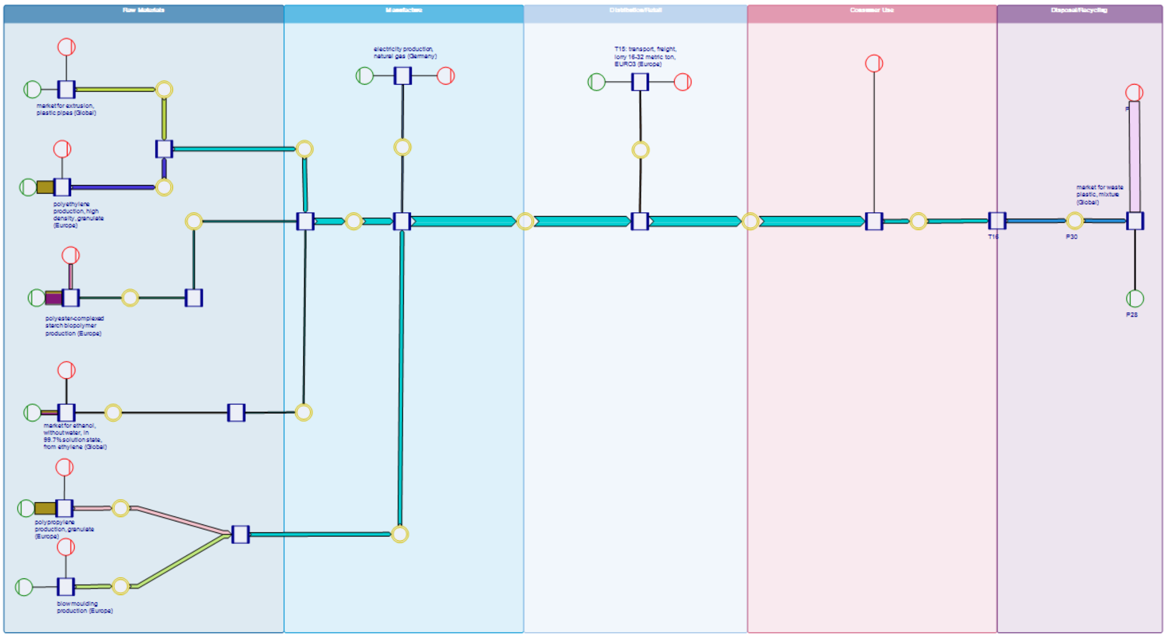


Figure 76: LCA model in 'Total Flows' Sankey Diagram mode

To switch to the Sankey diagram mode, click on the button 'Show Sankey Diagram' in the Model Editor toolbar. The diagram can be still be edited, even when in the Sankey diagram mode: elements can be moved, or you can click on an arrow to see the flows in the arrow. The Sankey diagram mode can be switched off, by clicking on the button 'Show Sankey Diagram' again.

The color for each flow is defined in the properties of a material. See chapter 6 on materials.

[5] The Sankey diagram component in Umberto LCA+ is based on the Sankey diagram tool e!Sankey (www.e-sankey.com) developed by ifu Hamburg GmbH.

To switch between the Sankey diagram view and the normal net model view (with simple arrows) toggle the button 'Show Sankey Diagram' in the toolbar. To be able to view a Sankey diagram the network must already be calculated.

Sankey Diagram Source: Apart from the total flows, it is also possible to show product-related flows (for multi-product systems), and the flows weighted with characterization factors (as LCIA contribution flows) per impact category in a Sankey diagram.

To select the type of Sankey diagram use the dropdown menu next to the button 'Show Sankey Diagram'. Alternatively you can open the window 'Source of Sankey Diagram' in the Properties window area.

The dropdown menu next to the button 'Show Sankey Diagram' only shows all entries after both calculations of the life cycle model (Total Flows, LCIA) have been performed. If it doesn't show any entries, please run the calculation first (see section 10.2).

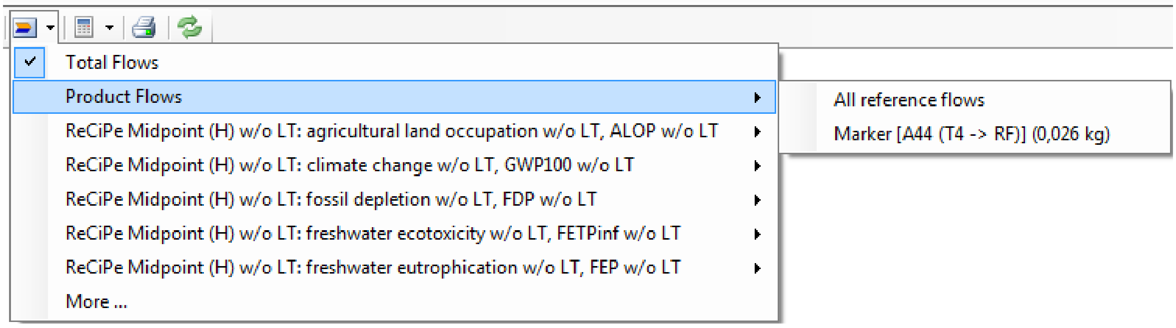


Figure 77: Dropdown menu 'Source of Sankey Diagram'

For creating a Sankey diagram that only shows the allocated product-related flows, select 'Product Flows' and choose one product in the cascading menu.

This option is meaningful only for life cycle models that have more than one reference flow. It will show one Sankey diagram with the physical flows per product. In case that the model only has one reference flow, the 'All reference flows' entry in the menu produces the same Sankey diagram as if the actual reference flow was selected.

Note that the 'Product Flows and LCIA' calculation must have been executed, before this Sankey diagram type becomes available.

Use the buttons in the toolbar of each tab, to export, print or save the result diagram or table. For more details refer to the section 11.4 on printing and exporting below.

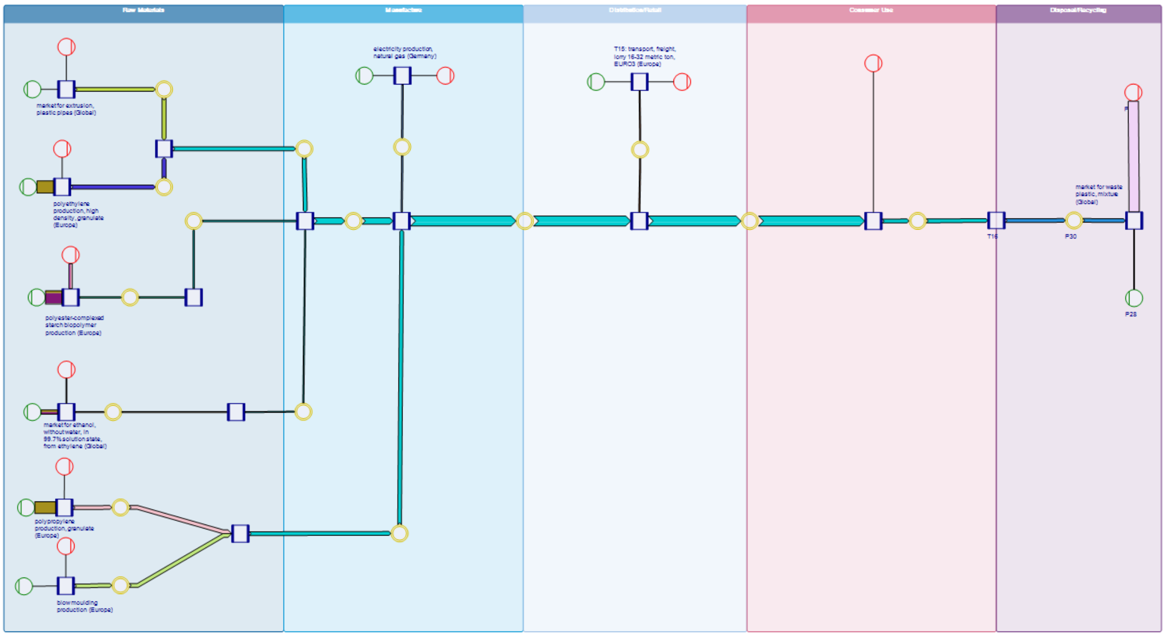


Figure 78: Sankey Diagram showing product-related flows

Sankey Diagram Scaling: By default, the flows in the Sankey diagram are created with a standard width in regard to the largest flow in the diagram.

The scale of the Sankey arrow width can be adapted on the tab 'Scaling of Sankey Diagram' in the Properties window area. Should this tab be invisible, it can be opened using the command 'Scaling of Sankey Diagram' from the Tools menu.

One slider is shown for every unit type that exists in the life cycle model. Typically these are mass (kg) and energy (MJ), but when working with other materials such as land use, passenger transport, freight transport, etc. additional basic units (ha, pkm, tkm, ...) are introduced and each one must be scaled individually with its own slider.

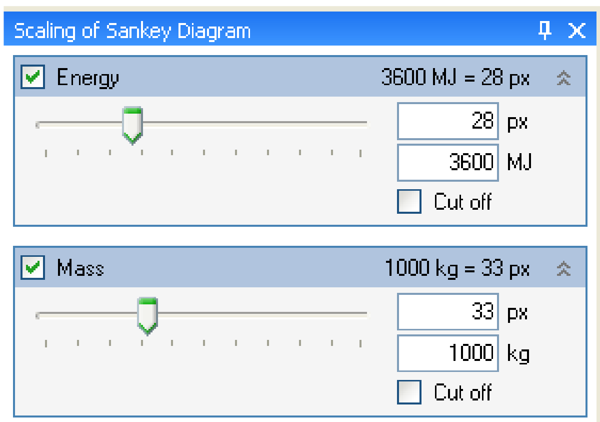


Figure 79: Scaling of Sankey Diagram

The scaling ratio is shown as px per basic unit. It can be adapted by dragging the slider.

Remove the check mark in front of the unit type name, to hide flows of that type.

Sankey Diagram Options: There are numerous options for adapting the Sankey diagram in Umberto LCA+.

Sankey Diagram Options for Individual Arrows: Please check the 'Sankey Options and Style' panel in the Arrow properties window. Also see the Net properties window for general options for Sankey diagrams. Thirdly, there are options related to the connectivity of Sankey arrows at a process and the stacking at the first Sankey arrow segment in the Process properties window.

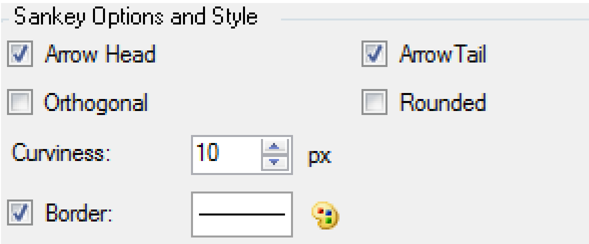


Figure 80: Sankey Options in the Arrow properties dialog

For one or more selected Sankey arrows, the following options can be set:

Arrow Head: Show an explicit arrow head for the arrow. Also note the settings for arrow heads for small arrows and arrow spikes.

Arrow Tail: Show an explicit arrow tail for the arrow.

Orthogonal: Show the Sankey arrow with orthogonal (90°) bends.

Rounded: Show the Sankey arrow with rounded bends. The setting in the 'Curviness' field determines if the rounded bends are soft or sharp. This option can also be used in combination with the 'Orthogonal' setting (see above)

Border: Show a borderline around the colored Sankey arrow. You may choose a line style and a color for the border line by clicking on the line symbol or on the button 'Select Color'.

Apply changes to the Sankey arrow for individual selected arrow, or for several arrows (Multi Element Editing, see 7.1 General Element Related). The keyboard shortcut CTRL+A marks the whole carbon footprint model, and when 'Arrows' is selected from the dropdown list in the Properties window, the changed will be applied to all arrows.

Sankey Diagram Options for All Arrows: Additional Sankey options are available for the whole Sankey diagram (rather than for individual arrows) in the property dialog for the diagram that shows in the Property Editor when no element is selected. These relate to spikes for the Sankey arrows:

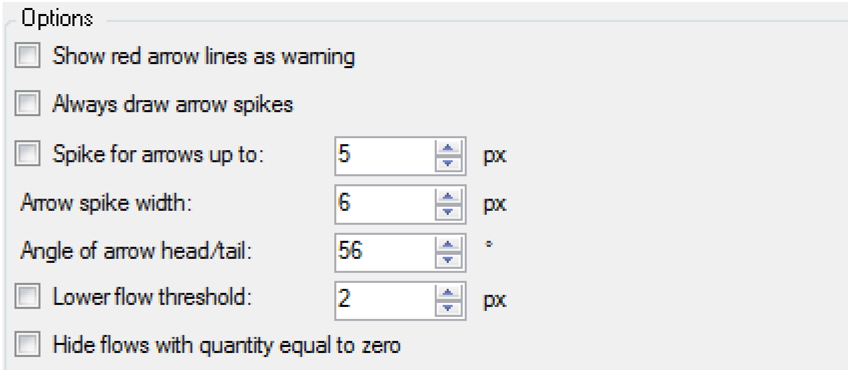


Figure 81: Sankey arrow-related options in the properties dialog of the net model

Always draw arrow spikes: all arrows, independent of the arrow width will show a spike.

Spike for arrows up to: Only arrows which have a width up to the chosen value (in pixels) will display a spike. This is to give more emphasis to small flows.

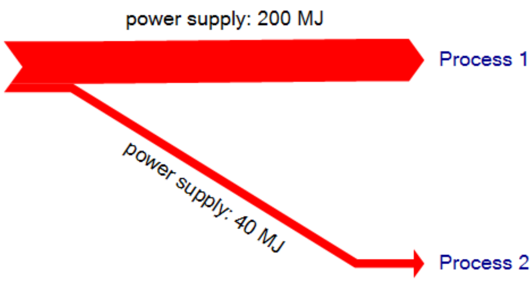


Figure 82: Example for arrow spike for small arrows only

Further options for Sankey diagrams relate to the way arrows connect to the process symbols, and how they are stacked. These options can be set individually for each process in the 'Sankey Arrow' panel of the Process Properties dialog, when the process is marked.

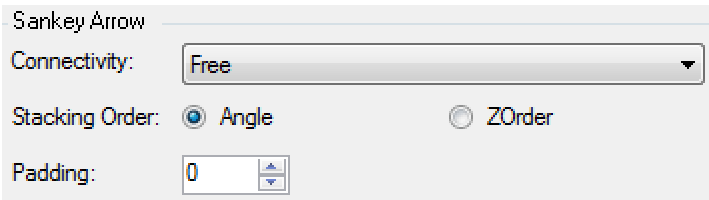


Figure 83: Sankey arrow-related options in Process Properties dialog

Connectivity: The connectivity setting for a process, describes how arrows can attach to the process.

The 'Connectivity' dropdown list allows restricting the general direction of the arrows linked to that process. As a default setting, the arrows are "free", and do connect to the top, left, right or bottom of the process symbol. In the setting "Free" the angle of the gray arrow point on the arrow determines the edge to which the arrow connects (see section on Arrow Points for more details).

To force the connecting arrows to leave a process at the bottom, and to arrive at a process only at the top edge, choose 'Top to Bottom'. If you wish the arrows to leave the process from the right edge, and to enter in the process from the left, choose 'Left to Right'. The opposite directions ('Bottom to Top') and ('Right to Left') are less common but are also available.

Stacking Order: If more than one arrow is connected to a process, either all leaving a process on the same side, or several arrows arriving on the same side as in a joint arrow head, the arrows are automatically stacked on the last segment of the arrow.

When the arrows branch off after the first horizontal or vertical segment (at the yellow lug point, see section on Arrow Points for more information) a wrong stacking order might lead to crossing arrows. There are two alternatives for determining the stacking order (order in which the arrows are connected to the process): 'Angle' and 'Z-Order'.

Sort by Angle: In the default setting for the 'Stacking' option, the stacking depends on the angle of the imaginary line between the centers of the two processes the arrow connects. When dragging a process around in the diagram, the stacking order might therefore be rearranged.

Sort by Z-Order: The Z-Order of arrows (the layer on the drawing area) can be influenced with the command 'Bring Forward' or 'Send Backward' from the context menu of an arrow. Using 'Bring To Front' brings the selected arrow all the way to the front, while 'Send to Back' sends it to the last layer of the diagram. With this option, the arrow which is in the front (topmost layer) will be the first arrow to connect to the process, while the one that is on the last layer is the one that connects at the bottom of the process.

Padding: The connection of the arrows at a process symbol is usually exactly at the border line of the process symbol (distance is '0' pixels). In some cases, however, it might be advantageous to set a padding distance (e.g. when using images instead of the default square box as process symbol). The padding distance can be set in the field 'Padding'.

The padding distance value can also be negative (e.g. -12 px). The arrow foot and the arrow heads connected at a process with a negative padding value seem to end under the process symbol. This effect can be used, for example for hidden process symbols, to let an arrow head connect apparently directly into an arrow tail.

Sankey Diagram Mode Display: Several Sankey diagram modes are available. You can visualize 'Total Flows', 'Product Flows', or a Sankey diagram, for any selected LCIA impact category. Switching between the Sankey diagram modes is done using the cascading menu next to the 'Show Sankey Diagram' button or in the View menu.

The currently set Sankey diagram mode can be shown as text element by choosing the entry 'Sankey Mode Label' from the Draw menu. Showing the Sankey diagram type is especially useful for printing and exporting the diagram, as it tells you what the Sankey diagram represents.

Just like a regular text label, its properties can be edited in the property dialog. Text font and size can be adapted. The label can be moved and positioned in the editor area.

The label text is generated automatically and cannot be edited. It reflects the entries chosen in the 'Show Sankey Diagram' cascading menus.

The Sankey diagram mode can be removed by choosing 'Delete' from its context menu, or by selecting the label and hinting the DEL key. Once deleted, it can be shown again via the 'Draw' menu.

11.3 LCI Inventory Export

Inventories are shown on the tab 'Inventories' for the last model calculation. Typically this comprises the entire LCA model, but it could also be a section thereof, if the 'Calculate Selection' command has been used (see section 10.2).

Export Active Inventory: The inventories and all results of the life cycle calculation can be exported to Microsoft Excel.

Several inventory views are available as described above in section 11.1. To export the current inventory view, use the button 'Export Active Inventory Table' from the dropdown menu under the 'Export Data' button. A name has to be given for the export file. The default location where the file will be saved is C:\Users\<USER>\Documents\Umberto LCA+.

Make sure to select the columns you wish to include in the spreadsheet from the 'Field Chooser' and to order the columns the way you would like to have them sorted in the Excel file.

Export Inventory Raw Data: The inventory raw data can be exported to Microsoft Excel. This allows for creating any other customized table with selected results and diagrams based upon these.

Note that each entry has a time stamp, so that when results of several (different) calculations are exported and then copied into one Excel sheet together, comparisons over the differences can be performed.

Should you wish to create specific graphical analyses and diagrams, it is recommended to make an export of all calculated flow data as raw data and work with Pivot tables in Excel. For more information and an example please refer to the section 12.4.

Export Inventory as Process Specification: To export all inventory data in raw format, use the button 'Export Material Flow Raw Data' from the dropdown menu under the 'Export Data' button. A name has to be given for the Excel export file.

Choose the command 'Export Input/Output Data (Linear Specification)' from the dropdown menu of the button 'Export Data' on the 'Inventories' tab. The inventory data will be exported in the following format:

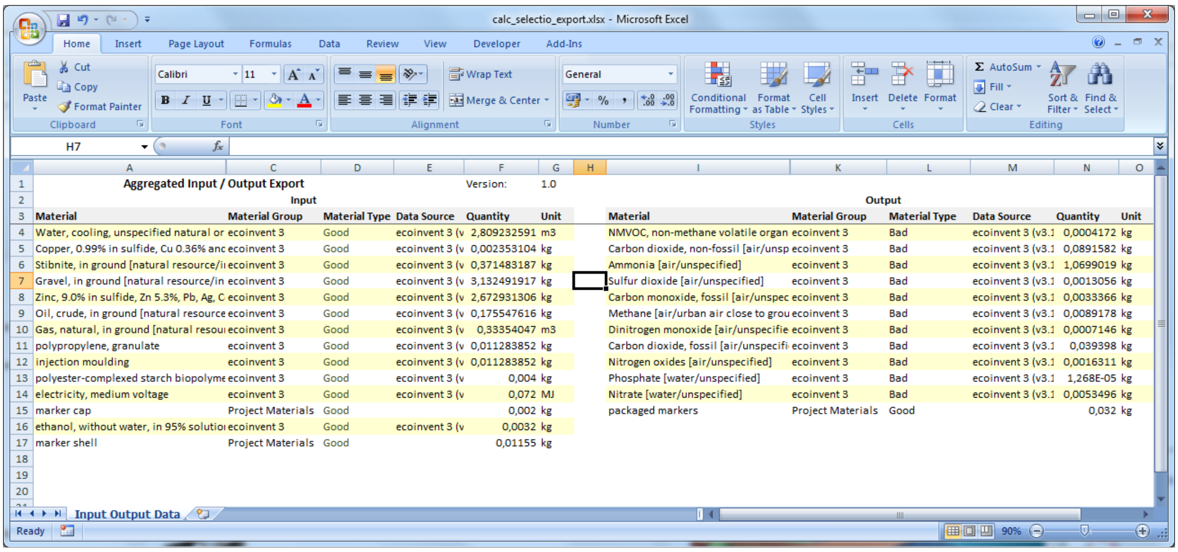
Input:

Column A	Material	Name of material entry.
Column B (hidden)	Material GUID	This is a unique GUID for the material. Do not modify. It is recommended to keep this column hidden.
Column C	Material Group	Name of material group
Column D	Material Type	"Good", "Bad" or "Neutral"
Column E	Data Source	The data source, if the material entry is from a master material database
Column F	Quantity	Value in full with all decimal digits even if less digits are shown in the inventory due to number format
Column G	Unit	Basic unit

Column H is empty and used for visual separation only.

Output:

Column I	Material	Name of a material entry.
Column J (hidden)	Material GUID	This is a unique GUID for the material. Do not modify. It is recommended to keep this column hidden.
Column K	Material Group	Name of material group.
Column L	Material Type	"Good", "Bad" or "Neutral"
Column M	Data Source	The data source, if the material entry is from a master material database
Column N	Quantity	Value in full with all decimal digits even if less digits are shown in the inventory due to number format
Column O	Unit	Basic unit


Aggregated Input / Output Export — Version: 1.0

	A	C	D	E	F	G	H	I	K	L	M	N	O
2		Input								Output			
3	Material	Material Group	Material Type	Data Source	Quantity	Unit		Material	Material Group	Material Type	Data Source	Quantity	Unit
4	Water, cooling, unspecified natural or	ecoinvent 3	Good	ecoinvent 3 (v	2,809232591	m3		NMVOC, non-methane volatile organ	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0004172	kg
5	Copper, 0.99% in sulfide, Cu 0.36% anc	ecoinvent 3	Good	ecoinvent 3 (v	0,002353104	kg		Carbon dioxide, non-fossil [air/unsp	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0891582	kg
6	Stibnite, in ground [natural resource/i	ecoinvent 3	Good	ecoinvent 3 (v	0,371483187	kg		Ammonia [air/unspecified]	ecoinvent 3	Bad	ecoinvent 3 (v3.1	1,0699019	kg
7	Gravel, in ground [natural resource/in	ecoinvent 3	Good	ecoinvent 3 (v	3,132491917	kg		Sulfur dioxide [air/unspecified]	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0013056	kg
8	Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, C	ecoinvent 3	Good	ecoinvent 3 (v	2,672931306	kg		Carbon monoxide, fossil [air/unspec	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0033366	kg
9	Oil, crude, in ground [natural resource	ecoinvent 3	Good	ecoinvent 3 (v	0,175547616	kg		Methane [air/urban air close to grou	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0089178	kg
10	Gas, natural, in ground [natural resou	ecoinvent 3	Good	ecoinvent 3 (v	0,33354047	m3		Dinitrogen monoxide [air/unspecifie	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0007146	kg
11	polypropylene, granulate	ecoinvent 3	Good	ecoinvent 3 (v	0,011283852	kg		Carbon dioxide, fossil [air/unspecifi	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,039398	kg
12	injection moulding	ecoinvent 3	Good	ecoinvent 3 (v	0,011283852	kg		Nitrogen oxides [air/unspecified]	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0016311	kg
13	polyester-complexed starch biopolyme	ecoinvent 3	Good	ecoinvent 3 (v	0,004	kg		Phosphate [water/unspecified]	ecoinvent 3	Bad	ecoinvent 3 (v3.1	1,268E-05	kg
14	electricity, medium voltage	ecoinvent 3	Good	ecoinvent 3 (v	0,072	MJ		Nitrate [water/unspecified]	ecoinvent 3	Bad	ecoinvent 3 (v3.1	0,0053496	kg
15	marker cap	Project Materials	Good		0,002	kg		packaged markers	Project Materials	Good		0,032	kg
16	ethanol, without water, in 95% solutio	ecoinvent 3	Good	ecoinvent 3 (v	0,0032	kg							
17	marker shell	Project Materials	Good		0,01155	kg							

Figure 84: Raw Data Export to Excel in the Linear Specification format

Note that this is the same format that can be used to specify a process. By this, you can export the inventories calculated for a whole model, for a subnet or for any chosen selection of the model, and use it as linear process specification (see section 8.1 for details).

11.4 LCI Inventory Printing

The network diagrams, the Sankey diagrams, the inventories and all results of the life cycle calculation can be printed.

Copy Model (Network Diagram) to Clipboard: To copy the network model (either in the default view, or in the Sankey diagram mode) to another application, such as a text application, a presentation software, or a graphics diagram) use the command 'Select All' from the context menu of the Model Editor area. Then use the command 'Copy' to copy it to the clipboard. Open the target application and paste the diagram.

Print Model (Network Diagram): To print the currently active model select the command 'Print Net' from the File Menu. Alternatively use the 'Print Diagram' button from the toolbar of the Model Editor. A print preview will be presented, that allows page setup and adapting the zoom for the printout. The page settings dialog can also be called from the File menu.

Print Inventories: The inventories and tables shown on the tab 'Inventories' can be exported to Microsoft Excel using the button 'Export'.

They can be printed by clicking on the button 'Print'. A PDF file will be generated for printout.

Should you wish to create specific graphical analyses and diagrams, it is recommended to make an export of all calculated flow data as raw data and work with Pivot tables in Excel. For more information and an example please see section 12.4.

Print Graphics: The result graphics of the life cycle model calculation on the summary and detail tabs can be printed by clicking on the button 'Print'. A PDF file will be generated for printout.

12 Life Cycle Impact Assessment and Interpretation

12.1 LCIA Results

The results of the life cycle model calculation are shown in the Specification Editor area after a successful calculation.

LCIA results are shown for the LCIA factors activated (see section 6.5). This can be one LCIA factor only, e.g. when tracing only the product carbon footprint along the life cycle, or several impact assessment factors (impact categories). By default the impact assessment method "ReCiPe Midpoint (H) w/o LT" (without long-term effects) is chosen, however, you can choose any of the more than 30 impact methods shipped in the ecoinvent database. For a complete list see Annexes A and B.

Choosing one LCIA method or individual LCIA categories from one or more LCIA methods is done in the 'LCIA Factors' dialog accessible via the Tools menu. Make sure you run the calculation of the model after activating or deactivating LCIA categories, so that results can be updated.

Should the LCIA result pages be empty after calculation, make sure that you have at least one LCIA factor selected in the 'LCIA Factors' dialog window (see section 6.5).

LCIA Summary – By Phases, scaled to 100%: A summary of the LCIA results grouped by phases of the life cycle for the activated LCIA factors is given on the tab 'LCIA Summary – By Phases, scaled to 100%'.

It shows the contribution to the from each life cycle phase, as a horizontal bar chart, and the contribution from each phase with percentage values.

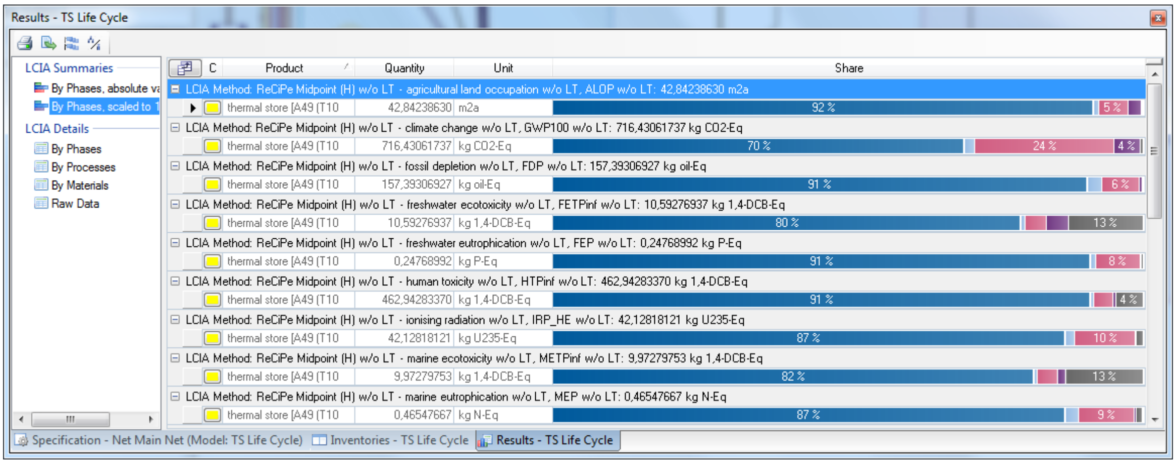


Figure 85: LCIA Summary, by phases, each impact category scaled to 100%

Please note that these values do not automatically refer to one unit of the product, but rather to the manual flow quantity that has been entered before the start of the calculation.

The colors of the bar chart are taken from the phase frame colors set by the user (see section 5.3). Values which do not lie within the life cycle stages frame (see above) are grouped under "Other". If no life cycle stages frame exists, this is the only bar that is shown.

LCIA Summary – By Phases, absolute values: A summary of the LCIA results for the activated LCIA factors is given on the tab 'LCIA Summary – By Phases, absolute values'.

It shows the contribution to the from each life cycle phase, as a horizontal bar chart, and the absolute values. Mind that the values cannot be compared as the impact categories might have different units.

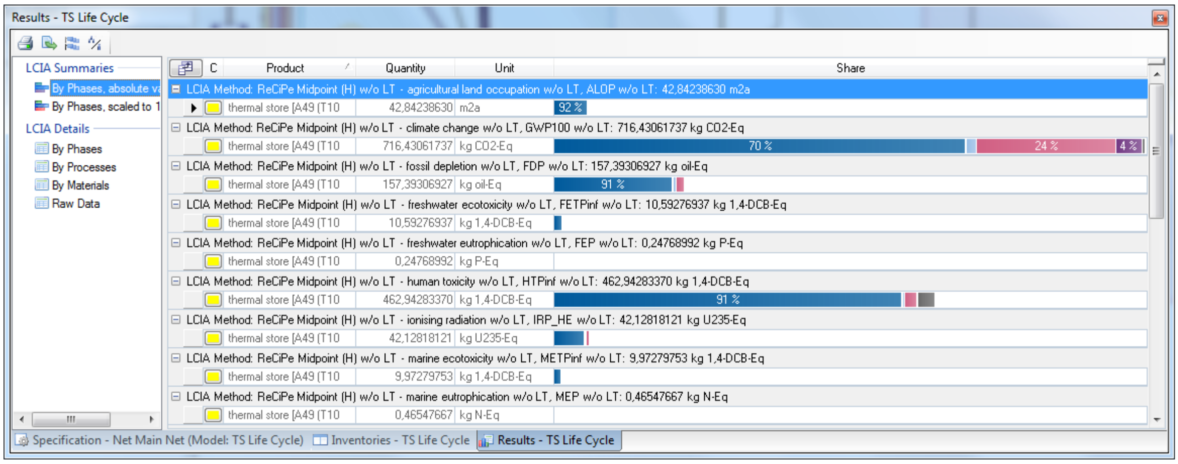


Figure 86: LCIA Summary, by phases, values each impact category

Note that the assignment of an environmental impact to a particular life cycle phase does not depend on the location of the process, but on the location of the input place that delivers a flow into the process, or the location of the output place that is connected to the process and that receives an emission or waste from that process.

Different Views of LCIA Details: Further pre-defined views of the detailed life cycle impact assessment data are available and can be selected in the list on the left.

For multi-product LCA models (LCA models that yield more than one product or have a main product and co-products) the inventories can be viewed for all products ('All Reference Flows') or for individual products. Select the product for which you want to see the inventory of input and output flows from the dropdown list 'Selected Product'.

The following LCIA detail views are available:

- **LCIA Details By Phase**: A list of impacts from inputs and outputs of the model grouped by life cycle phase. The attributing of an impact flow to a certain phase depends on the location of the place from/to the underlying elementary exchange flows. For further details see hint above and read in section 5.3 on Life Cycle Phases. Largest contributions to the impact by default shown at the top, in descending order.

- **LCIA Details By Process**: A grouped list of impacts for each impact category by process. This is similar to the above view "By Phase". Largest contributions to the impact by default shown at the top, in descending order.
- **LCIA Details By Material**: A grouped list of elementary exchange inputs and outputs with the associated contribution to the impact category. The aggregated view shows the sum of the impacts caused by all materials (one entry per elementary exchange).
- **Raw Data**: This is a plain view of all LCI data. It can be grouped individually or can be used for export of all data to Excel. In Excel the inventory data can serve as the basis for creating Pivot tables and graphs. Please read below for further information.

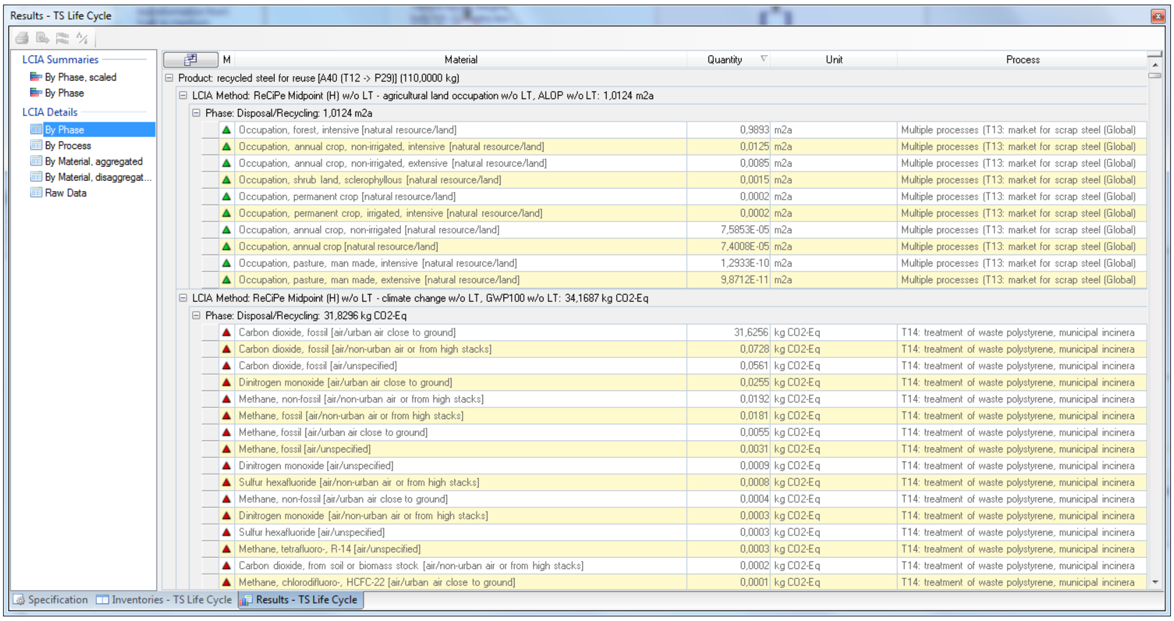


Figure 87: LCIA details grouped by phase

See the section on grid handling above to learn how to further sort and group the list of input/output flows.

Grouping and Sorting of LCIA Details: Details of the life cycle impact assessment can be grouped and sorted in many different ways, allowing for detailed analysis and assessment.

The different levels of detail can be expanded one by one by clicking on the button with the plus sign in front of the title. Levels can be collapsed by clicking on the minus sign.

A different grouping can be done the following way: First, open the group-by area by clicking on the button 'Toggle Group-By Box' in the toolbar. Then drag the column headers into the group-by area at the sort-order position.

The possibility to remove certain columns from the detailed LCIA results view is extremely helpful in conjunction with the grouping feature, to customize any kind of results display.

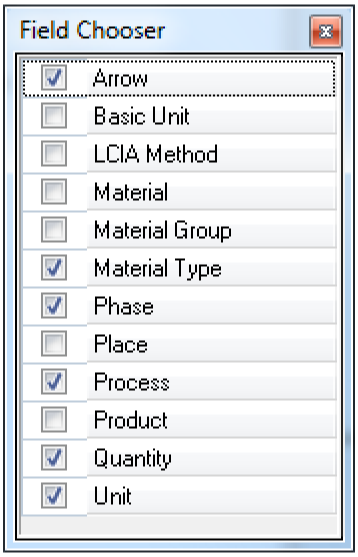


Figure 88: Field Chooser

One typical grouping/sorting of the LCIA results is by Product / LCIA Factor / Process. This allows assessing the contribution of each process to a certain impact category, and a tracing of the substances that contribute most to the selected impact category.

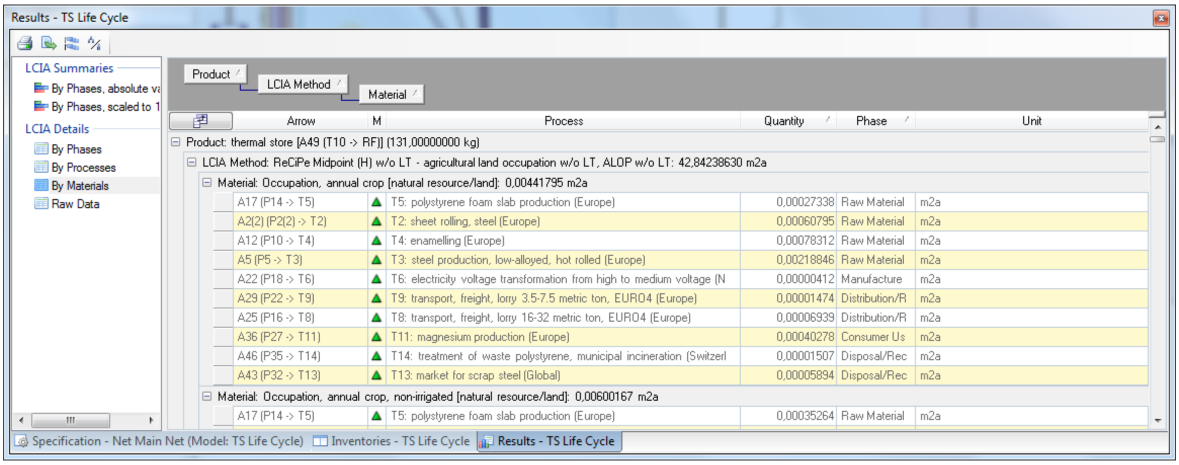


Figure 89: LCIA details, by material with additional columns.

Use the buttons in the toolbar of each tab, to export, print or save the result diagram or table. For more details refer to the section 11.4 on printing and exporting below.

Scaling of LCIA results: The results displayed on the tab 'Results' are by default shown for the actual flow quantity that has been calculated. Note that depending on the manual flow (see section 10.1) defined, this is not necessarily one unit of product, but can be, for example, the yearly production quantity.

To have this value scaled to one unit use the functional unit flag for the material in the Project Explorer. If this flag has been set and the conversion to one unit of product (e.g. for a product with mass basic unit 'kg' → "one piece" with 400g) has been defined then the clicking of the 'Toggle Scaled/Normal Values' button will allow switching between scaled and unscaled results.

Scaling to on unit of product might be meaningless in some views, especially when the values for more than one reference flow (product) are shown. In that case the scaling feature is disabled, the button greyed.

12.2 LCIA Weighted Flows Sankey Diagrams

Sankey Diagram Source / LCIA Flows: Apart from the physical flows on the inventory level, an even more interesting view of the life cycle model are the flows weighted with characterization factors (as LCIA contribution flows) per impact category in a Sankey diagram. This is a compelling visualization of where the main contributions to an impact category occur in the life cycle, and can be called for any of the activated LCIA factors.

To select the type of Sankey diagram use the dropdown menu next to the button 'Show Sankey Diagram'. Alternatively, if there are more than five activated LCIA factors you can open the window 'Source of Sankey Diagram' in the Properties window area by using the entry 'More...'.

The dropdown menu next to the button 'Show Sankey Diagram' only shows all entries after both calculations of the life cycle model (Total Flows, Product Flows and LCIA) have been performed. If it doesn't show any entries, please run the calculation first (see section 10.2).

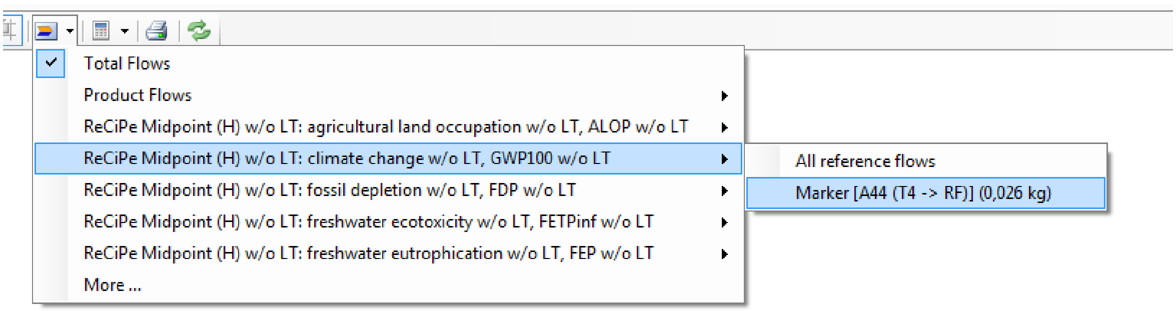


Figure 90: Dropdown menu 'Source of Sankey Diagram'

For showing the LCIA Sankey diagram for one impact factor, select the LCIA factor from the menu and one product of the life cycle system in the cascading menu.

This option is meaningful only for life cycle models that have more than one reference flow. In case that the model only has one reference flow, the 'All reference flows' entry in the menu produces the same Sankey diagram as if the actual reference flow was selected.

Note that in this Sankey diagram the flow direction of the Sankey arrow turns around for emissions and wastes, in such a way that the Sankey diagram shows the contribution of these flows to the selected impact category. In these

LCIA Sankey diagrams one can observe, how the material and energy consumption as well as the direct emissions add up the environmental impact along the product life cycle, and that typically the end-of-life phase (with inverted Sankey flow direction) also adds to the environmental impact.

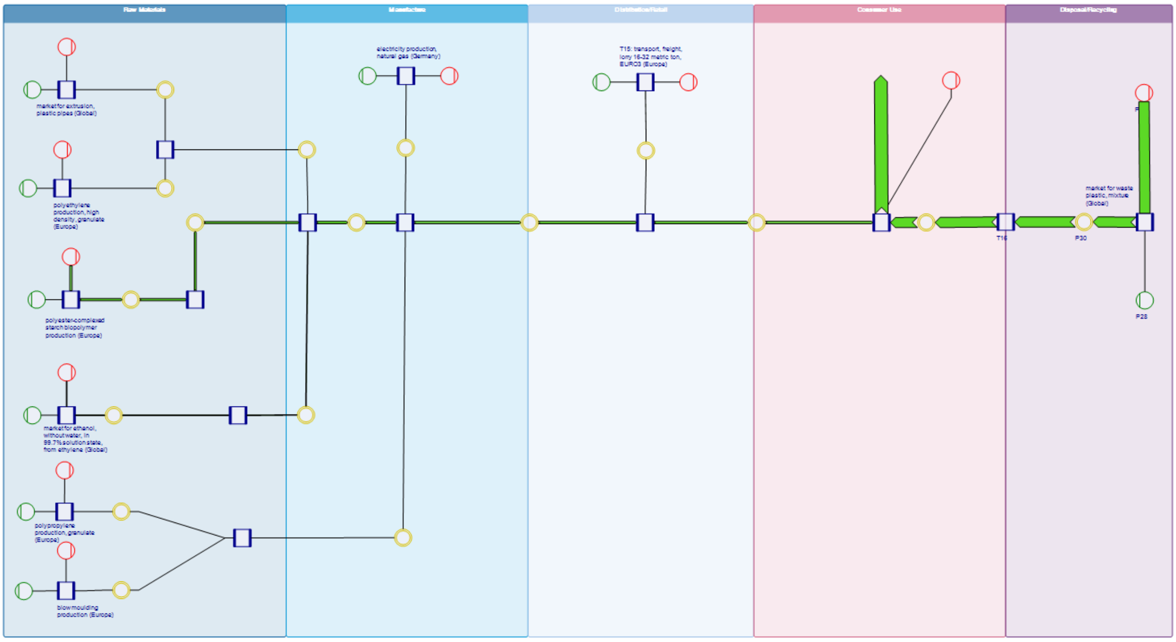


Figure 91: A LCIA Sankey Diagram with weighted flows, where the disposal flows have an inverted direction, as their environmental loads also contribute to the selected impact category

In this LCIA Sankey diagram the "virtual flow" of the product (large green Sankey arrow) is visible, as it represents the total environmental impact.

The chosen LCIA category for display as Sankey diagram can be shown in the editor as a Sankey Model Label. Read more in section 11.2 under 'Sankey Options'..

12.3 LCIA Printing and Exporting

The LCIA details and the weighted LCIA Sankey diagrams can be printed and exported.

Copy LCIA Sankey Diagram to Clipboard: To copy an LCIA Sankey diagram of the model showing the contributions to a certain activated impact category along the life cycle use the command 'Select All' from the context menu of the Model Editor area when in the LCIA Sankey diagram view (see section 12.2).
Then use the command 'Copy' to copy it to the clipboard. Open the target application and paste the diagram.

Print LCIA Sankey Diagram: To print the currently active LCIA Sankey diagram select the command 'Print Net' from the File Menu. Alternatively use the 'Print Diagram' button from the toolbar of the Model Editor.

A print preview will be presented, that allows page setup and adapting the zoom for the printout. The page settings dialog can also be called from the File menu.

You may wish to switch on the Sankey Mode Label (see section 11.2 under Sankey Options) before printing or exporting the Sankey diagram. The Sankey Mode Label indicates what LCIA impact category indicator is displayed in the Sankey diagram.

Print or Export LCIA Results: The life cycle impact assessment (LCIA) tables shown on the tab 'Results' can be exported to Microsoft Excel using the button 'Export'. The current view (including grouping and sorting) will be used in the spreadsheet file. An ungrouped view is available with the 'Raw Data' view.

The LCIA results can be printed by clicking on the button 'Print'. A PDF file will be generated for printout.

Print or Export Graphics: The result graphics of the life cycle model calculation on the summary and detail tabs can be exported to Excel using the button 'Export'.

They can be printed by clicking on the button 'Print'. A PDF file will be generated for printout.

12.4 Raw Data Export (Additional LCIA & Interpretation)

The number of default diagrams created automatically with every calculation of a life cycle model is limited to the LCIA Summary (featuring the value of the impact assessment factor for each category) and a breakdown by phases. It might be required to create other diagrams that include specific data or are more suitable to answer particular questions for interpretation.

To this end, all data calculated can be exported to an Excel table as raw data. The raw data can then be used with the Pivot Table / Pivot Chart feature of Excel to produce virtually any type of diagram needed.

Due to the vast number of exchanges in the ecoinvent database, the raw data export feature can only be used with Excel 2007 or higher (xlsx file format). Older Excel version can't handle more than 65.536 lines of data.
There's also the option of exporting in CSV format.

From the dropdown menu of the button 'Export Data' choose the command 'Export LCIA Raw Data' on the 'Results' tab, and state a name for the Excel file. The resulting export file will be opened upon completion of the export.

The raw data includes the following columns:

- Project Name
- Model
- Timestamp (=Version)
- LCIA Method
- Phase
- Product
- Process

- Material
- Quantity
- Unit

Note that the use of the timestamp allows doing model comparisons. Two or more life cycle calculation results can be exported and the raw data can be copied into one large Excel table. Replace the time stamp with a real name, e.g. "Scenario 1 Baseline" and "Scenario 2" to make charts for comparisons.

The Excel file contains several worksheet tabs. The first tab 'Description' has a short explanation on how to use the raw data to create individual graphics.
The raw data itself can be found on the second tab 'LCIA Raw Data'.

On the tab 'Charts' some sample pre-configured diagrams are shown. They are gathered from the subsequent tabs 'PivotTable 1', 'PivotTable 2', 'PivotTable 3', etc. Use these tabs to create new diagrams or adapt existing diagrams based on the raw LCIA data.

To modify the default diagrams, use the Pivot Table Field List on the right side of the 'Pivot Table' tabs. In case it is hidden, it can be shown with the 'Field List' button on the 'PivotTable Tools' ribbon.

To adapt a diagram, select the fields to be displayed in the field list at the top. In the default diagram the 'LCIA Method', the 'Process', the 'Phase' and the 'Quantity' (read: quantity of the environmental impact for the selected LCIA method) are active.

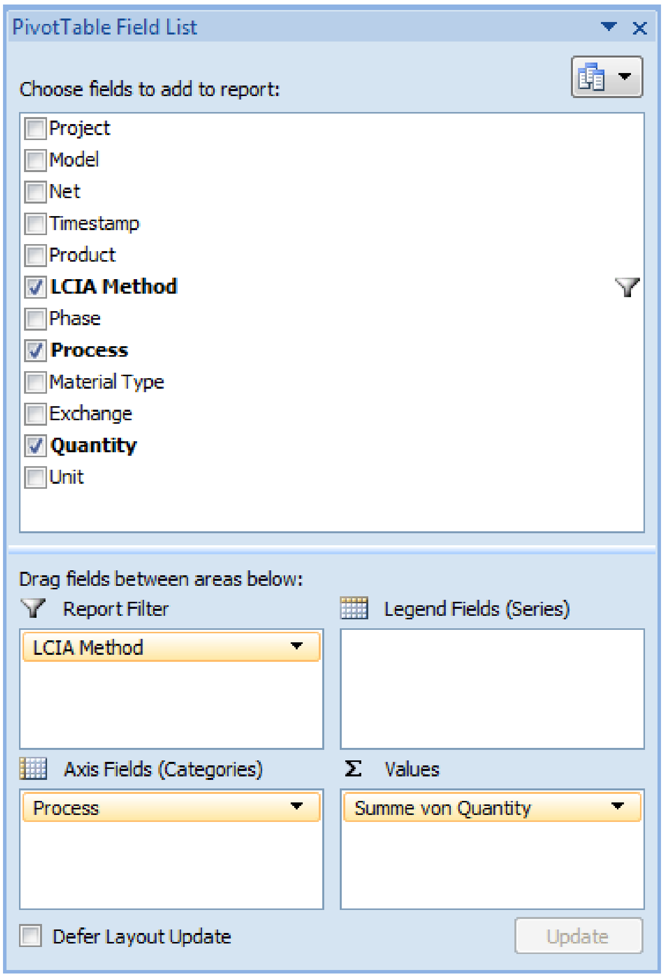


Figure 92: Selection of data series and filter criteria for Pivot graph ('PivotTable Field List')

The sections at the bottom are used to arrange the diagram, select the axes, and define the order of display of the data series. In the default diagrams the 'LCIA Method' is set as the 'Report Filter'. Hence the diagram displays one (or more) selected impact assessment categories. The name of the LCIA Method also appears as diagram title. The 'Process' is set as 'Column Labels', and the 'Phase' as the 'Row Labels'. The 'Values' list has the entry 'Quantity'. Additionally in the dropdown list the properties are set to 'Sum of Quantity'.

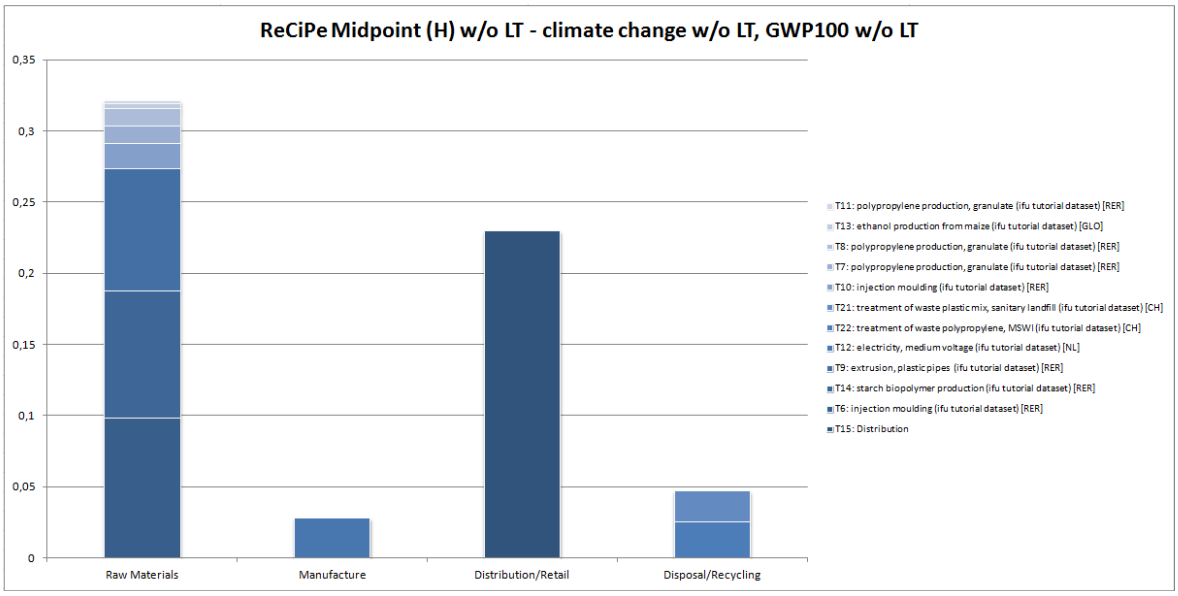


Figure 93: Default Pivot Graph for the LCIA Method 'ReCiPe Midpoint (H) w/o LT - climate change' with stacked bars for each phase and each segment of the bar representing the contributing process

To rearrange the diagram, simple drag&drop the entries in the four field lists at the bottom back to the list at the top, and choose another filter or sorting criteria.

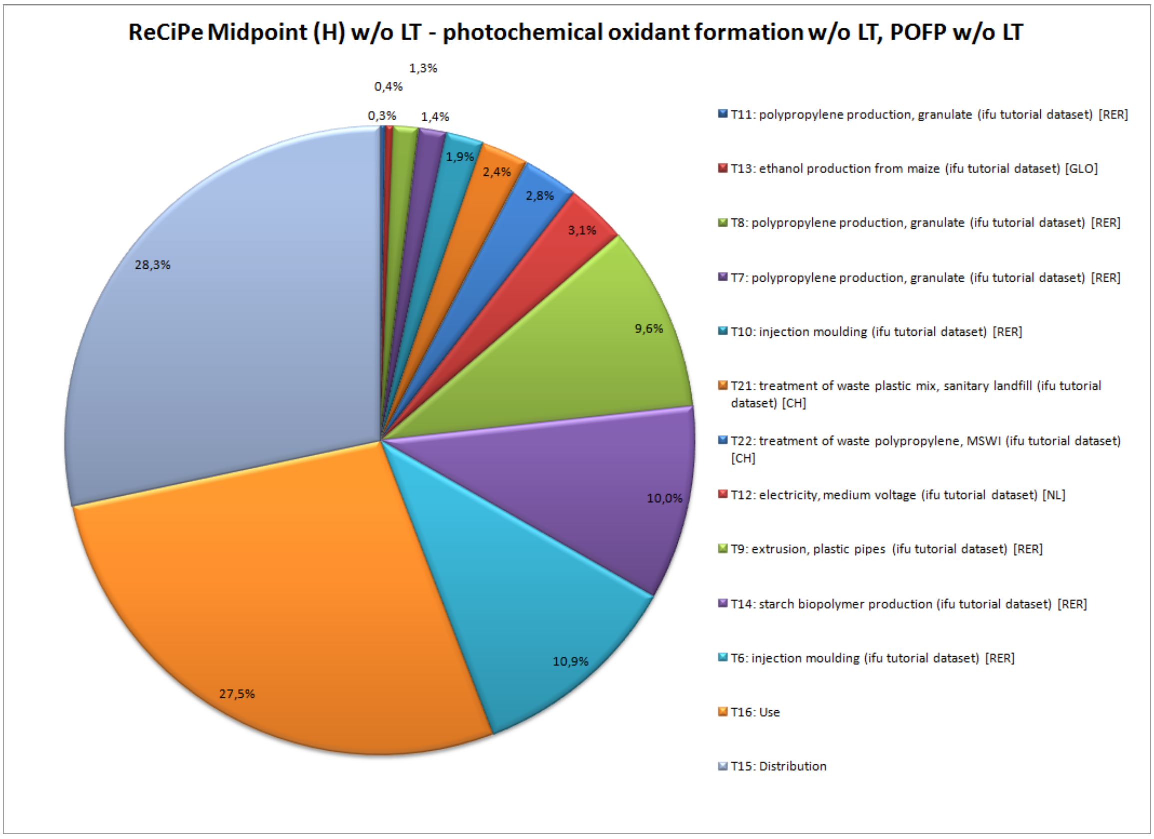


Figure 94: Adapted Pivot Graph for the LCIA Method 'ReCiPe Midpoint (H) w/o LT – photochemical oxidant formation POFP' pie chart with percentage for each contributing process

The diagrams can be adapted and arranged using the numerous options available in Excel 2007 and 2010. The most often used among these are:

- Change Diagram Type
- Change Diagram Colors
- Show/Hide Legend
- Show/Hide Data Values (absolute values or percentage)

Please use the Excel online help and documentation to learn about the many features for adapting the Pivot Graphs.

12.5 Product Comparison

Comparing Products or Product Variants: To do comparative LCAs, either of two different products that fulfil the same service (i.e. have the same functional unit), or for variants of a product, it is required to calculate the different scenarios separately. The LCIA results can be compared by exporting the raw data for each of the models and then copying the two (or more) raw data export files together into one large Excel file (tab 'LCIA RawData'). To be able to distinguish the products either use the field model (comparing different models) or replace the timestamp value, if you are comparing LCIA for two or more calculations made within the same model, e.g. when doing a sensitivity analysis and recalculating the model with different parameter values.

12.6 Interpretation

The interpretation step in an LCA study should include identification of significant issues based on the results of the LCI and LCIA phases. It should further include an evaluation of the study in regard to completeness, sensitivity and consistency checks; advice on the limitations of the study, conclusions and recommendations.

The models in Umberto LCA+ help understanding the impact assessment results, and tracing them to their origin. This is accomplished by identifying the processes and substances that contribute significantly to each impact category. Doing sensitivity analysis of the significant parameters and assumptions is also a key element of the interpretation

Completeness and consistency of the study should be assessed and documented before drawing conclusions and recommendations.

Several features in Umberto LCA+ support the interpretation step. Among these are process and net parameters that can be modified to run different scenarios or check the significance of assumptions. The expand feature allows unfolding a supply chain step by step to see which part of the supply chain contributes to a certain environmental impact. The LCIA Details and the raw data export allow tracing the environmental impacts to specific substances. The direct link to the ecoinvent documentation facilitates understanding of the background data used.

13 Advanced Features for LCA Modelling

This chapter contains explanations of the more advanced features of Umberto LCA+. These features target at the more advanced user, as they are related to specific aspects of LCA and allow exploring additional possibilities for life cycle modeling and calculation.

13.1 User Defined Functions

In addition to the common linear specification of processes using coefficient, or parameters values that are being evaluated, Umberto LCA+ also offers the possibility to define processes using mathematical functions and operators. This is a feature most likely not used in common LCA, but for advanced modelling where the relationship between input and output of a process is best described as a mathematical function, this can be very helpful.

To turn a process specification from a simple linear specification to the 'User Defined Function' mode, choose 'Convert' from the context menu of the process, and 'User Defined Functions'. Reverting a process defined with mathematical operators and functions back to a simple linear process specification and maintaining the functional relationship is in most cases not possible. However, should you wish to abandon the user defined function mode and prefer to specify a process with coefficient again, you can do so by using the command 'Convert' from the context menu of the process, and 'Linear'.

A process that has been converted to the 'User Defined Functions' type, will not show the coefficient column any more. Instead, an additional column 'Var' on the input and output side now sports the variable identifier with which the flow entries can be referenced in the mathematical formulas and function terms.

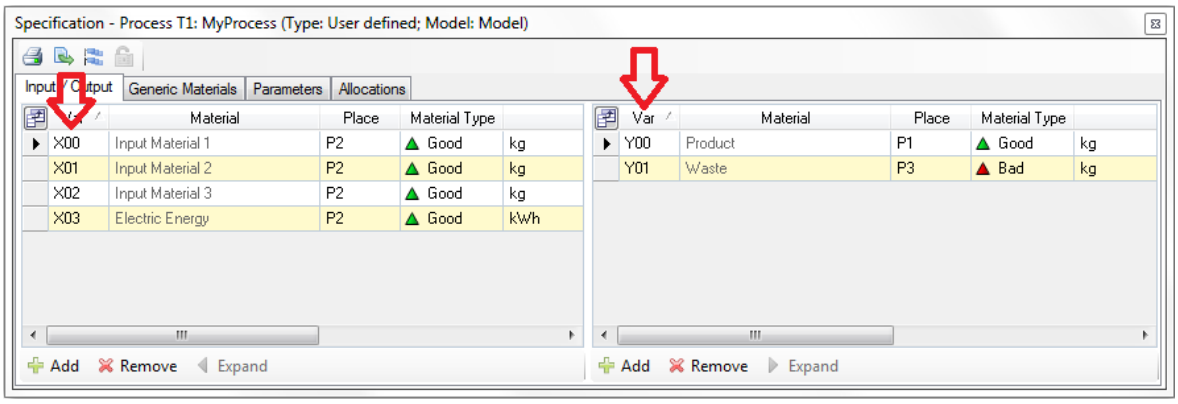


Figure 95: Specification Editor window for a process, 'Input/Output' tab with 'Var' column

In the main area (where the editor is located) a tab 'Functions' will be opened, which provides a text editor. In each line of the editing field a definition for one of the flows can be entered. The name of the variable ("Var") is on the left of the equals sign and makes reference to the flow entries on the "Input/Output" tab.

The term of the function is right of the equals sign. In this term other variables, transition parameter and net parameter identifiers, and all valid expressions for functions can be used. The valid expressions for mathematical formulae are compiled in the annex.

Examples:

```
X00 = (Y00*C00)/N02
Y00 = X00 + X01
Y01 = IF(<(X00,THRESHOLD),X00,THRESHOLD)
```

In the above example "Y00", "X00" and "X01" are variable names for flows in the process, "C00" is a variable name for a process parameter (see below section 13.3) and "N02" is a variable name for a net parameter (see below section 13.5). Variable names for process parameters and net parameters can be used in the expression on the right side of the equal sign, they cannot be assigned new values.

To be able to calculate the process independent of the flow direction of materials it is recommended to state the conversion formulas for all variables where possible (or sensible). Otherwise the system may find a specification insufficient when calculating in a specific direction and thus be unable to calculate parts of the material flow model. The calculation direction mainly depends on the location of the manual flow in the material flow model (see chapter 10 of this user manual).

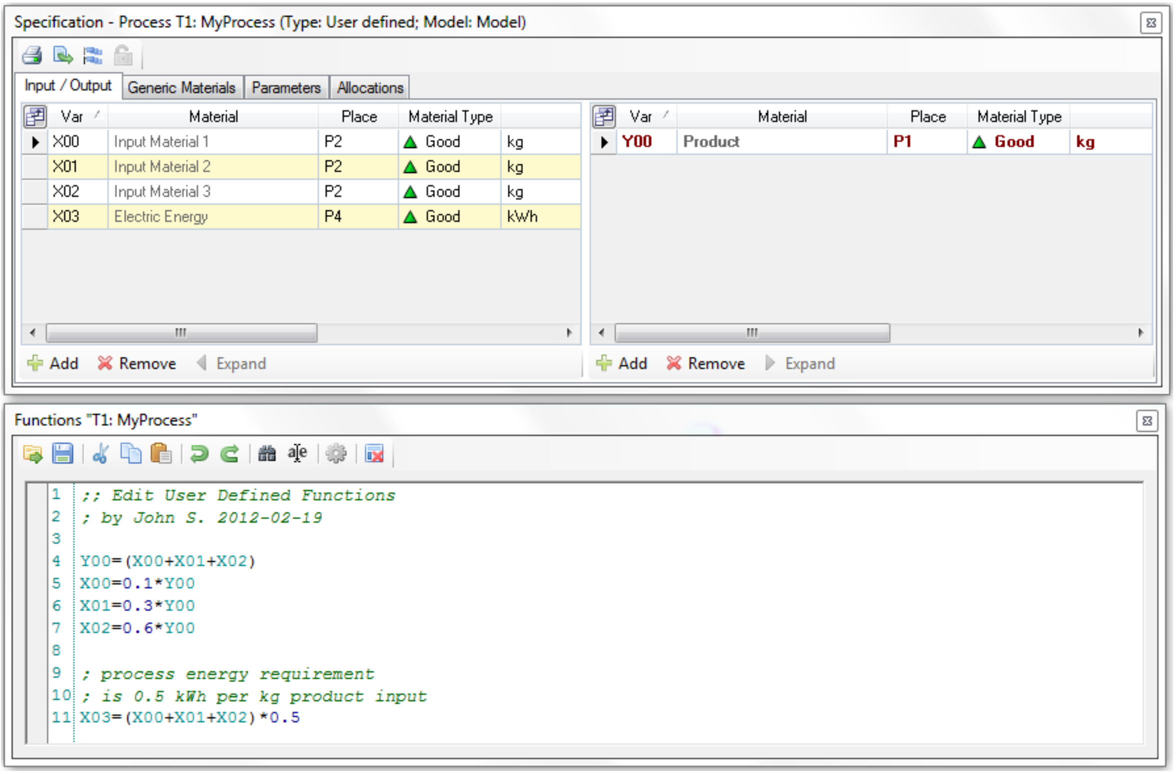


Figure 96: "Functions" Editor for specification of a process in the 'User Defined Functions' mode.

Comment lines can be inserted. Comment lines have a leading semicolon (";") and are shown in green. Make use of this feature and leave lines empty to maintain the comprehensible structure of the function definition.

The decimal point used is the dot ("."). Spaces may be inserted in front and after operators for better readability.

Commands Available in the Functions Editor

Import Text	Open text file and add text to the editor
Export Text	Save text in editor as text file
Cut	Cut selected text
Copy	Copy selected text to clipboard
Paste	Paste text in clipboard at cursor position
Undo	Undo last step in editor
Redo	Undo last step in editor
Search	Text search in editor
Replace	Replace text in editor
Settings	Editor settings
Close	Save and close functions editor

Note that this is not a programming language or script, but rather a list of assignments or definitions. The order of variable assignments is therefore not important. The expressions will be assessed until no further entries remain to be evaluated. If all variables in the process do have a value, the process can be calculated successfully. If one or more variables remain without a value, the process calculation cannot be completed successfully

After you typed the first letter of a reserved function name, you can use the keyboard combination CTRL+SPACE to bring up code completion for pre-defined functions and parameters that have been defined for this process.

Note that Undo/Redo in the functions editor is possible only until the editor is closed and the text of the process specification has been saved.

13.2 Use of Generic Materials

Instead if explicitly defining a specific material in a process specification it is also possible to create entries for so-called generic materials. These are defined on the second tab of the Specification Editor.

Just like for specific material on the 'Input/Output' tab, create a generic material entry by clicking on the 'Add' button on the input or output side. Generic materials can be created either on the input side only, on the output side only, or the same generic material entry on the input and output side.

For the new generic material entry, a name must be stated, a place must be assigned, the material type must be set, and a unit type must be chosen.

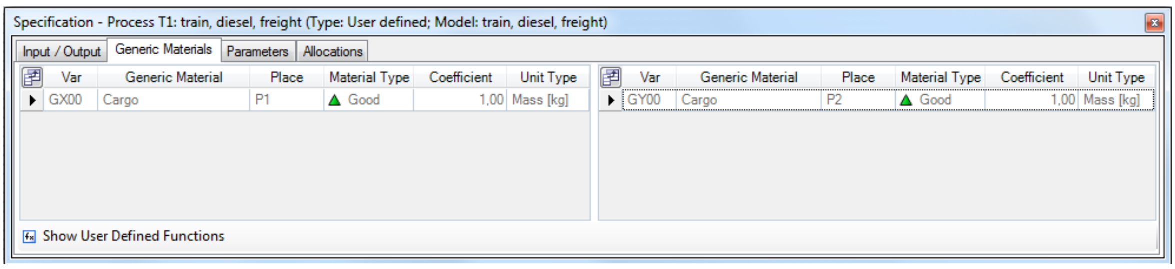


Figure 97: Specification Editor window for a process, 'Generic Materials' tab

Generic names on the will accept a materials arriving on the arrow that connects to the place assigned, if it has the same material type, and the same unit type. It is not possible to have flows of different unit type in one generic material entry. It is not important whether there is one, or if there are several flows on the arrow, as long as they have the same material type and unit.

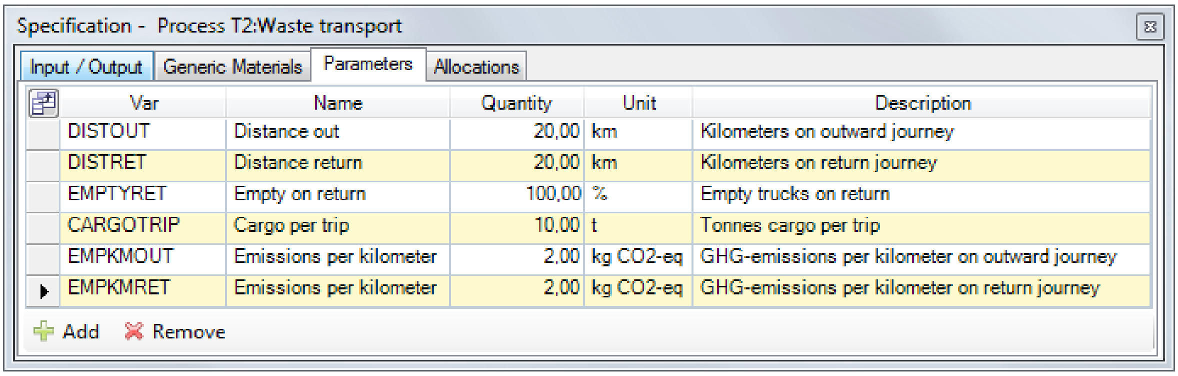
The quantity of the flows will be added in the generic material. The flows on the 'Input/Output' tab will calculate in regard to one unit ("1,00") of the generic material. You can use this feature, for example that model processes that depend on the overall quantity (sum) of different wastes arriving in a MSWI plant, without specifically knowing these flows or their exact composition beforehand.

Transport processes, if modelled with generic materials, typically have the same generic materials entries (same name, same material type, same unit type) on both input and output side. The material (in this case cargo, or different types of cargo) enters and leaves the process, and the emissions are calculated based on the total weight, and the diesel consumption per kilometer (parameters are described below).

Examples for processes with generic materials can be found in the tutorials, in separate documents.

13.3 Process Parameters

Parameters can be used to calculate the process specification. They are defined for each process on the 'Parameters' tab of the Specification Editor. Parameters can be used in functions for calculation of coefficients on the 'Input/Output' tab. They can also be used in the calculation of the process using 'User Defined Functions' (see above section 13.1).



Var	Name	Quantity	Unit	Description
DISTOUT	Distance out	20,00	km	Kilometers on outward journey
DISTRET	Distance return	20,00	km	Kilometers on return journey
EMPTYRET	Empty on return	100,00	%	Empty trucks on return
CARGOTRIP	Cargo per trip	10,00	t	Tonnes cargo per trip
EMPKMOUT	Emissions per kilometer	2,00	kg CO2-eq	GHG-emissions per kilometer on outward journey
EMPKMRET	Emissions per kilometer	2,00	kg CO2-eq	GHG-emissions per kilometer on return journey

Figure 98: Specification Editor window for a process, 'Parameters' tab

Defining Parameters: To define a flow parameter in a process specification, click on the button 'Add'. A default entry will be created in the table on the 'Parameters' tab, which can subsequently be edited: enter a name and a unit, and set a value for the parameters. The default variable name (C00, C01, …) can be edited as well, to allow for a better identification of a parameter.

The parameters are referenced in the functions with the variable name given for an entry in the column 'Var'. In the above example, the default parameter names have been replaced with DISTOUT, DISTRET, EMPTRET and the like for better understanding.

Process parameters are used locally in the process only. If a parameter is to be used for a whole model, or a subnet level, use net parameters instead (see section 13.5)

Removing Parameters: To remove a parameter entry from a process specification, mark the entry and click on the 'Remove' button. Note that by removing parameter entries the coefficient calculation on the 'Input/Output' tab may become invalid. The removal of a parameter may also cause errors in the calculation if the process has been defined with 'User Defined Functions', and the variable name have been used in the functions for the specification of the process.

Using Function Terms to Determine Parameter Values: If the value of the parameter is dependent on other parameters, a function term can be entered for the parameter in the "Function" field. The function term will be assessed and the value be shown in the "Coefficient" field. All valid expressions and operators can be used to define the function term. See Annex E for a comprehensive list of valid expressions.

Examples for function terms used to define a parameter value:

DIST1	Distance1	250	km	
DIST2	Distance2	550	km	
LOAD1	Average Load1	40	%	
LOAD2	Average Load2	60	%	
WLOAD	Weighted Load	430	km	DIST1*LOAD1/100+DIST2*LOAD2/100

In the above example, the net parameters `DIST1`, `DIST2`, `LOAD1`, `LOAD2` are set manually by the user. The value for parameter `WLOAD` is determined from the other values using the function term shown.

Live Links to Parameter Values: Parameter values can also be fed from an external data source via a Live Link. A reference to a cell in an Excel spreadsheet file is created and linked to the coefficient. An update of the value in the source file leads to an update of the parameter value.

To establish a Live Link, copy the value of a cell and paste it on the line of the parameter table. A coloured icon signals that this value is fed via a Live Link. In case the icon is shown in grey the data source file is closed and values will only be updated when it is next opened, or when the update is triggered manually.

Note that entering a parameter value manually or adding a function for the calculation of the parameter will overwrite an existing Live Link reference.

To paste a Live Link use the command 'Paste Live Link' from the context menu of the parameter. To delete a Live Link that has been created for a parameter mark the entry on the 'Parameter' page, then use the command 'Remove Live Link' from the context menu.

13.4 Subnets (Hierarchical Models)

Subnets are a possibility to build hierarchical life cycle model. Subnets represent an "encapsulated" network section "hidden" behind a subnet symbol on the next hierarchical layer. For example, a manufacturing process, which is at first represented as a simple linear process specification can be refined and the individual processing steps (e.g. melting, forming, grating, assembly, packaging) can be modeled in a subnet with individual processes.

Subnet transitions are displayed with a blue double line square symbol. By clicking on the symbol of the subnet transition, a further model editor page will open, where the subnet can then be edited.

Hence subnets can be used to refine a single process and by representing it by several process steps. It can also be used to aggregate several process steps and to encapsulate them in one single process symbol on the parent model level. Subnets "hide" details which lie on subsequent levels of the model, at the same time the details of a calculated hierarchical model are available both in the inventory (LCI) as well as in the results (LCIA).

The hierarchical structure of the networks contained in a model, i.e. the topmost network and all subnets on subordinate levels are displayed in a tree-like structure in the Project Explorer. The number of hierarchical subnet levels is not limited. A subnet can have one or more subnets on the next level.

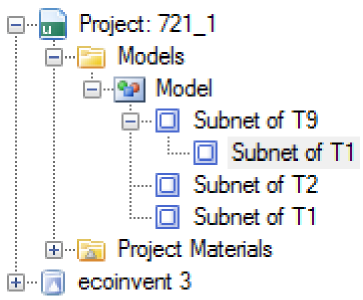


Figure 99: Subnet structure of a model shown in the Project Explorer

Subnets lie "behind" a process symbol. To create a subnet use an existing process symbol, or add a process symbol on purpose. Then select 'Convert To' from the context menu and 'Subnet' from the cascading menu.

Warning: Should the process symbol already contain a process specification, this specification will be lost, if a subnet is created. If you are not sure whether you are actually going to specify a subnet, make sure you have a backup of the existing process, either by copying it to the Module Gallery or by working on a copy of the model.

The editor for modelling the subnet opens on a separate page in the editor area. It contains copies of the places that are neighbouring places that were connected to the process symbol as the subnet was created. These so-called port places are the connections to the superior level (or: parent process): arrows from the input port places are the arrows that deliver flows from the upper level into the subnet, arrows to output port places are the arrows that hand flows from the subnet level back up to the upper model level.

If the places on the parent level have names (labels) when the subnet is created, the port places will also receive these names. However, the names are not synchronized so that the names can be changed individually. A place name on the parent level can have a distinct name from its counterpart in a subnet.

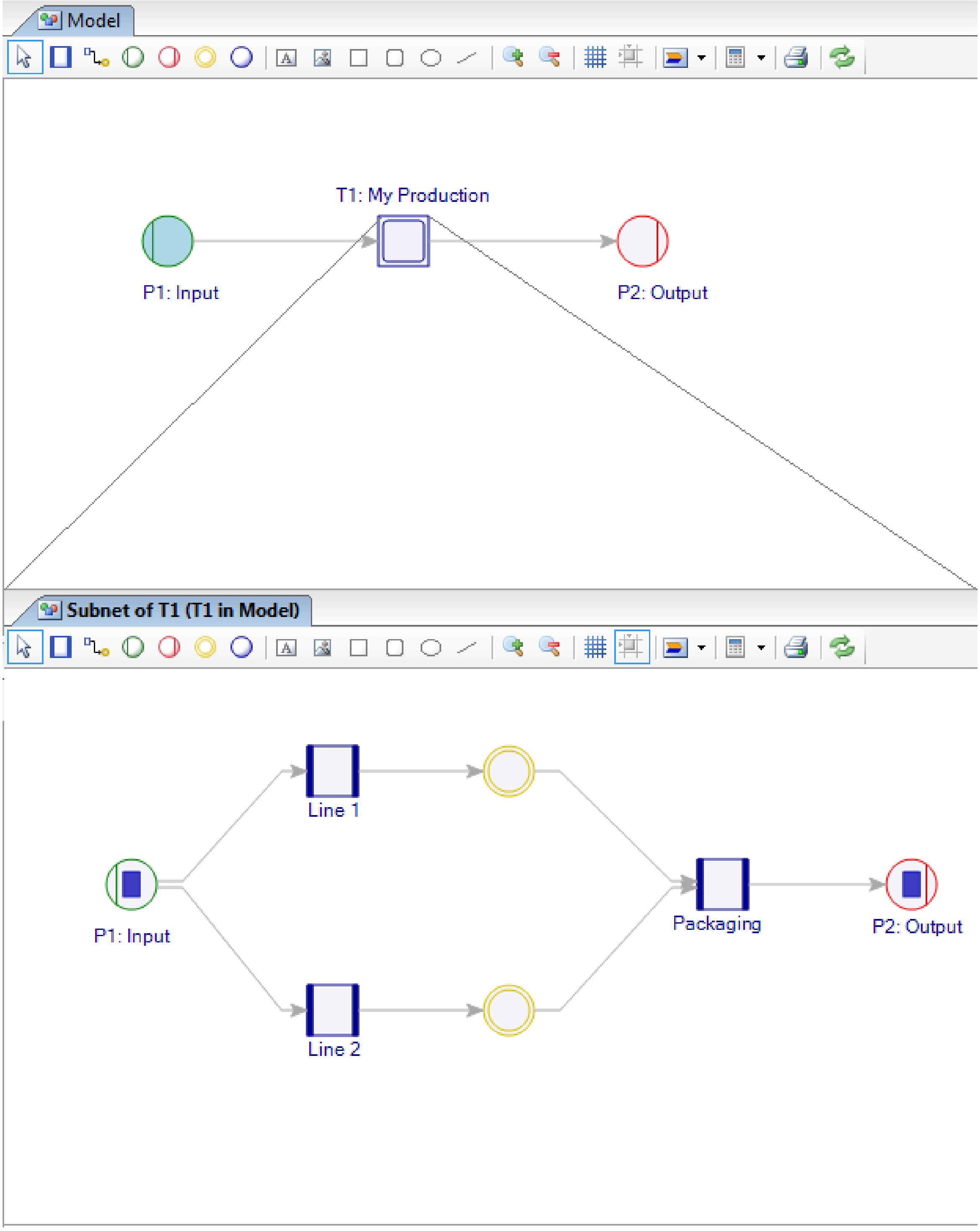


Figure 100: Subnet: The process T1 has been converted to a subnet ("Subnet of T1") that opens in a new editor window. The port places P1 and P2 serve as the connecting link between

parent and subnet level. In the subnet there are three processes "Line1", "Line2" and "Packaging",

Note that it is not allowed to create new input and output places on a subnet level. The flows on the arrows from and to these input and output places would not be accounted for in the inventory of the model as being exchanges from the system with the system surrounding (i.e. exchanges of the life cycle model with the biosphere).
Therefore it is mandatory to always connect input and output places on a subnet level to the port places forming the link to the parent level. Use the feature to merge places as described in section 7.3 to connect the input and output places to the existing port places with the colored marker in the center.

Unconnected input and output places in a subnet will be automatically connected to a default input and output place that is created as a new input or output place to the subnet process on the parent level.

The automatic connecting of input and output places on the subnet levels to default input and output places (named "Default Input" and "Default Output") on the top level of the model is make sure there are no hidden sources or sinks of the model. Should the connecting to these places be inappropriate to you it is easy to reconnect the arrows to another port place. Use the red point of an arrow and connect it to another port place (see Reconnect Arrow feature described in section 7.4).

To delete a subnet delete the process symbol using the DEL key or the 'Delete' command from its context menu. Note that the process symbol may have several subordinate network layers with specified model sections, which will also be deleted when the subnet process symbol is removed. A warning will be issued and confirmation has to be given to delete the subnet.

To store a subnet, mark the subnet structure and copy (CTRL+C). Then go to the Module Gallery and paste it in one of the folders. Alternatively copy the subnet process symbol with the neighbouring places and store it to the library. All subordinate net levels will be copied and stored in the Module Gallery as well. From the Module Gallery the subnet with all subordinate hierarchical levels can be copied into another net (e.g. in another Umberto project).

13.5 Net Parameters

The value of a net parameter can be used in the 'User Defined Functions' (see above section 13.1) for the calculation of the process.

Net parameters are defined on the 'Net Parameters' tab in the Specification Editor. This tab is visible when no element in the net editor is clicked. If it is not visible, just click in an empty area of the Net Editor.

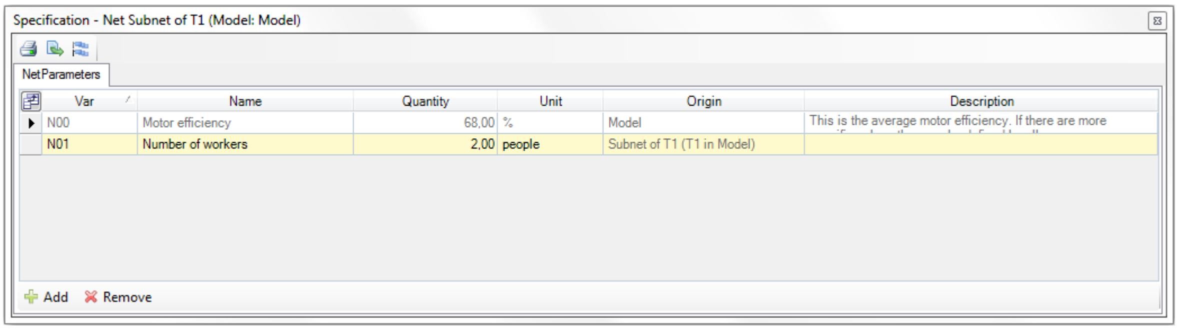


Figure 101: Specification Editor window, 'Net Parameters' tab

Defining Parameters: To define a net parameter for the current net level of the model click on the button 'Add'. A default entry will be created in the table on the 'Net Parameters' tab, which can subsequently be edited: enter a name and a unit, and set a value for the parameters. The default variable name (N00, N01, …) can be edited as well, to allow for a better identification of a parameter.

In the above example, the net parameter 'N01 Number of workers' has been defined and it has the value '2 people'. The parameter can be referenced in the user defined functions by its variable name (column 'Var'). This value is valid locally for the current net level 'Subnet of T1'. The level where the net parameter has been defined is shown in the column 'Origin'.

Note that in subnets there can be other net parameters from the above net levels, which can be referenced in the current subnet level as well. This is due to an inheritance mechanism implemented. Net parameters from a higher net level are shown in grey with their current value. If a net parameter with the same variable name is introduced locally, it will overrule the value defined on another net level.

Removing Net Parameters: To remove a parameter entry from a process specification, mark the entry and click on the 'Remove' button. Note that by removing parameter entries the coefficient calculation on the 'Input/Output' tab may become invalid. The removal of a parameter may also cause errors in the calculation, if the process has been defined with 'User Defined Functions', and the variable name has been used in the functions for the specification of the process.

Using Function Terms to Determine Net Parameter Values: If the value of the parameter is dependent on other parameters, a function term can be entered for the parameter in the "Function" field. The function term will be assessed and the value be shown in the "Coefficient" field. All valid expressions and operators can be used to define the function term. See Annex E for a comprehensive list of valid expressions.

Examples for function terms used to define a parameter value:

```
DIST1      Distance1        250   km
DIST2      Distance2        550   km
LOAD1      Average Load1    40    %
LOAD2      Average Load2    60    %
WLOAD      Weighted Load    430   km    DIST1*LOAD1/100+DIST2*LOAD2/100
```

In the above example, the net parameters DIST1, DIST2, LOAD1, LOAD2 are set manually by the user. The value for net parameter WLOAD is determined from the other values using the function term shown.

Live Links to Net Parameters: Net parameter values can also be fed from an external data source via a Live Link. A reference to a cell in an Excel spreadsheet file is created and linked to the coefficient. An update of the value in the source file leads to an update of the net parameter value.

To establish a Live Link, copy the value of a cell and paste it on the line of the parameter table. A coloured icon signals that this value is fed via a Live Link. In case the icon is shown in grey the data source file is closed and values will only be updated when it is next opened, or when the update is triggered manually.

Note that entering a net parameter value manually or adding a function for the calculation of the net parameter will overwrite an existing Live Link reference.

To paste a Live Link use the command 'Paste Live Link' from the context menu of the parameter. To delete a Live Link that has been created for a parameter mark the entry on the 'Parameter' page, then use the command 'Remove Live Link' from the context menu.

13.6 Allocation on System Level

In chapter 10.3 allocation in multi-output processes (processes that deliver more than one product or service are described. Expenses must be shared between the products and co-products using allocation factors. Allocation is also an issue on the system level, i.e. if the whole life cycle model has more than one product or service as output. This case is very common especially when materials used in the production process are being recycled, if the product itself or parts thereof can be reused or recycled in the end-of-life phase, and/or if there are real by-products that appear in the life cycle model as outputs, which are lead to other markets.

As explained in section 10.3 products are being identified as entries on the output side of a process having a green material type ("Good"). Flows on the input side of a process that have a red material type are also identified as products (e.g. waste being accepted by a waste incinerator).

In case the benefit or the product function has been fulfilled in the use phase of the product life cycle and the product has turned into a "waste" at that stage, a virtual reference flow with a green material type ("Good") should be modelled. Please see section 10.1 for details.

The inventory of the life cycle model will show the product either as a flow with a green material type on the output side or a flow with a red material type on the input side. It is recommended to view the inventory results in the "By Compartments" view, because flows that are not elementary exchanges are shown in a separate group at the top of the inventory. The LCIA results will also sport all products of the life cycle model and present the associated environmental impacts for all of them.

Allocation on the system level hence is a method of handling multiple product outputs of a system, typically by-products of the actual product life cycle, or recycled materials.

One possibility to handle by-products or recycled materials is the cut-off approach. In this case these material flows are not further considered in the model. In most cases however, especially if the by-products or recycled materials are actually fed back into other markets (such as off-heat being used for electricity production fed back to the grid, or packaging cardboard being collected and led back to serve as an input to the production of new paper products), the common way of handling this issue is through allocation on the system level. Either the system is expanded to account for the additional products (System Expansion), or an avoided burden system is modelled and its environmental impacts are subtracted from the environmental impacts of the actual product life cycle. This is referred to as a "credit" for avoided burdens (System Expansion with Avoided Burden Credit).

At present there is no "automatic" feature for system expansion and/or avoided burden credits. The LCA practitioner can model an avoided burden system in the same model in a separate section, and then either transfer the quantity of the by-product/recycled material as a negative manual flow to this avoided burden system.
For the avoided burden it should be considered, whether the by-product or recycled material actually displaces the production of a material from other production paths, and whether it is functionally equivalent.

A substitution factor can be introduced if the functional equivalence is not given. Also, should additional processing steps be required (such as recycling processes, transports) to upgrade the by-product or material for recycling in order to reach functional equivalence these should be modelled explicitly and the expense shared between the two models ("Shared Burden Approach")

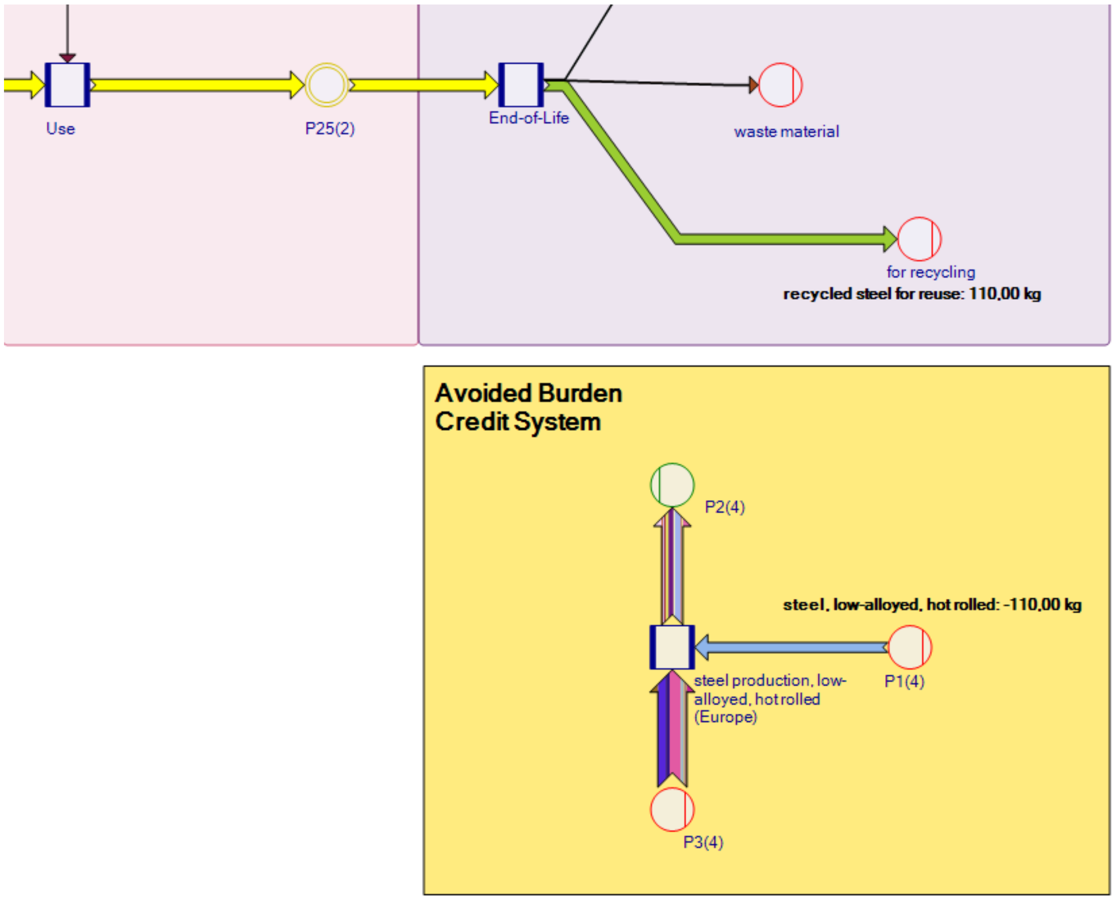


Figure 102: Avoided burden credit system modelled below the product life cycle. The output flow 'recycled steel for reuse' (110 kg) is transferred as manual flow with a negative quantity to the avoided burden system (-110 kg) where it replaces the production of the same amount of 'steel low-alloyed, hot rolled'.

After the calculation of the models the inventories show the gross inventory for the actual product life cycle and the inventory of the avoided burden credit system separately. In the LCIA Results the avoided environmental impacts are shown as negative bars.

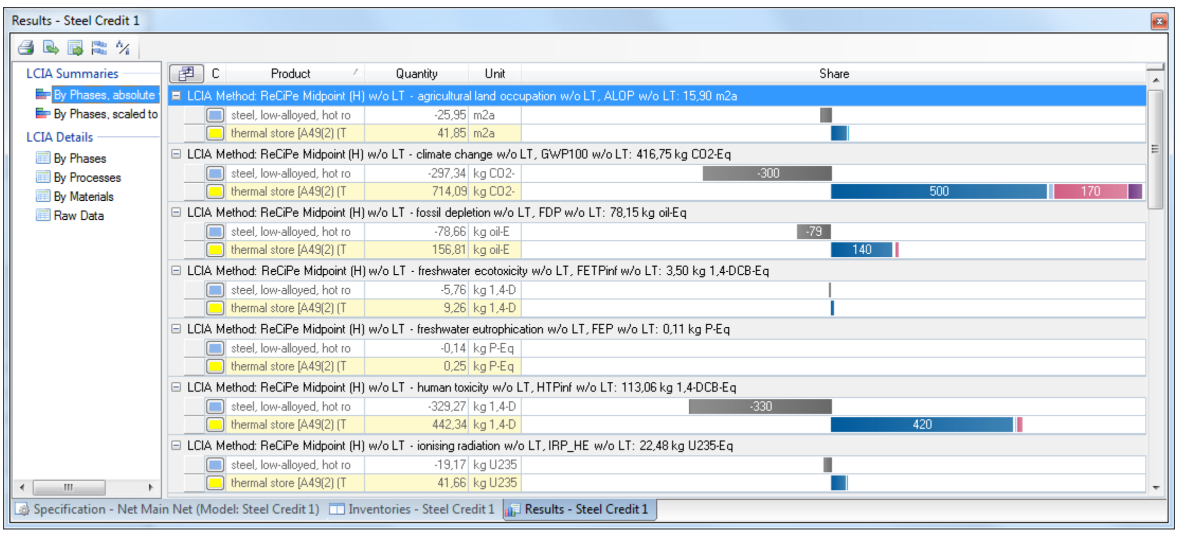


Figure 103: Results view with credits for avoided burden for each selected impact category as negative bars. Absolute values for the gross, the credit and the net impacts.

Depending on the approach for handling allocation on the system level chosen for the LCA study, Umberto allows different modelling approaches. Please refer to literature on LCA for further details.

13.7 System Models

This section is mainly applicable to ecoinvent v3 data that is available based on different system models. In ecoinvent v2.2 no different system models were available to choose from.

The term "system model" in Life Cycle Assessment may refer to the life cycle model (the modelled product system) itself or to a set of assumptions made in regard to the handling of allocation and system expansion.

Typically in activity datasets, they are analysed "as stand-alone datasets, each representing a specific human activity (...). No specific model has been described to explain how these stand-alone datasets can be combined into contiguous, isolated product systems (life cycles). Since practically all human activities influence and link to each other, isolated product systems do not exist 'in real life'. They are artificial thought constructs that isolate some human activities from the rest, and define these as a product system, related to one specific product. It is the purpose of system models to provide rules for linking the activity datasets into contiguous product systems, each one isolated from all other product systems." [ecoinvent Data Quality Guidelines, p. 27/28].

The ecoinvent v3 activity data is provided in variants (i.e. calculated based on different system models) and the user can choose the version of the datasets which are in line with his or her requirements and specific modelling context. Some system models are not used in Life Cycle Assessment, but target other application fields.

This section is intended to be a summary of these system models and aims at supporting the practitioner's choice for one specific system model. The choice should be made at the beginning of the study and it is recommended that it is maintained for all activity datasets used in the model.

"Two classes of system models are distinguished: System models with partitioning (allocation) and system models with substitution (system expansion)." [ecoinvent Data Quality Guidelines, p. 133].

Umberto LCA+ is shipped with datasets from the following three system models:

- Substitution, consequential, long-term
- Allocation, at point of substitution (APOS)
- Allocation, cut-off by classification

The system model "Allocation, cut-off by classification" was re-introduced again with version ecoinvent v3.01. It has been the approach used in ecoinvent v1 and v2. The ecoinvent Centre recommends useimg data from this system model for users new to LCA.

13.8 Creating own Elementary Exchanges

In chapter 6.4 it was mentioned, that it is not very common in a typical LCA to use other elementary exchanges and characterization factors than the ones provided in the published LCIA methods.

The advanced LCA practitioner might, however, feel the need to create new, own elementary exchanges and supplement them with impact factors. There might have been new scientific findings, which have not yet been taken up by the sources and providers of impact assessment methods, it might simply be an error detected in the published LCIA methods that is shipped by ecoinvent.

New elementary exchanges can be defined just as any other exchange in a project. A value for the impact assessment factors can be set. At present it is not possible to define a new LCIA factor name or group (this will only be provided in one of the next releases).

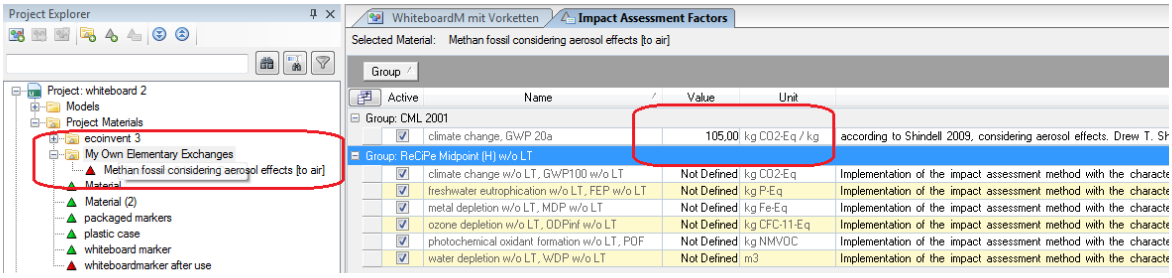


Figure 104: Creating new Elementary Exchanges and supplementing them with characterization factors

Note that the new substance or the elementary flow with a modified characterization factor value contributing to an environmental impact must be supplemented to the processes in the model. When using several activities from the ecoinvent database as background data, the new elementary exchange would have to be supplemented to all of them with the appropriate quantity.

14 Live Link to Excel

With this feature a "live" connection from one or more Excel spreadsheets to elements in an Umberto model can be established. When changes are made in the spreadsheets connected to the Umberto model, it can be updated (automatically or manually). The next calculation of the model will then be performed using the new values.

Live Links are currently supported for:

- Process flow coefficients (input and output side), see section 8.1
- Arrow flow specification, see section 7.4
- Place begin quantity specification, see section 7.3
- Process parameters, see section 13.3
- Net parameters, see section 13.5

Live Links to Excel can only be created for existing coefficients. Creating new flow coefficients or parameters directly with this feature is not possible. The Live Link to Excel works for the following versions of Microsoft Excel: Excel XP (2002), Excel 2003, Excel 2007, Excel 2010 and Excel 2013.

Live Link for Numeric Values: The Live Link dynamically links the coefficient value (process specification flow coefficient, process parameter value, net parameter value, etc.) in an Umberto model to a cell in an Excel spreadsheet. When the user changes the value in the cell of the Excel sheet, the value in the model will be updated automatically. The subsequent model calculation will result in new values and reflect the updated data.

Mind that changes made in the data source (Excel spreadsheet) file may also lead to a model that yields errors during the calculation due to the modified values. This is especially dangerous, if the Excel spreadsheet file is accessible to other persons for editing, that are not aware that the Umberto models draw their values via Live Links from these files

Establishing Live Link: A Live Link is created by copying a cell value in Excel ('Ctrl-C') and pasting it ('Ctrl-V') in the "Quantity" field of an input or output flow entry in a process specification (or any other target field). Alternatively paste the copied cell address using the command 'Paste Live Link' from the context menu of the "Quantity" column.

A Live Link reference to the address of the cell in the spreadsheet will be created. An icon is shown, in the field to indicate the existence and status of the Live Link.

It is required to save the Excel spreadsheet file at least once so that the file name and path are available, before the Live Link can be created. Freshly created and still unsaved files will not allow creating Live Links.

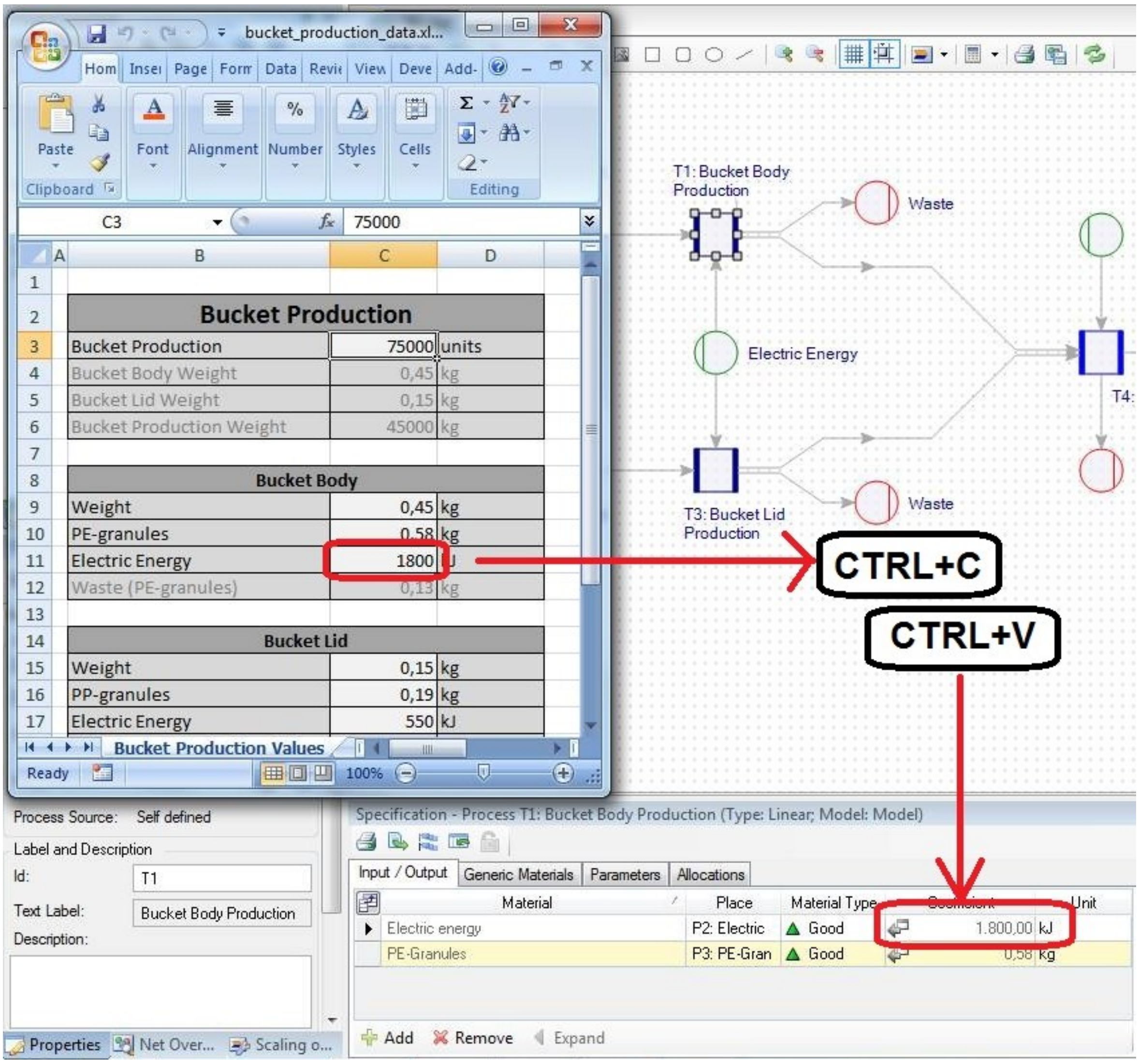


Figure 105: Copy the cell value in Excel. Select the target element in the Umberto model. In the specification area paste it into the 'Coefficient' column.

Note that there can be multiple Live Links from one or more Excel worksheet(s) in one or more Excel file(s) into one or more models in an Umberto project.

The Excel files can also be located on a shared network drive so that other users can update the values. When handing over an Umberto project file (.umberto file) to another user, make sure that the data source file to which there are Live Link references are also shared to keep the Live Link operational.

Note that the Live Link references only the value of the cell content, so that the cell in Excel may also contain a formula or a currency sign (e.g. "1.000 $").

Update of Live Links: When an Umberto model that contains Live Links is opened, the user is prompted with a dialog box and asked whether the Live Links should be updated.

Live Links can also be updated at any time using the commend 'Update Live Links' (menu 'Tools' > command 'Update Live Link') or by clicking on the 'Update Live Links' button in the main tool bar.

If the Excel file is kept open for editing, any changes made to the Excel file will lead to an update of the linked coefficient or parameter value in the Umberto model. However, the new model results (LCI and LCIA results) will only be determined in the calculation of the model.

Editing Live Links: An overview of all Live Links can be seen in the 'Edit Live Links' dialog (menu 'Tools' > command 'Live Links…'). Note that this command in the Edit menu is only active after the first Live Link has been set, otherwise it appears greyed (inactive).

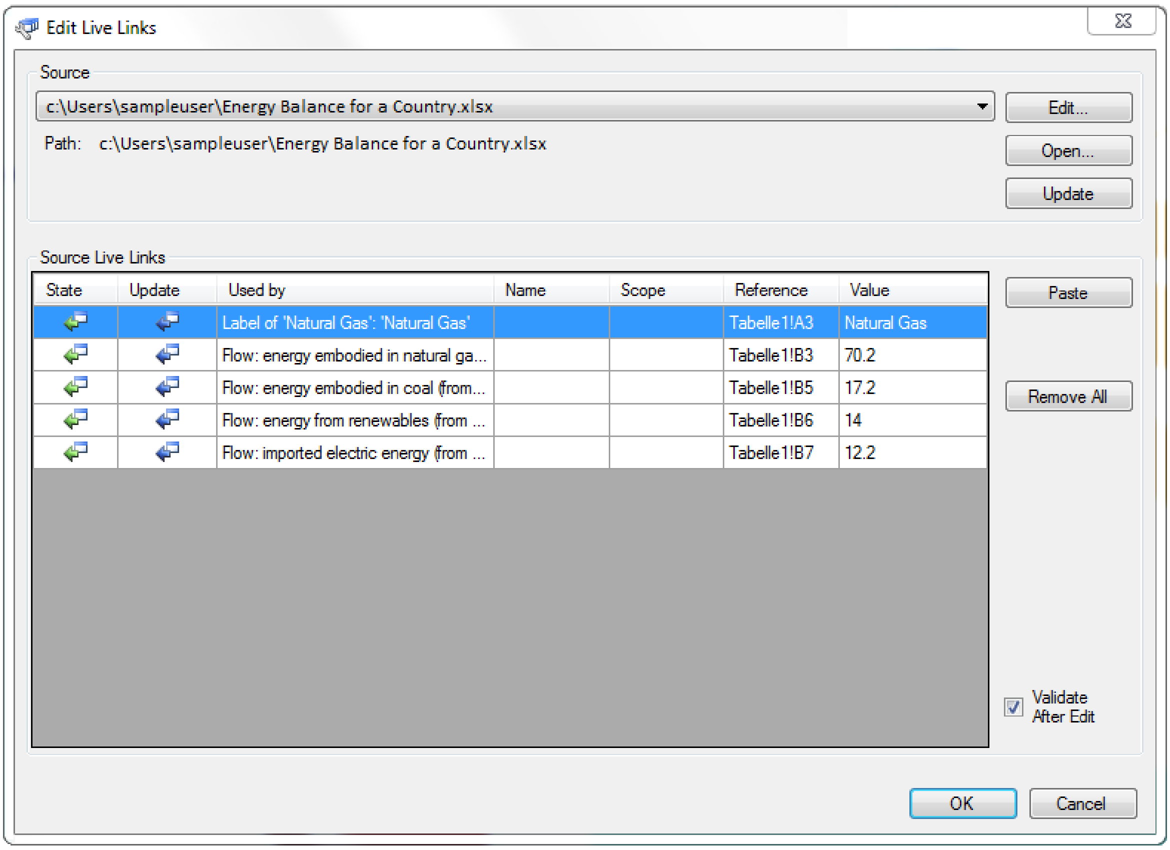


Figure 106: Edit Live Links dialog shows Excel files and cells to which Live Links have been set

The name of the source Excel file is shown in a selection list in the panel 'Source' at the top. The path to the location of the file is shown below the list. To modify the source Excel file click on the button 'Edit…'. To open the connected Excel file click on 'Open…'.

For the Excel file selected in the dropdown list 'Source' above, all existing Live Links are shown in the 'Source Live Links' table below. Switch between the different source files to see the respective Live Link references in the table.

Each Live Link entry can also be directly edited in this table: A Live Link reference can be pasted directly in one selected line (as an alternative to pasting it into the flow table in the Properties dialog of an arrow as described above).

In case the Live Link is to a cell address, this address (e.g. "Table1!A15") is shown in the column 'Reference'. Should the reference be into a named cell (see below), this is shown in the columns 'Name' and 'Scope' (i.e. the name of the worksheet).

Using Named Cell Areas in Excel to Maintain Live Links to Cells: When a Live Link is created to a cell in an Excel sheet, the reference is by default made to the cell ID (e.g. "C1"). However, if the spreadsheet layout is changed, the location of the cell with the value that is linked to the diagram might be shifted. This happens, for example, when columns or lines are inserted.

In order to maintain the Live Links even when the location of the original cell changes, it is necessary to work with named cells.

Before you create the Live Link as described above, name the cell in Excel[6]. Names must start with a letter and must not contain spaces.

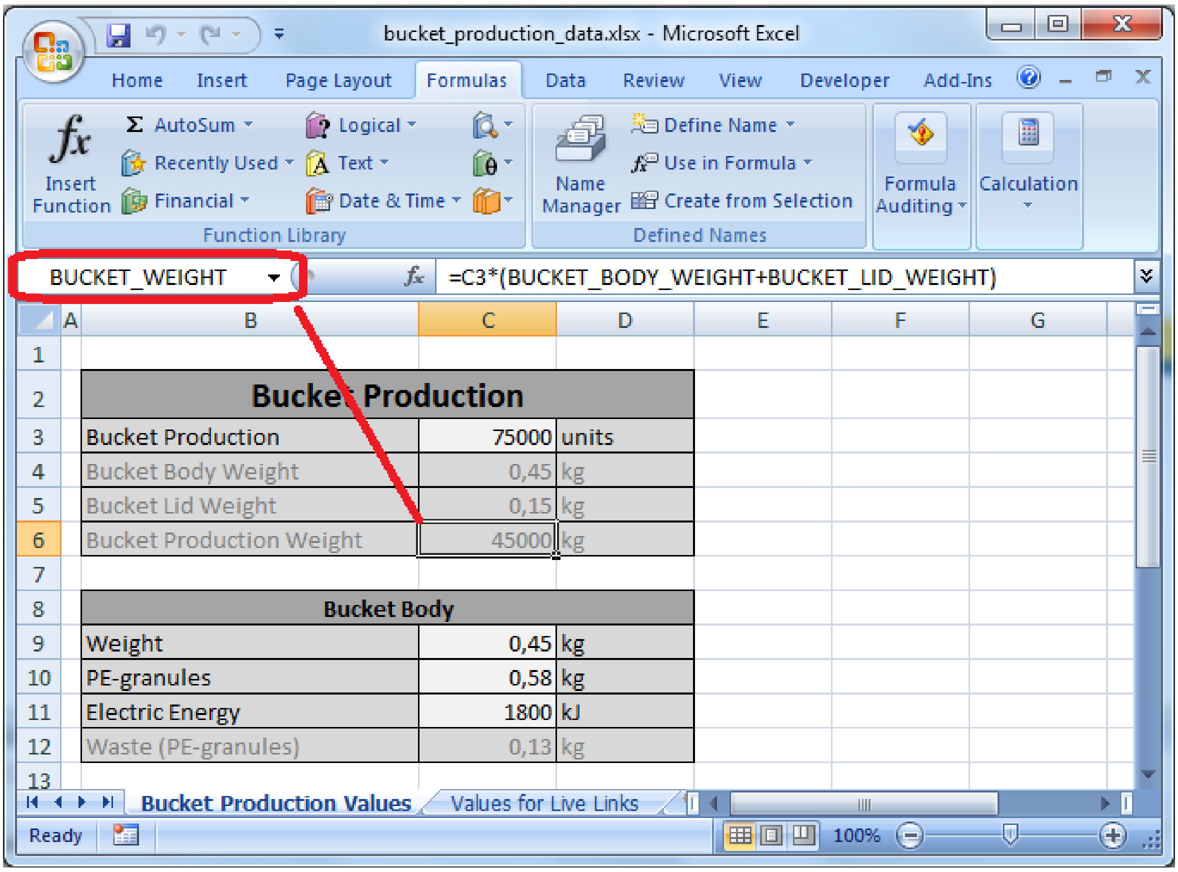


Figure 107: Named cell in Microsoft Excel 2007. For cell C6 the name 'BUCKET_WEIGHT' has been defined.

When a Live Link is created from a value in a named cell, it will use the name of the cell instead of the direct cell address ID. The named cell can be located

[6] In Excel 2003: Menu Insert > Names > Define. In Excel 2007 and Excel 2010: Menu Formulas > Define Names or context menu of selected cell > Name a Range > New Name).

anywhere in the Excel sheet, even when it is moved. When the value in the named cell is updated, the Live Link will still work even though it might have a different location.

The cell name is shown in the "Edit Live Link" table in the "Reference" column.

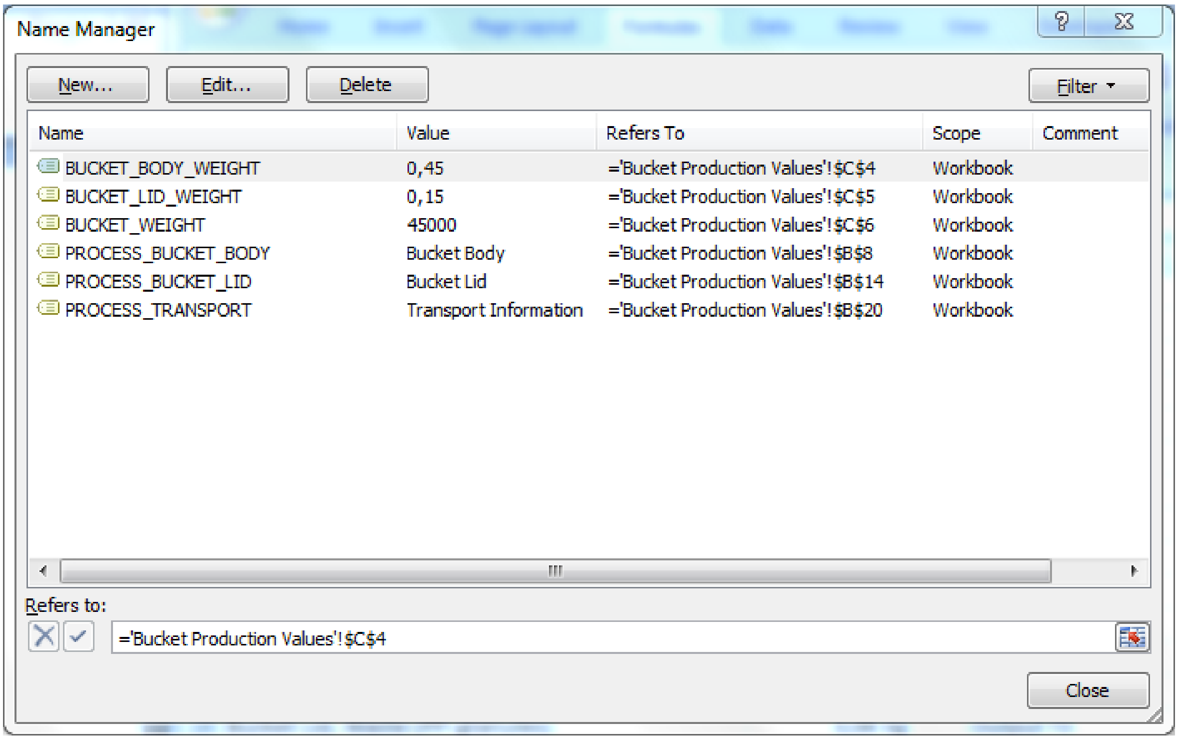


Figure 108: Microsoft Excel 2007 Name Manager also shows the named cells, their current value and the cell it references.

There are speedier and more robust solutions than Live Link references and Excel as data source for import of data. ifu Hamburg GmbH can provide customized solutions for reliable data import to Umberto. Please inquire.

15 Material Flow Analysis (MFA) and Material Flow Cost Accounting (MFCA)

The information is intended as a short introductory summary on Material Flow Analysis (MFA). It is not thought to replace publications on how to do a MFA or energy efficiency study.

The chapter on Material Flow Cost Accounting (MFCA) is a condensed summary of this relatively new field. As scientific research continues and many new practical MFCA studies are being conducted, we strongly advise to consult additional publications.

15.1 Introduction to MFA

Material Flow Analysis (MFA) is the quantitative study of physical flows (mainly mass and energy flows) within a defined system. It is sometimes also referred to as Material and Energy Flow Analysis (MEFA), or Material Flow Management.

The scope of the system under study can be a single process, a system of processes (such as a production line), an entire production facility, a company, or even a number of companies linked by the exchange of material, components or semi-finished products (supply chain, industrial park). On a regional or national level Material Flow Analysis is used to analyse and describe the metabolism of certain physical flows. For further information please refer to the publications listed below.

Note that in this user manual, the term MFA is used primarily for the quantitative material flow analysis on a company level rather than to what is referred to as Substance Flow Analysis (SFA) or Material Flow Accounting on a national level.

Motivation to do a material flow analysis study is often driven by the wish to optimize the system in regard to consumption of material and energy resources, in regard to emissions and waste. This can be done by implementing more efficient processes, by recovering material and energy, by closing loops. In other words, material flow analysis strives to improve a production system, making it more efficient and yield the same or more output (products) with less material and energy consumption, and with less emissions and waste, hence reducing the systems impact on the natural environment.

To optimize a material flow system (whatever the scope of the system is), it is first required to fully understand the material and energy flows that exist in the system. A holistic view of the system and understanding of interactions between the processes is required, in order to be able to modify the system in such a way that measures to be implemented improve its overall impact.

One possibility to achieve such an optimization of a production system is by installing measurement and control devices and measuring all flows and consumption. This is a costly approach, and often fails to support the systematic overview. Therefore material flow analysis in Umberto relies on modelling of production systems in order to determine material and energy flows in the system. Rather that measuring the actual flows, a model of the system is created that represents the production system. If all processes are described accurately how their inputs are transformed to outputs, then with one given known flow (e.g. the annual production volume) it should be possible to determine all other material and energy input flows that were consumed in order to produce, and all output flows that were released from the system along the production process. Additionally, all flows within the production system itself, i.e. the interchange of materials, components or semi-finished products between two subsequent processing steps can be calculated.

Umberto uses the modelling approach with the so-called material flow models. In the material flow models, transformation of material and energy occurs at processes. Material and energy flows along the arrows from one process to the next process(es). So-called places constitute the system boundaries, either as sources (input to the system from a surrounding market) or as sinks (output from the system to a surrounding market).

These elements of material flow networks are the toolset in Umberto to model any kind of process system from a single process to a complex production system.

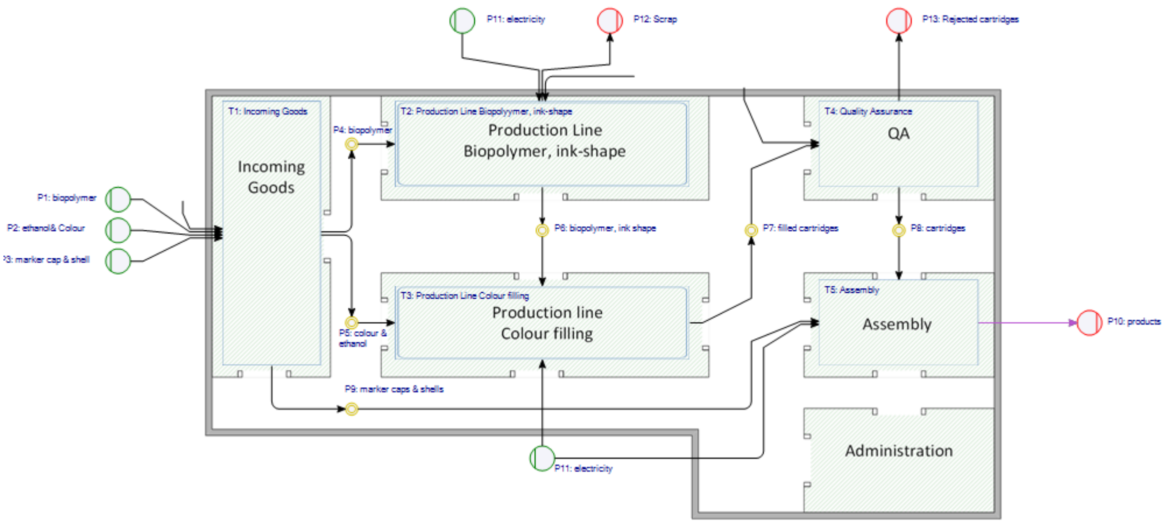


Figure 109: The model of the production system is the basis for determining all flows and analyse improvement measures in regard to material and energy consumption and reducing emissions.

The material flow analysis can focus on one or a few specific substances or materials (e.g. analysis of heavy metals in waste streams, quantification of solvents in a production system), or can include all mass of the system under study. In the latter case the goal is to establish the mass balance. When the focus is on energy, the energy balance can be a goal. The scope of materials under study depends on the goal set forth for the MFA study.

Typically, a material flow analysis study starts out by describing the current situation of the system ("As Is" model). Once the model has been checked and "calibrated" if its calculation results correspond to the actual situation, one can continue to run different variations of the baseline scenario. These can be done on the same model by modifying certain parameters (parameter variation), or on modified models (alternative "What If" scenarios). Hence it is possible to do material flow calculations for planned scenarios, and analyse whether planned implementation of changes or measures in the system actually lead to improvement or optimization in regard to the environmental impact.

Additionally, a costing component allows linking the physical flows in the production system model to costs. The production engineer hence can analyse what costs incur in the targeted reduction of material and energy consumption, or the reduction of waste output, and how the implementation of changes in a production system leads to a an increase of costs or a reduction of costs in a mid-term.

Material Flow Analysis (MFA) creates a transparent knowledge of material and energy flow in a production system. It gives a holistic and systematic view of the system under study and allows understanding the overall reaction of the system on changes made. It further supports "playing" with the model to understand modifications and study alternatives. MFA links physical flows in a production system to the costs, thus giving a better basis for decision making.

15.2 Suggested Reading on MFA

Chemical Engineering & Technology. Special Issue: Material and Energy Flow Analysis (April 2010). Volume 33, Issue 4. Pages 539–703.

Möller, A.: Grundlagen stoffstrombasierter betrieblicher Umweltinformations-systeme. Dissertation [in German]: Projekt Verlag, Bochum, 2000

Möller, A., Rolf, A., Page, B., Wohlgemuth, V.: Foundations and Applications of Computer Based Material Flow Networks for Environmental Management. In: Rautenstrauch, C., Patig, S. (Eds.): Environmental Information Systems in Industry and Public Administration, Hershey, London, 2001, S. 379-396.

Page, B., Wohlgemuth, V.: Linking Economic Optimisation and Simulation Models to Environmental Material Flow Networks for Ecoefficiency. In: L.M. Hilty, E.K. Seifert, R. Treibert (Eds.): Information Systems for Sustainable Development. Idea Group Publ., Hershey, 2004, pp. 94-108.

Wikipedia Article on 'Material Flow Analysis' http://en.wikipedia.org/wiki/Material_flow_analysis (accessed September 03, 2015)

Wikipedia Article on 'Material Flow Accounting' https://en.wikipedia.org/wiki/Material_flow_accounting (accessed September 03, 2015)

15.3 Introduction to MFCA

Based on the material and energy flow modelling described above in the section on MFA, it is possible to do a material flow cost accounting (MFCA). Material Flow Cost Accounting (MFCA) is an instrument to identify and calculate the real cost of waste and material losses. It can be an important element in tackling corporate resource efficiency.

Material Flow Cost Accounting (MFCA) is "a management tool that can assist organizations to better understand the potential environmental and financial consequences of their material and energy use practices" (ISO 14051). It is based on the observation that losses and rejects in a production system – and the costs associated with them - are often not considered adequately in conventional management cost accounting. MFCA is therefore proposed as an additional, alternative perspective on costs. Rather than only looking at the costs of the product, MFCA also looks at the cost of losses and rejects (waste). By doing so, management can take into account these financial losses and work on reducing these them.

ISO 14051:2011 Environmental management -- Material flow cost accounting -- General framework is the guiding document and provides a framework for material flow cost accounting (MFCA).

The International Organization for Standardization (ISO) published the ISO 14051:2011 to offer a general framework for Material Flow Cost Accounting (MFCA).

The standard assists companies with the implementation steps of MFCA including the development of a material and energy flow model for the quantification of material, energy, system and waste management costs, the communication of the MFCA results and the identification of improvement opportunities.

ISO 14052/CD is currently (Sept 2015) at the 'committee draft' stage. If going ahead, the standard will extend ISO 14051 to provide 'Guidance for practical implementation in a supply chain'.

Typically an MFCA is performed for a defined group of production processes. This can be a single process, a production line, or the entire production facility. Before starting a material flow accounting project it is required to define the boundary of the system under study. Furthermore, the ISO standard advises to clarify the time period, for which the data is collected and the MFCA is done.

In material flow cost accounting a process and storages are referred to as "Quantity Centre" (QC). It is an "area where materials are stocked and/or transformed" and for which physical material and energy flow inputs and outputs have to be quantified. Additionally material costs, energy costs and system costs are quantified per quantity centre.

Although the MFCA standard has a slightly different terminology, the material flow modelling, as described above in section 15.1 is an ideal basis to be extended and run a material flow cost accounting (MFCA).

Material balances are set up for each quantity centre in the model. They form the basis for calculation of costs per quantity centre.

The physical material and energy flows in a production process are used to produce a good, a product (or several products). A part of the material and energy also ends up as loss or reject (waste). In order to understand these losses better, in each quantity centre inputs and outputs are accounted for. Additionally the material and energy losses are systematically quantified in each quantity centre.

Allocation of material and energy flow inputs to the product outputs and to the losses in each quantity centre are by mass (physical allocation). This is referred to in the MFCA standard as material distribution percentage.

Since storages are also considered as quantity centres, inventories and inventory changes within the accounting period can be consistently considered in an MFCA. Mind that a material balance at a quantity centre does not necessarily have to be balanced, since inputs into the quantity centre during the period for which the material flows are accounted may have increased the inventory, and/or outputs from the quantity centre as product or material loss may be explained with reduction of an inventory stock.

Process specifications in the Umberto material flow models are the equivalent of the material balance in a quantity centres. Inventory changes are consistently considered in storage places. By inserting the materials into pre-defined material groups and automatically using the adequate material types for material entries depending on their role, the requirements of the material flow cost accounting as set out in the ISO 14051 standard are fully covered.

The cost calculation used in material flow cost accounting aims to provide an additional perspective on costs, not on replacing conventional cost accounting established in most companies.

The direct cost for purchased material and energy that does not find its way into the actual product is typically not accounted for separately in conventional cost accounting. Costs for waste management are either associated the product cost, or are accounted for in the overhead costs

By focusing on the costs for material losses, the inefficiencies of the production process become quantifiable and attention is drawn to those losses.

In MFCA, costs are accounted for in a systematic way, by distinguishing four different account types:

- material costs
- energy costs
- system costs (e.g. labour, depreciation, maintenance, transport)
- waste management costs

In each quantity centre these four cost types should be considered. The calculation of material costs is described in Annex B, clause B1 of ISO 14.051

Check ISO 14051 section 5.3 on cost calculation to understand the specific cost accounting approach used for MFCA.
Annex A (informative) of the standard describes the "Difference between MFCA and conventional cost accounting".
The calculation of material costs is described in Annex B, clause B.2.2 of ISO 14051
The calculation of material costs for intermediate products is described in Annex B, clause B.2.3 of ISO 14051
Cost allocation is explained in Annex B, clause B.3 of the standard.

When setting up the material flow model in Umberto, calculation of the MFCA is done automatically, taking into account the above-mentioned material losses and the cost type groups.

Results can be viewed in the MFCA perspective and in the conventional cost accounting perspective. The material flow cost matrix for each single quantity centre can be viewed, as well as for the entire system (as shown in Table B.6 in Annex B.4 of the ISO 14051).

Taking advantage of the integrated Sankey diagram capabilities of the Umberto product range, in addition a cost Sankey diagram can be presented.

ISO 14051 describes in its last chapter the implementation steps for MFCA. Like with other management tools it requires the involvement of management and a level of expertise of the staff involved.

The results of an MFCA are recommended to be presented in an adequate way, such as in a material flow cost matrix. They are the basis for communication of the stakeholders, most likely the staff and the management of the company.

Assessment of the results can lead to identification of improvement opportunities. Measures will be developed to improve the overall production system in regard to minimizing material and energy losses.

Using the material flow model as a basis a systematic and holistic approach is ensured, that will lead to overall reduction of material and energy consumption and reduced losses.

15.4 Suggested Reading on MFCA

Asian Productivity Organization: Manual on Material Flow Cost Accounting: ISO 14051 (2014). Available online at http://www.apo-tokyo.org/publications/wp-content/uploads/sites/5/Manual_on_Material_Flow_Cost_Accounting_ISO14051-2014.pdf (accessed September 03, 2015).

Hyršlová, J.; Vágner, M.; Palásek, J. 2011. Material Flow Cost Accounting (MFCA) – tool for the optimization of corporate production processes. Business, Management and Education 9(1): 5–18. doi:10.3846/bme.2011.01

ISO 14051:2011 Environmental management -- Material flow cost accounting -- General framework

Kokubu, K.; Kos Silveira Campos, M.; Furukawa, Y.; Tachikawa, H.: Material flow cost accounting with ISO 14051.

Kokubu, K.; Kitada, H.: Material flow cost accounting and existing management perspectives. In: Journal of Cleaner Production, Volume in print (2014)

Material Flow Cost Accounting: MFCA Case Examples. Tokyo 2011. Available online http://www.jmac.co.jp/mfca/thinking/data/MFCA_Case_example_e.pdf (accessed September 03, 2015).

Schaltegger, S.; Zvezdov, D.: Expanding material flow cost accounting. Framework, review and potentials. In: Journal of Cleaner Production, Volume in print (2014)

Schmidt, A.; Hache, B.; Herold, F.; Götze, U.: Material Flow Cost Accounting with Umberto

Schmidt, M.: The interpretation and extension of Material Flow Cost Accounting (MFCA) in the context of environmental material flow analysis. In: Journal of Cleaner Production, Volume in print (2014)

Schmidt, M.; Nakajima, M.: Material Flow Cost Accounting as an Approach to Improve Resource Efficiency in Manufacturing Companies. In Resources 2013, 2, pp. 358-369; doi:10.3390/resources2030358. Open access article available online http://www.mdpi.com/2079-9276/2/3/358 (accessed September 03, 2015)

Wikipedia Article on 'Material Flow Cost Accounting' https://en.wikipedia.org/wiki/Material_Flow_Cost_Accounting (accessed September 03, 2015)

Additional bibliography can be found on the last two pages (after Annex C) in the ISO 14051 standard.

16 Costs

Both versions of Umberto, Umberto LCA+ and Umberto Efficiency+ include a managerial cost accounting feature. It allows calculation of costs based on the calculated materials and energy flows (material direct costs) and other costs that incur in cost centers i.e. processes (process costs). Fixed costs can also be handled. In addition it supports a material flow cost accounting (MFCA) perspective according to ISO 14051.

Users wishing to only do a classic Life Cycle Assessment (LCA) may ignore this chapter, if they are not interested in costs.

16.1 Material Direct Costs

The primary objective of modelling production systems is to determine the physical flows (mass, energy, ...) that enter and leave the production system and that flow between the processes. This is done using the process specifications and one or more given flows to eventually determine all other flows.

Once the physical flows in the production system have been calculated, it is just a small step to link the flow quantities to the prices for a flow, in order to obtain the material direct costs. Material direct costs are calculated by multiplying the price for one unit of material or product with the quantity of the material or product. Material direct costs are considered variable costs.

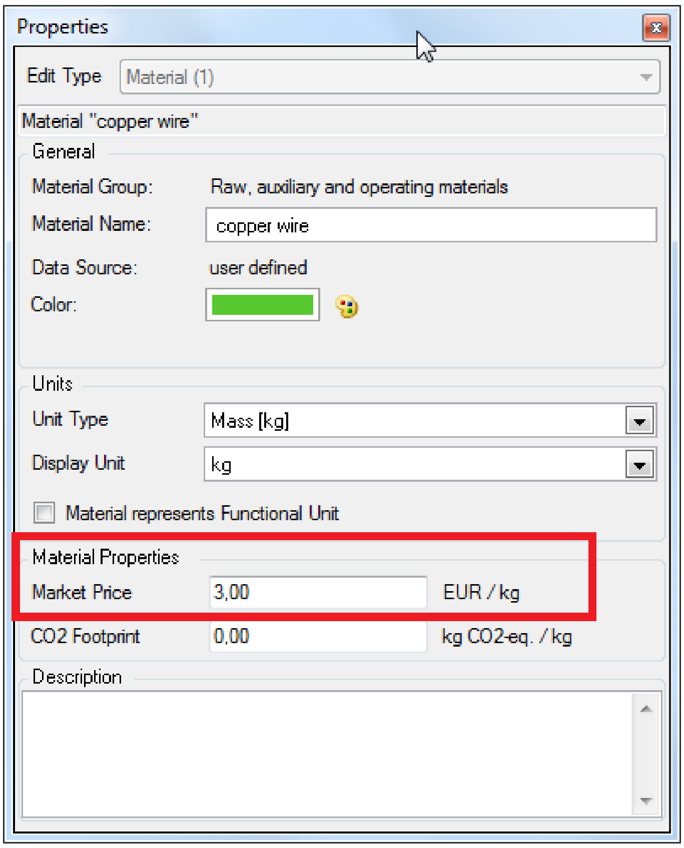


Figure 110: Market price is defined for a material in the properties panel.

Material direct costs are managed in the properties dialog for each material.

Note that by default materials do not have a pre-defined value for market price or disposal costs. The default is "0.00".

Note that to be able to have a proper cost accounting for a production system model and all of its products, all goods (items flowing on an arrow that crosses the system boundary as an input) and emissions/wastes that have to be paid for (items flowing on an arrow that crosses the system boundary as an output) and all final products (items flowing on an arrow that crosses the system boundary as an output to the market) should have a price tag assigned.

Define/Modify Market Price: Material entries in the groups "Raw, auxiliary, and operating materials", "Energy", "Intermediate goods" and "Products" do have a market price. Enter or modify the market price for a material simply by typing a price in the "Market Price" field.

Define/Modify Disposal Costs: Similarly, for material entries in the groups "Unavoidable Waste" and "Emissions" enter or modify the disposal costs for a material entry by typing a price in the "Disposal Costs" field. The value can be "0.00" if the material (e.g. a gaseous emission) can be released to the environment without causing a particular cost.

The currency unit is the project currency unit defined and the price relates to one display unit of the material.

Live Link to Market Price or Disposal Costs: The market price for material entries in the groups "Raw, auxiliary, and operating materials", "Energy", "Intermediate goods" and "Products" and the disposal costs for material entries defined in the groups "Unavoidable Waste" and "Emissions" can be fed from an external Excel sheet using the Live Link feature.

For a general description of the Live Link please see section 14 of this user manual

To create a Live Link for a market price (or a disposal cost) for a material entry, copy the value from an Excel workbook, right mouse-click in the 'Market Price' (or 'Disposal Costs' field) of the material entry, then select 'Paste Live Link' from the context menu.

An icon will be shown to indicate that the Live Link has been established. The reference to the cell in Excel will also be featured in the list of Live Links in the "Edit Live Link" window.

A market price (or disposal cost) that is fed by Live Link from Excel cannot be directly overwritten any more. To return to manually defining a market price (or disposal cost) value, you have to remove the Live Link again.

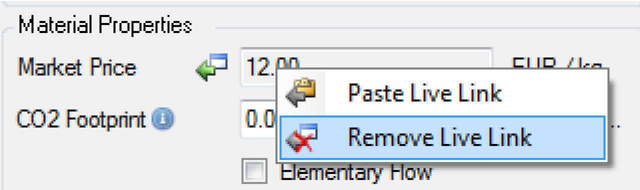


Figure 111: Context menu for market price field in material properties.

To remove an existing Live Link for a market price (or a disposal cost) for a material entry, right mouse-click in the 'Market Price' (or 'Disposal Costs' field) of the material entry, then select 'Remove Live Link' from the context menu.

See section 16.6 for details on use of materials in process specifications and inclusion of material direct costs in the calculation of costs.

16.2 Process Costs / Other Costs

Besides the material direct costs, there are other variable costs that incur in the processes. Such other costs are not directly linked to material consumption, but rather to the activity in a cost center or process. Examples for other costs (non-material direct costs) are: machine maintenance cost, wages, salaries, taxes, fees, etc.

16.3 Cost Type Groups

Other costs are defined as entries under the Cost Types folder in the Project Explorer. A root folder 'Cost Types' is shown under which the pre-defined cost type groups "Energy costs", "System costs" or "Waste management costs" are available.

These cost type group names are specific to Material Flow Cost Accounting and can be found in ISO 14051 under terms and definitions (3.4., 3.21 and 3.22).

Energy Costs: In this cost type group one can define and manage cost types for electricity, fuels, heat, cooling, or compressed air. Costs can be defined in each process using a cost type from this group.

Note that alternatively, if energy costs are variable, they can also be calculated as material direct costs. The ISO 14051 standard states that "energy cost can be either included under material cost or quantified separately" in this group.

System Costs: Under the system cost cost type group you can define cost types for other costs, such as taxes, depreciation, labour cost, maintenance or transport. The material flow cost accounting standard ISO 14051 considers all cost types that are not "Energy costs", "Material costs" or "Waste management costs" to be in this group

Waste Management Costs: This group can be defined to define cost types for management of waste. This includes costs for handling gaseous emissions, wastewater, solid waste, as well as for waste transport, waste storage and waste recycling activities. The ISO 14051 standard defines waste management costs as "cost of handling material losses generated in a quantity centre".

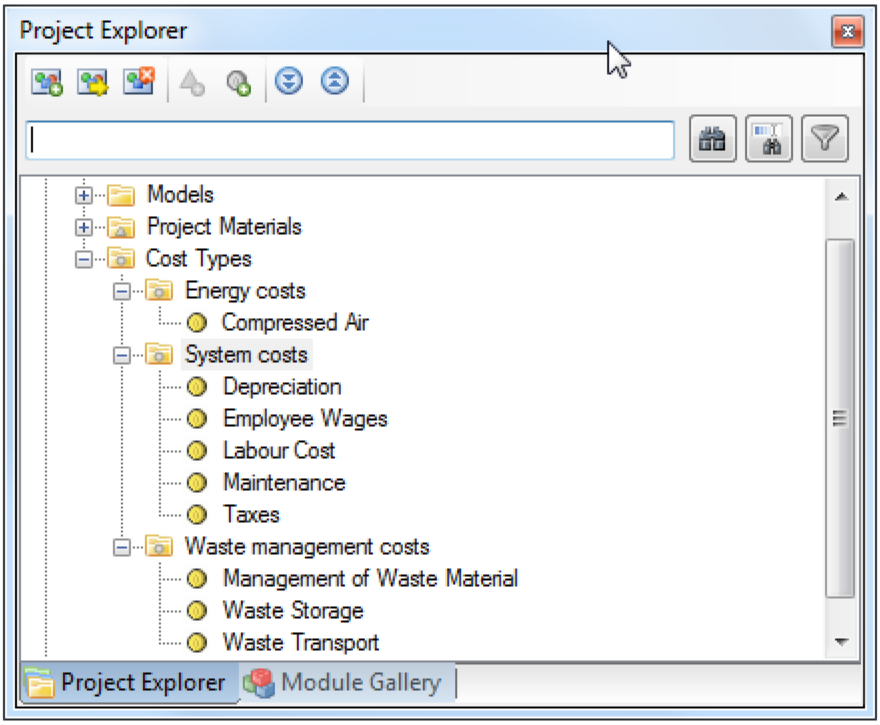


Figure 112: Cost type groups with cost type entries

Calculated cost data is presented in the cost inventory (see section 16.7) broken down into the cost type groups. For each quantity centre the material flow cost matrix shows the respective costs.

16.4 Cost Types

New Cost Type: To create a new cost type mark one of the three cost type groups and click on the button 'New Cost Type'. The cost type will be inserted in the selected group. Alternatively right mouse-click on the cost type group, and choose the command 'New Cost Type' from the context menu.

In the properties window state a name for the cost type. A description may be entered in the field at the bottom.

A color is suggested and can be modified by clicking on the color mark or on the 'Select Color' button. This color is used for display of costs of this type in the cost Sankey diagrams (see section 16.9)

The flag 'Fixed Cost' must remain unmarked, if the cost type is considered a variable cost type. Check the 'Fixed Cost' box, if the cost type should be considered a fixed cost type. Fixed cost types are defined in regard to a time period, typically a year. Variable cost, on the other hand, are defined in relation to a material flow or process throughput. For further details please read in section 16.6 on use of cost types in process specifications. Fixed costs and variable process costs are handled and displayed separately in the cost inventories (see section 16.7). Fixed costs are not displayed in the cost Sankey diagrams (see section 16.9).

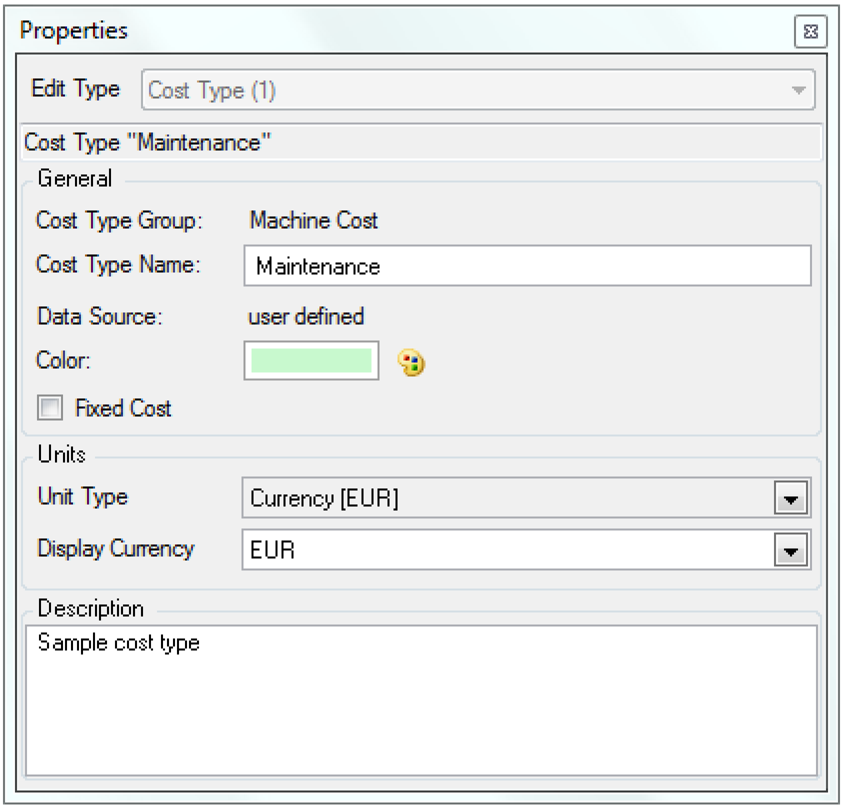


Figure 113: Cost type properties panel

The symbol of the cost type is a coin. The color of the coin symbol is gold for variable cost types and copper for fixed cost types.

The unit type of a cost type is always 'Currency'. The display unit can be modified. However, note that there is no implementation of a currency conversion yet.

Cost Type Properties: Properties of a cost type, such as its name or a description can be edited in the Properties Editor when the group is selected.

Move Cost Type: If you wish to insert a cost type into another cost type group in the hierarchy, just drag&drop the coin symbol onto another cost type group folder.

Delete Cost Type: To delete a cost type, right mouse-click on the cost type entry in the Project Explorer and choose the command 'Delete' from the context menu. Please note that it is not possible to delete a cost type, if it is are already in use in the specification of a process within any of the models in the project.

Using Cost Type in Process Specification: To add a cost type entry to a process specification simply drag the cost type entry from the Project Explorer onto the input side of the "Input/Output" grid of a process specification. Alternatively, drag the cost item directly onto the symbol of a process in the net editor window.

16.5 Cost Accounting in Umberto

Umberto provides two different cost accounting perspectives. One is a conventional cost accounting approach, the other is the specific material flow cost accounting (MFCA) approach described in ISO 14051. These two perspectives are further described in this chapter.

16.5.1 Conventional Cost Accounting

The cost accounting is a typical managerial cost accounting. It is an additional "layer" on top of the "layer" of material and energy flows. This means that it is first required to set up a material flow model that can be calculated and that delivers an overview of input and output flows that represent the exchanges of the process system (production system) with the system surrounding.

System Boundary/Scope: The system surrounding can be considered as the market. For example, if the material flow model represents a company and its production of products, the system surrounding would be the suppliers of the company delivering raw materials, water or energy. The wholesalers to which the product is delivered are across the system boundary on the output side. And, least not forget, companies that pick-up production waste are also in the system surrounding on the output side.

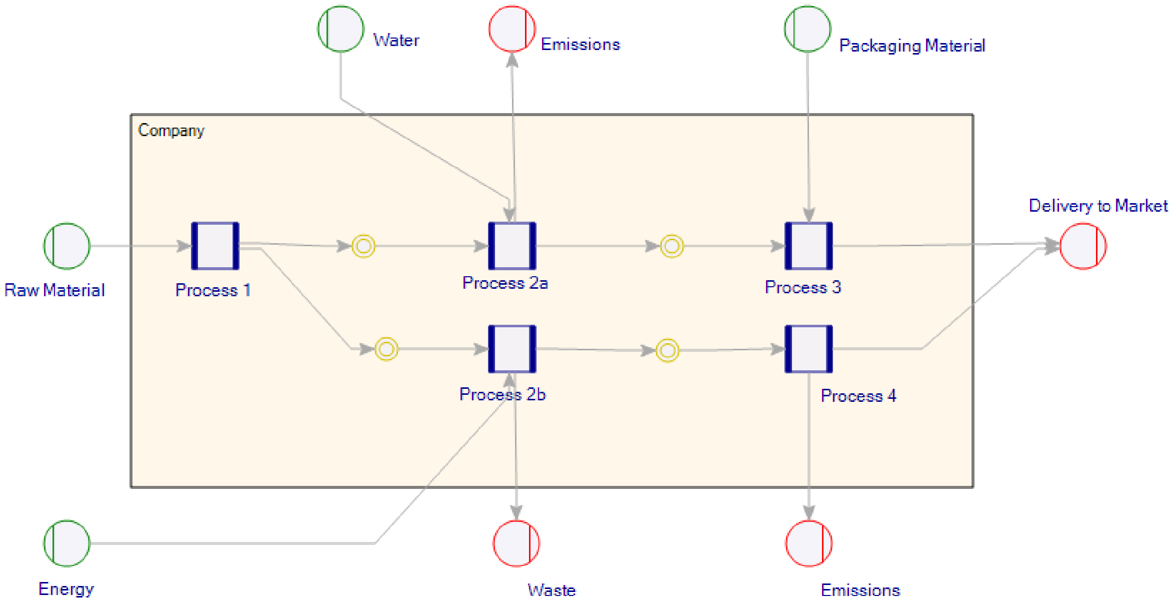


Figure 114: Schematic sample material flow model representing a company with a number of production steps. The input places deliver from outside the system boundary (from the market) to the company. The output places take up product and emission/waste outputs from the system. These input output flows run on arrows that cross the system boundaries.

The flows that run on arrows across the system boundary are the inputs into and outputs from the system. These flows are shown as Input/Output inventory. This inventory is the basis for calculating the material direct costs. The company pays for goods and services acquired from suppliers, and possibly also has to pay for output of waste and emissions.

Material Direct Costs: Material direct cost may result from material consumption (input-side of the inventory) or from material releases (output-side of the inventory).

Input-sided expenses based on material direct costs are determined by calculating the input quantity of goods (entries located in material groups "Raw, auxiliary, and operating materials", "Energy", and "Intermediate goods") multiplied with the assigned market price for these goods.

Output-sided material direct costs are determined by calculating the output quantity (materials located in material groups "Unavoidable Waste" and "Emissions", and in case of conventional cost accounting also those located in the material group "Losses") multiplied with the assigned market price for these wastes and emissions. These output-sided material direct costs are additional expenses that incur in the creation of the main product (cost unit) and are born by them.

The material group "Losses" plays a central role in the material flow cost accounting (MFCA) perspective. Read more about it in section 16.5.2.

Revenue: The revenue is calculated from the output of goods. Goods are automatically identified as products, if they are defined in the material group "Products" and "Intermediate goods" and are typically located on the output side of the inventory.

Additionally flows that are located in either the "Unavoidable Waste", "Emissions" or (in case of conventional cost accounting) in the material group "Losses" can also be considered as products and services that can deliver revenue if they are located on the input side of an inventory. For more information on the reference flow see section 10.2.

Hence in a first step of the conventional cost accounting the input and output flows are determined and the material direct costs for creating the products as well as the revenues created by selling to the market are calculated. These material direct costs are considered variable costs, since the costs are linearly proportional to the flow quantity.

Note that these costs incur exclusively at the system boundaries. At this stage the flows within the company (arrows between the processes) do not have costs assigned. See hint below on costs for model sections and internal prices.

Variable Process Costs: In addition to the above, there can be costs that are not directly caused by materials purchase or exchange of inputs/outputs with the market. These are costs that incur at the process. This is why we also refer to them as process cost. Examples are cost types like wages, machine maintenance, cost for training of staff, etc.

These costs are linked to the activity of the process. The amount hence is specified proportionally to the production volume (product output) in the process specification. These costs are therefore called variable process cost. For details on how they are specified in the process and examples, please see section 16.6

When a variable process cost entry is added to a process specification on the input side, it is automatically assigned to an input place called 'CI' (for cost input). The place and the arrow are hidden by default, but can be used to show the cost input in a cost Sankey diagram. The cost input at the process is treated similarly to a physical flow input. The cost input can be linearly proportional to the process throughput (process specification type 'Input/Output. It can also be defined non-linearly with mathematical functions (process specification type 'User Defined Functions', see section 13.1).

Fixed Costs: Fixed costs are not linked to a process activity directly. They exist, independent of the process throughput. Examples are administration costs, office worker salaries, car fleet, fees, spendings for the company restaurant, etc. Note that sometimes costs can be included as variable process cost or as fixed costs, depending at the discretion of the practitioner or the company's cost accounting rules. The main distinction of fixed costs is that they relate to a period (here: the business year) and that these costs are considered independent of whether the company produces a high amount of product output, a low amount of product output, or no product output at all.

Fixed costs are also defined in the process specification on the input side, but they are not shown as flows on an arrow. Fixed costs are listed separately in the presentation of the cost inventories.

Multi-Product Systems and Cost Allocation: Allocation of costs (variable process costs) is done in the same way as for material and energy flows. Material direct costs are using the inventories per product for the calculation. Hence, in multi-product systems, costs per product are calculated based on the material expenses determined for the individual products and the allocated variable process costs.

Mind that there are two different set of allocations, depending whether they are used for conventional cost accounting (tab "Allocations) or for the material flow cost accounting (tab "MFCA Allocations"). Please read in section 8.3 for details.

Display of Calculated Costs: After the calculation of the physical flows ('Total Flows') and the subsequent calculation of 'Product Flows & Costs' the most important results (revenues, expenses, marginal income) are shown on the 'Results' tab in the section "Classic" as "Costs Summary" and "Costs per Product".

Read in section 12.1 for details on cost results.

On the inventories tab several cost result views are presented and allow analysing the calculated costs in more detail. Cost inventories can be grouped and sorted. Detailed cost data can be exported to Excel.

Read in section 16.7 for details on cost inventories and cost details.

Another presentation of calculated cost information can be with cost Sankey diagrams.

Read section 16.9 for more information on how cost data in a production system can be displayed in a Sankey diagram.

16.5.2 Material Flow Cost Accounting

Umberto supports material flow cost accounting (MFCA) according to ISO 14051. It is an additional perspective on costs in a production system and supplements the classical cost accounting approach described above (in section 16.5.1)

The MFCA approach allows looking at inefficiencies in a production system by considering waste or rejects in a process as a material loss. By doing so, the whole costs of input materials and their handling along the process chain that are subsequently turned into waste (and do not end up in the product itself) are considered as additional costs.

What has been explained in the previous section regarding system boundary and scope, material direct cost, and variable process cost is also valid for the material flow cost accounting approach.

Revenue: The revenue is calculated from the output of goods. Goods are automatically identified as products, if they are defined in the material group "Products" and "Intermediate goods" and are located on the output side of the inventory.

In contrast to the conventional cost accounting the expenses caused as material direct costs from the output of emissions and waste are not born by the product, but are shown separately. The revenue for the actual product(s) of the production system is therefore typically lower than in a conventional cost accounting approach. While material losses do not create any revenue, they still have material direct costs and variable process cost, leading to a negative balance.

Material Losses: One important role in Material Flow Cost Accounting is the consideration of material losses in each processing step (or 'quantity centre') of a manufacturing process. By explicitly considering losses and assigning them the status of material losses, then treating them consistently as such in the cost accounting, a MFCA aims to yield the true costs of inefficiencies, rejects and waste. The material losses will be assigned, not only the purchasing cost of raw material, but also the handling cost (e.g. transport, storage, etc.) as well as the process cost for the fraction of material purchased that does not turn into or end up as a valuable product sold to the market for revenue.

All entries in the material group "Losses" with its four subgroups "Production Waste", "Waste", "Wastewater", and "Miscellaneous" are automatically considered as material losses. Typically these items are listed on the output side of a process (quantity centre).

MFCA Cost Allocation: Material losses in processes (quantity centres) in the MFCA approach are treated similar to units of cost (products). Therefore, allocation of costs for MFCA must be done by assigning expenses to the actual products of the process and to output flows considered material losses.

Allocation of costs for MFCA is done on the tab "MFCA Allocations" of the process specification. By default the material and energy expenses are allocated physically ("Allocation by Mass") to the products and material losses. One can choose to set individual allocation factors though ("User Defined").

Read more about cost allocation in section 8.3.

Display of Calculated Costs (MFCA Perspective): After the calculation of the physical flows ('Total Flows') and the subsequent calculation of 'Product Flows & Costs' the MFCA results (cost matrix, costs per product and costs per material loss) are shown on the 'Results' tab in the section "MFCA" in the views "Cost Matrix Overview", "Cost Matrix" and "Costs per Product".

Read in section 12.1 for details on cost results.

On the inventories tab several cost result views are presented and allow analysing the calculated costs in more detail. The cost inventories are the same for the MFCA perspective and for the classic cost accounting perspective. The cost entries in the inventories can be grouped and sorted. Detailed cost data can be exported to Excel.

Read in section 16.7 for details on cost inventories and cost details.

Another presentation of cost information calculated with the MFCA approach can be with cost Sankey diagrams. A specific MFCA Cost Sankey diagram is available for every product and every material loss, to get a visual idea of the "value stream".

Read section 16.9 for more information on how cost data from the material flow cost calculation can be displayed in a Sankey diagram.

Read more about the ISO standard on Material Flow Cost Accounting (MFCA). Refer to the official ISO 14051 document.

16.6 Costs in Process Specification

Separate from the material and energy flows used in a process specification, but handled similarly, are the cost entries. The input and output flows defined in the grid on the "Input/Output" tab will be automatically considered when material direct costs are calculated (see section 16.1). For other costs (variable process costs) the cost types defined in the Project Explorer must be added in the process specification on the input side.

Adding Variable Process Cost Entry: To enter a variable process cost entry, drag it from one of the three cost type groups "Energy Costs", "System Costs", or "Waste Management Costs" under the 'Cost Type' folder in the project explorer onto the left side of the grid on the "Input/Output' tab of the process specification. Alternatively, drag the cost entry onto the process symbol in the editor directly.

An entry will be created, and it will automatically be assigned to an input place "CI" (cost input). This place is added as hidden place in the model.

The cost entry can be distinguished from the material entries because it is from one of the three cost type groups "Energy Costs", "System Costs", or "Waste Management Costs" (indicated in the 'Material Group' column). Also the field in the 'Price' column remains empty for a variable process cost entry, since the cost relates to the process activity, as defined in the process specification.

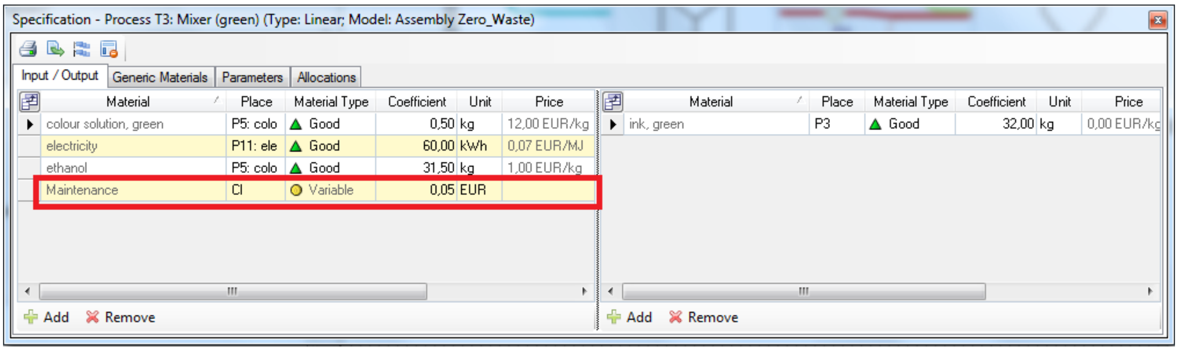


Figure 115: Specification of a process, 'Input/Output' tab with a variable process cost entry

For variable process cost enter the cost as numerical value in the column "Coefficient". The coefficients represent the relation between the flows entering and leaving the process, as well as among the flows among each other on the same side. In case of the variable process cost entry the amount should be in relation to the product being produced in this process.

Example: if a machine needs a maintenance cycle after a throughput of 10.000 tons of material and this maintenance costs 500 Euro, then the cost for maintenance in relation to 1 kg throughput (e.g. as the quantity of product shown on the output side) would be

```
500 Euro maintenance cost per 10.000 tons  or
500 Euro maintenance cost per 10.000.000 kg  or
500 / 10.000.000 Euro maintenance cost per 1 kg  or
0,00005 Euro maintenance cost per 1 kg
```

The factor '0,00005' would be entered as coefficient in relation to an output of 1 kg of the product.

This example is for linear cost. Should the cost occurrence be other than linear, this can be defined using the 'User Defined Function' process specification type. See section 13.1

For fixed cost types enter the cost as numerical value in the column "Coefficient". This is the cost per year, independent of the process activity. No matter how much the throughput at this process, the fixed amount will be considered for this process per year. Fixed costs will be shown separately in the cost inventories, however, they can be assigned to individual processes.

Note that some cost types can be considered variable process cost, but can also be modelled as fixed costs.

Live Links to Cost Entries: In the same way as described above for flow coefficient values, values for cost entries on the input and output side of a process specification can also be fed from an external data source via a so-called Live Link.

To establish a Live Link for a cost datum, copy the value of a cell and paste it in the 'Coefficient' field of the specific entry. Pasting can be done with the shortcut CTRL+V or using the command "Paste Live Link". A coloured icon signals that this value is fed via a Live Link.

Removing Cost Entry: To remove a cost entry from a process specification, mark the entry on the input or output side, and click on the 'Remove' button.

16.7 Costs Inventory

The cost inventory data shown on the "Inventories" tab is the same whether you opt to take a conventional cost accounting or the material flow cost accounting (MFCA) approach. Differences can be observed only in the interpretation and display of results on the "Results" tab (see sections 12.1 and 16.11.2)

All costs calculated in the system (material direct costs and variable process cost) are shown on the tab "Inventories" in the window pane below the editor area.

Mind that the cost inventory only shows meaningful data, if material direct cost and/or variable process cost have been used. Otherwise cost data will be shown as "0,00"

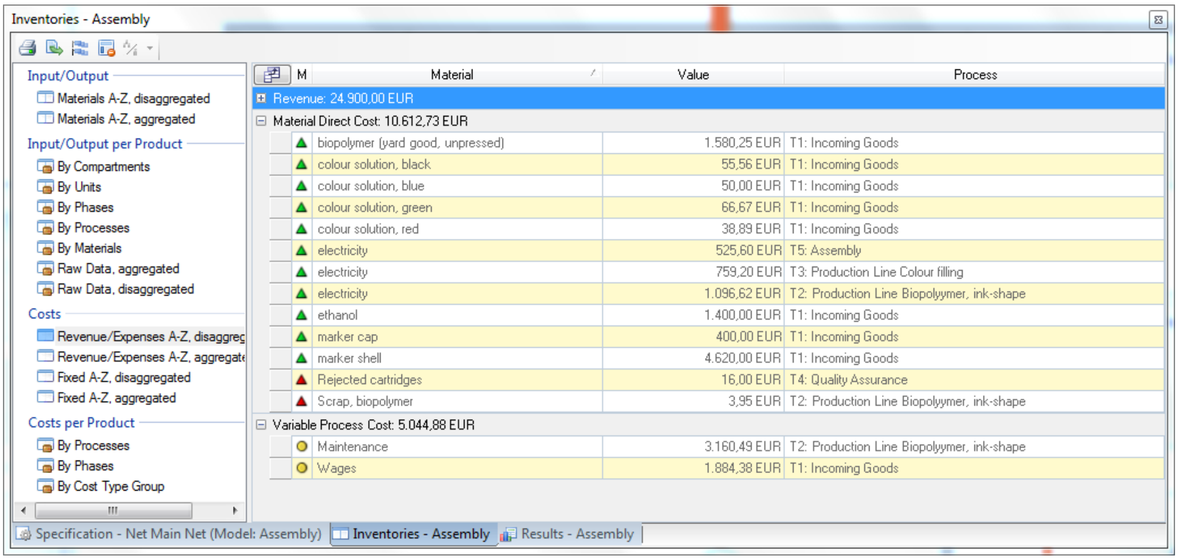


Figure 116: Default view of costs inventory with Input/Output Flows, materials A to Z, disaggregated

Several views on the cost data are available in the list on the left side under the "Costs" and the "Costs per Product" header.

Costs Summary Views: Two summary views for costs are available to choose from under the headline "Costs":

- view 'Revenue/Expenses A-Z, disaggregated'
- view 'Revenue/Expenses A-Z, aggregated'

The view 'Revenue/Expenses A-Z, disaggregated' shows revenues as well as material direct costs and variable process costs with individual entries.

Revenues are calculated from the market price of flows that represent reference flows of the system (i.e. products sold to the market). Material direct costs are calculated based on the market price defined for a material with a green material type that is taken up as an input to a process from outside the system (i.e. "the market"). Additionally, material direct costs may also be determined for a flow that is released from a process to the system environment across the system boundaries and that has a red material type. Variable process costs are calculated using the cost type entries defined in the process specifications that are linked to the production output proportionally.

The group headers show the sum of the revenues, material direct costs and variable process costs.

The view ' Revenue/Expenses A-Z, aggregated' in the selection list on the left of the grid is a different view where cost entries will be shown aggregated. The hint 'Multiple Processes' is displayed in the 'Process' column if a cost entry occurs at several processes.

Fixed costs are shown in the view 'Fixed Costs A-Z, disaggregated'. These are expenses that are identified as fixed and that relate to a time period (e.g. the business year) and therefore are independent of the variable production output. The view 'Fixed Costs A-Z, aggregated' aggregates fixed cost inventory entries if multiple entries of the same fixed cost type entry exist.

Cost per Product Detail Views: Two summary views for costs are available to choose from on the left side under the headline "Costs per Product":

- By Processes
- By Phases
- by Cost Type Group

The view 'Revenue/Expenses A-Z, disaggregated' shows revenues as well as material direct costs and variable process costs with individual entries.

Costs per Product: For multi-product models (systems that yield more than one product or that have a main product and co-products) the cost inventories can be viewed for all products individually. Select the product for which you want to see the cost data from the dropdown list 'Selected Product'. This allows analysing the cost per product, or if scaled to one unit of a selected product, the cost per unit (unit price).

The following additional cost views per product are available:

- **By Process**: Select one of the products in the 'Selected Product' dropdown list at the top of the grid. Similar to the default view for all costs the grid is grouped by revenues (in this case for one product only), material direct costs incurred for the materials used to produce the selected product, and variable process cost. Both material direct costs as well as variable process costs are allocated to the individual products using the allocation rules defined in the process.
- **By Phase**: If the phase frame has been used to distinguish different sections of the production model (e.g. different departments of the company), the 'By Phase' cost view shows the revenues and expenses (material direct costs and variable process costs) for the selected per phase. Fixed costs are not shown in this view.
- **By Cost Type Group**: Revenues and material direct costs are shown grouped by the material groups defined in the Project Explorer on the first level under the 'Project Materials' root node. Variable process costs are shown per cost type group defined in the Project Explorer on the

first level under the 'Cost Types' root node. By this material direct costs and process costs can be further broken down. Fixed costs are not shown in this view.

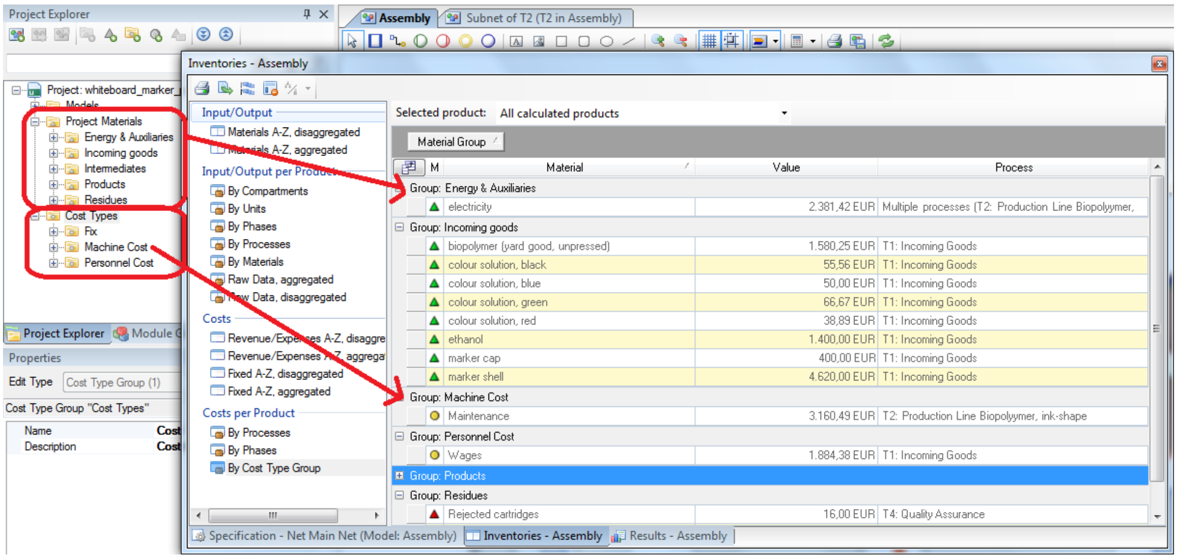


Figure 117: In the Costs per Product / By Cost Type Group view costs are structured by material groups and cost type groups defined in the Project Explorer

16.9 Cost Sankey Diagrams

Similar to the Sankey diagrams that show mass or energy of the flows in the process system, cost Sankey diagrams can be created based on the calculated values. These show the variable costs associated with the production of one or all products in the system.

Note that the 'Product Flows and Costs' calculation must have been executed, before this Sankey diagram type becomes available.

Similar to the cost display in the inventory, a cost Sankey diagram can be created. It shows the flows associated to each reference flow. This includes the material direct costs (based on flow quantities and the market price or disposal costs) as well as the variable process costs. A cost Sankey diagram can draw the attention to the parts of the process model, where most costs incur.

In the conventional cost accounting perspective, only products or intermediates are identified as reference flows. Emissions and waste constitute expenses that are born by the products. For creating a Sankey diagram that only shows the allocated product-related cost flows, choose "Classic" from the 'Show Sankey Diagram' menu, and 'Costs' from the cascading menu. Then choose one product in the next cascading menu.

In the material flow cost accounting (MFCA) perspective, material losses are also interpreted as reference flows that carry costs. For creating a Sankey diagram that shows the allocated costs per product and per material loss, choose "MFCA" from the 'Show Sankey Diagram' menu, and 'Costs' from the cascading menu. Then choose a product or a material loss in the next cascading menu.

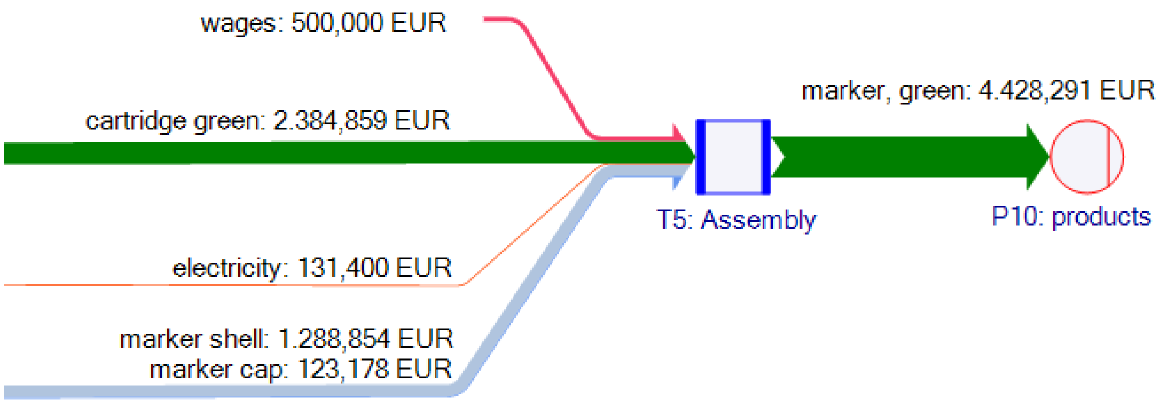


Figure 118: The sum of costs on the input side (material direct costs and variable costs e.g. wages at the process) add up to the output value.

Allocation of variable costs to the different products in a multi-product system is done based on the allocation coefficients defined on the "Allocations" tab in each process. Allocation of variable costs to the different products and material losses in the MFCA perspective is done based on the allocation coefficients defined on the "MFCA Allocations" tab in each process. (see section 8.3)

Scaling of cost Sankey diagrams can be done with the slider for 'Currency' on the 'Scaling of Sankey Diagram' window.

Hovering over a cost Sankey diagram shows the cost value in a tooltip.

The cost value that is represented by the Sankey arrow can be displayed next to the arrow by using the 'Display Flow Label' option from the arrow properties. See section on arrow labels in section 7.4

More about the cost accounting feature in Umberto models can be found in chapter 16

16.11 Cost Results

The results of the material flow model calculation in regard to costs are shown in the Specification Editor area after a successful calculation. Both, results of the material flow cost accounting (MFCA) and of the conventional cost accounting can be viewed on the "Results" tab below the model editor area.

16.11.1 MFCA Results

In Umberto the results of the material flow cost accounting calculation is shown directly in the Specification Editor area after a successful calculation.

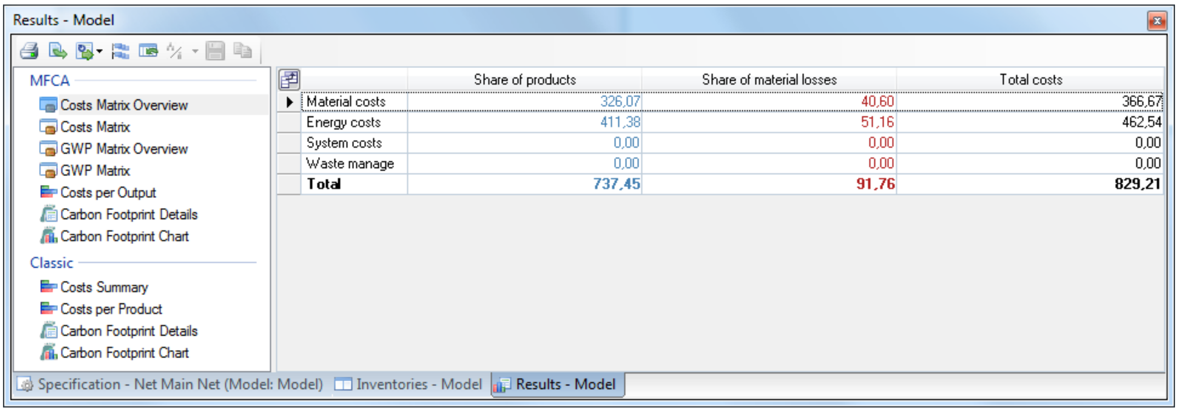


Figure 119: Costs Matrix Overview. This summary of the MFCA calculation is shown directly after a successful calculation of the material flow model

If no market price has been assigned to materials and no cost type has been defined and used in the process specification, then the 'Results' tab will remain empty.

There are two cost result views for material flow cost accounting that can be selected under the headline "MFCA" in the list on the left side of the "Results" tab:

Costs Matrix Overview: This is the summary of the MFCA calculation of the material flow model. It shows "Material Costs", "Energy Costs", "System Costs" and "Waste Management Costs" of the overall system (i.e. the entire manufacturing process). Note that material costs are determined from the input output inventory (see section 16.1 above) and the material direct costs ("Market Price" and "Disposal Costs"). The other costs are collected from the process costs (see section 16.4 above) defined in the processes (quantity centres).

The "Total Costs" are split into the costs for actual products ("Share of Products", blue numbers) and for material losses ("Share of Material Losses", red numbers).

Note that in contrast to the cost matrix shown in ISO 14051 in paragraph 6.9 on 'MFCA data summary and interpretation' as example for result display, the table in Umberto has been rotated (pivoted).

Costs Matrix (Costs Matrix per Quantity Centre): Highlight the entry "Cost Matrix" in the selection list on the left to view the MFCA costs results. This is another summary of the MFCA calculation of the material flow model that is more detailed than the overview described above.

One section or block of the cost matrix table relates to one quantity centre (represented by a process symbol in the model). The block can be hidden by clicking on the minus symbol in front of the quantity centre name in the header.

The "Total Costs" are split into the cost types "Material Costs", "Energy Costs", "System Costs" and "Waste Management Costs" for each of the quantity centres.

The third column shows the total costs in this quantity centre ("Total in this QC"). They are made up from the results of the previous quantity centre ("Carry Over") and the "New Costs" added in this quantity centre.

The fourth and fifth column shows the costs for intermediates, broken down into the share of the intermediate cost that is embodied in the product ("Share of Intermediates") and the share of the intermediate cost that ends up as a material loss, but not in the product ("Share of Intermediate Material Loss").

The last two columns give a breakdown of the costs in this quantity centre for actual products ("Share of Products", blue numbers) and for material losses ("Share of Material Losses", red numbers). These two columns and the two columns for intermediates add up to the total in the third column.

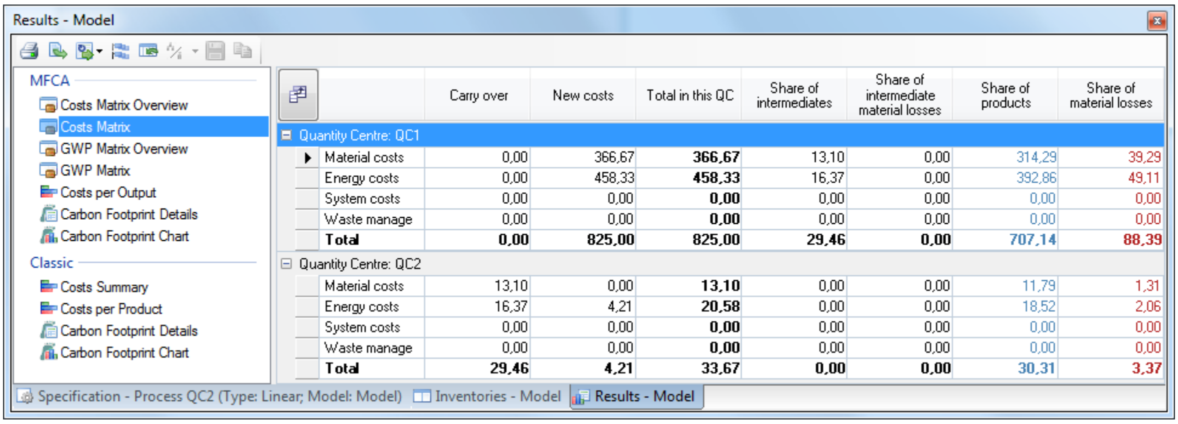


Figure 120: Costs Matrix. This summary of the MFCA calculation gives a more detailed view of the results of the MFCA calculation. In particular, the build up of costs in a sequence of quantity centres can be traced.

The sort order of the table blocks for each quantity centre depends on the ID of the process (QC1, QC2, QC3, …).

Costs per Output: An alternative way of looking at the MFCA results is the "Cost per Output" view. For each product of the system (an entry from the material group "Products" or "Intermediate Goods" that is located on the output side of the Input/Output inventory) and for all material losses the costs are shown in separate blocks in the table. A block can be hidden by clicking on the minus symbol in front of the name prefix "Product:" or "Loss:" in the header.

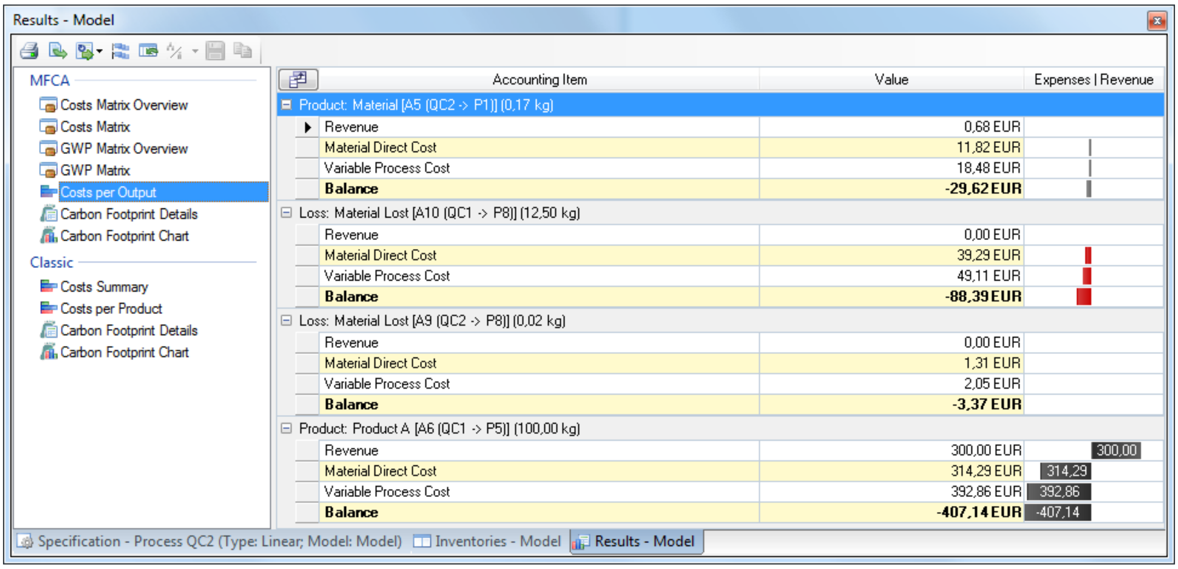


Figure 121: Costs per Output

In each block the costs are summarized as "Revenue" (the market price defined for a product or a negative revenue for materials that have a disposal cost defined. Deducted from the revenue value in the first line of each block are "Material Direct Costs" and "Variable Process Costs" (from the cost type groups "Energy Costs", "System Costs" and "Waste Management Costs"). The difference is shown in the line "Balance". The values are shown as a small horizontal bar chart in each block.

Mind that this matrix display is not capable of adequately showing cost data for recursive use of material (loops in the system). Hint to include internal recycling costs adequately:

If you have calculated only a section of the model (either one individual cost centre, or a grouped set of quantity centres, the display of the costs relates only to the section of the model that has been selected for calculations.

The other views under the "MFCA" header on the "Results" tab relate to the carbon footprint calculation. These result views are explained in chapter 17.3.

16.11.2 Conventional Cost Accounting Results

The results of the material flow model calculation for a conventional cost accounting perspective are shown in the Specification Editor area under the headline "Classic" in the list on the left side of the "Results" tab. There are two cost result views:

Costs Summary: This is the summary of the cost results calculated for the material flow model. It shows a chart with four horizontal bars, with positive values to the right and negative values to the left. The top bar represents the revenues from all products. The second are all material direct costs, and the third bar the variable process cost. The fourth bar shows the difference between revenue and expenses ("Balance"), which can be positive or negative depending on the revenue and the expenses (material direct costs and variable process cost).

If the phases frame (see section 5.3) has been used in the model editor, the first three horizontal bars in the chart will show the contribution from each phase with segments according to the color defined for the phase. Costs at processes which do not lie within the phases frame are grouped under "Other".

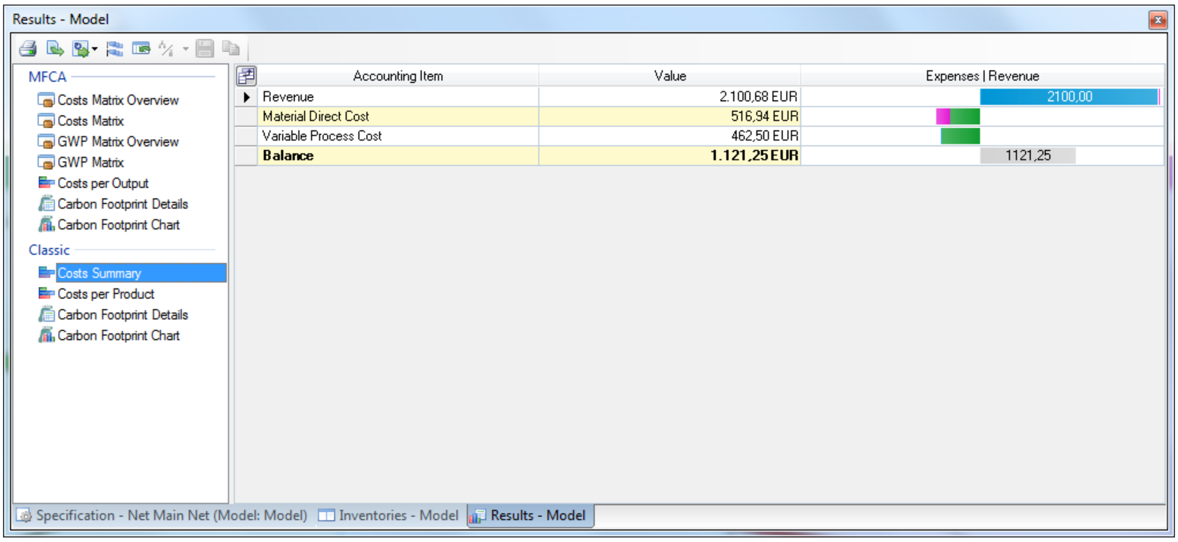


Figure 122: Costs Summary

Please note that these values do not automatically refer to one unit of product, but rather to the manual flow quantity that has been entered before the start of the calculation. This can be, for example, the annual production volume of the company.

Costs per Product: This cost results view is similar to the above cost summary, but shows an individual group of horizontal bars for each of the products of the system. As mentioned before, the products of the system (the reference flows) are identified automatically.

Again, for each of the products there are revenues, material direct costs, and variable process costs. The marginal income per product is calculated as the difference of revenues and expenses (material direct costs and variable process cost).

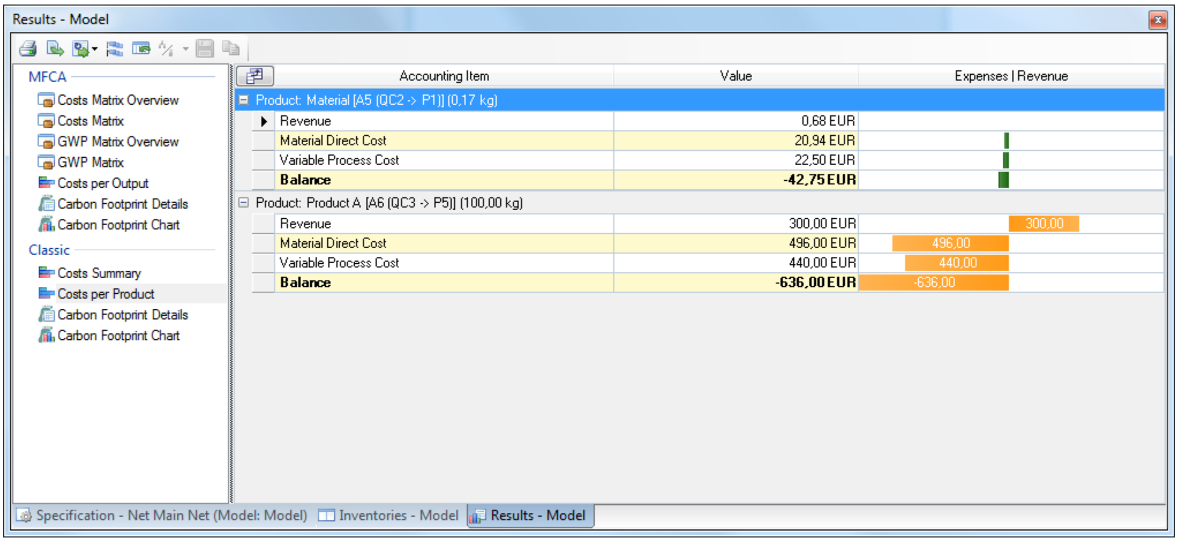


Figure 123: Costs per Product in the conventional cost accounting group on the 'Results' tab

The color used for each group of horizontal bars is that defined for the product in the material properties panel. The quantity of product underlying the cost results is shown in the group header.

Use the buttons in the toolbar of each tab, to export, print or save the result diagram or table. For more details refer to the section 11.4 on printing and exporting below.

The other views under the "Classic" header on the "Results" tab relate to the carbon footprint calculation. These result views are explained in chapter 17.3.

Scaling of Results: The results displayed on the tab 'Results' are the default shown for the quantity of flows that has been calculated in the model. Note that depending on the manual flow (see section 10.2) defined this can be, for example, the yearly production quantity.

To have this value scaled to one unit use the functional unit flag for the material in the Project Explorer. If this flag has been set and the conversion to one unit of product (e.g. for a product with mass basic unit 'kg' → "one piece" with 400g) has been defined then the clicking of the 'Toggle Scaled/Normal Values' button will allow switching between scaled and unscaled results.

Scaling to on unit of product might be meaningless in some views, especially when the values for more than one reference flow (product) are shown. In that case the scaling feature is disabled, the button greyed.

17 Carbon Footprint

Users of Umberto LCA+ will typically determine the carbon footprint as one of the impact categories (climate change) within their Life Cycle Assessment. To this end the LCIA methods 'climate change, GWP 100a, IPCC2007' and 'climate change, GWP 100a, IPCC2013' are provided in the ecoinvent databases.

This section targets at users that have previously worked with the Umberto NXT CO2 version and are aiming not at doing a full LCA, but rather build a carbon footprint model.

Climate change caused by greenhouse gas emissions is an important issue. Industry is addressing the challenge of tackling climate change and striving to reduce the release of carbon dioxide and other GHGs.

Both Umberto LCA+ and Efficiency+ include features to model, calculate and analyze the release of greenhouse gases for the production system being modelled. This is achieved by analyzing direct GHG emissions from the process system and adding carbon rucksacks (embodied carbon GWP 100a values) for material and energy inputs into the production process, as well as for waste output that receives further treatment.

Typically the carbon footprint will have a cradle-to-gate scope, since – in contrast to a life cycle model – the material flow models will not include an explicit use phase and end-of-life phase for a product.

17.1 GWP100a Database

In the current version Umberto the following GWP100a databases are available:

- LCI database ecoinvent (version 2.2, as of May 2010)
- LCI database ecoinvent (version 3.2 as of November 2015)

Important Hint: We are providing these data as we find them in the original source, and are not taking any liability for their correctness. Please read the End User License Agreement (EULA). It is in the responsibility of the software user who builds and calculates the model, to check the GWP values taken from third party sources (e.g. ecoinvent database). Other publications and sources might provide differing values, and databases suppliers might also update their values over time.

Other sources may be data available from your suppliers, or industry associations. There are a number of other LCI databases, from which the value for GWP (impact category climate change) could be extracted[7].

You may have GWP data for material and components you purchase from your suppliers. Read in the next chapter how to

[7] Check out, for example, U.S. NREL Life Cycle Project Database, JRC's ELCD database, the free German GEMIS model, the ICE database maintained by University of Bath, and other sources.

add GWP100a data for purchased materials individually.

ecoinvent 2.2 LCI database

The ecoinvent database (www.ecoinvent.org) is the most renowned databases for life cycle inventory (LCI) datasets. It contains harmonized, reviewed and validated datasets for use in Life Cycle Assessments (LCA), approximately 4000 in ecoinvent 2.2 and 9000 in ecoinvent 3 respectively. These datasets are all fully documented[8].

The ecoinvent database offers several life cycle impact assessment (LCIA) methods, with numerous impact categories, and characterization factors for each of the materials, for use in LCA studies where ecoinvent datasets are being used.

For a carbon footprint calculation, only one impact category (Climate Change / Greenhouse Warming Potential, GWP) is looked at, and only one indicator is being determined (GWP value, or CO2 Footprint, unit: kg CO2-equivalents). In Umberto only the GWP value in the 100-year perspective (GWP 100a) is included as a material property.

From the datasets the so-called elementary flows which do not contribute to the climate change impact categories were deleted. The so-called activity datasets are represented by their product output with a weighted GWP indicator. The structure of the folders (represented by categories and subcategories) has been adjusted, and the folder names have been changed for ease-of-use.

Some hints on the assumptions and parameters for establishing these data, and in the use of the datasets form the ecoinvent database are given below, but it is strongly recommended to check the original ecoinvent documentation, to learn how this data has been collected[9].

---

8 Register as "Guest" at http://www.ecoinvent.org to access the meta information of all LCI datasets, and to download the reports with information on process datasets.

9 Reports can be downloaded from http://www.ecoinvent.org. Users need to register as 'Guest' to get access to the more than 1000 pages of documentation.

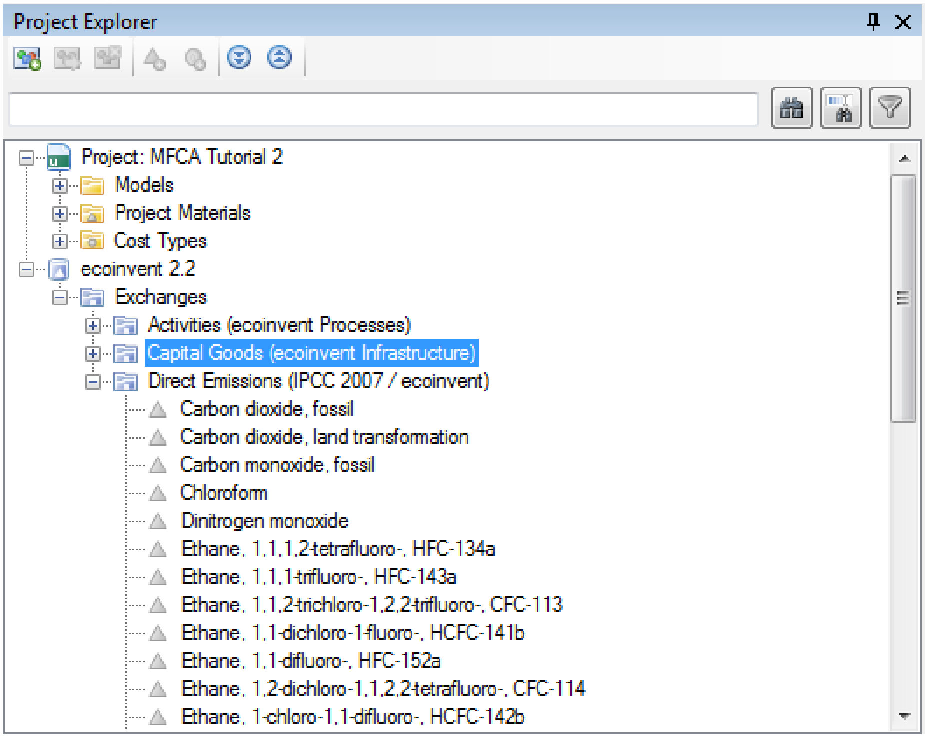


Figure 124: Project Explorer with models, project materials and master material databases.

The 'Direct Emissions' subfolder contains the elementary flows that contribute directly to climate change. The GWP 100a values for these emissions are from the official IPCC reports, in ecoinvent 2.2 this would be IPCC 2007, for ecoinvent 3 it is IPCC 2013. In the Properties Editor of ecoinvent materials, hover over the small 'Information' (i) icon next to the field 'CO2 footprint' with the mouse pointer. The source process and indicator of the GWP value will be shown in a tooltip.

GWP 100a values for substances and production of materials are grouped under 'Activities (ecoinvent Processes)'. There are several subfolders, such as plastics, textiles, glass, chemicals, building components and many more. The datasets in this group are mostly in regard to the production of one mass unit (kg) of a material or intermediate product, some. The associated GWP 100a value or CO2 rucksack, thus is in 'kg CO2-eq per kg' of the material produced. It includes the embodied carbon burdens of all upstream production process for providing this material.

GWP 100a values for energies can also be found under 'Activities (ecoinvent Processes)'. These datasets are either in regard to a unit of providing energy (MJ), or in regard to a mass unit of feedstock (kg).

Carbon rucksacks of transports are accounted for in ecoinvent with service input flows with the units ‘metric ton*km’, ’person*km’, or ‘km’. When modelling a freight transport with these entries, one should use the datasets named "transport, …" (e.g. transport, lorry 16-32t, EURO3 [RER]). The datasets whose name starts with "operation, …" are for the mere operation of the vehicle.

Note that transports (and the emissions caused by the transports) can also be modelled with a process, rather than with input flows of a transport.

Waste management and waste disposal activities are originally modelled in ecoinvent as an input service as well. This means that GWP expenses for disposal of a certain waste would have to be represented as a flow on the input side in a process. Since the approach in Umberto models are more flow-oriented, we have adapted them in such a way that they can be used on the output side in a process specification.

The indicator in square brackets shows the geographical reference of the dataset ([RER] ≙ Europe, [GLO] ≙ Global, [CH] ≙ Switzerland, [US] ≙ United States, …)

The GWP 100a values for infrastructure processes (e.g. a chemical factory, building, steel plant, airport, road) are available in the folder 'Capital Goods (ecoinvent Infrastructure)'.

17.2 Managing GWP Values

When calculating an inventory of material and energy flows for a production system (see section 10.2), the results shown in the Input/Output inventory table are the flows that cross the system boundaries. In case of a gate-to-gate model of the production site these flows are the materials and energy purchased (received from suppliers) on the input side and the product output to the market, along with emissions and waste flows on the output side.

If all the inputs and outputs in the inventory table had GHG factors (for greenhouse gases emissions caused by them) as a property attached to them, it would be easy to calculate the overall carbon footprint of the system: Direct emissions of GHGs from the production system would have to be listed with their emission factors, the materials (intermediates, semi-finished products) and energy on the input side would be accounted for with their CO2 rucksack, and finally waste and other outputs that require further processing and cause further impact to climate change downstream would have to be included.

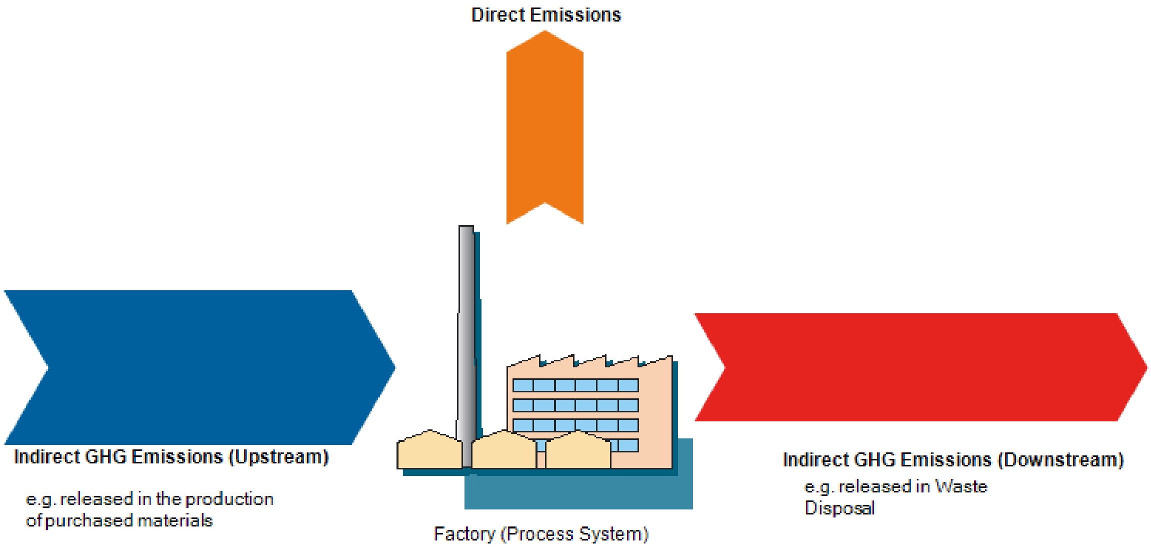


Figure 125: Schematic overview with carbon footprint made up from direct emissions, indirect emissions upstream (goods received) as well as indirect emissions downstream (treatment of waste), all contributing to climate change.

To obtain carbon footprint values for all input and output flows

- Direct emissions (GHG gases) must be part of the inventory and their emission factors (GWP100a coefficients) must be available as a property
- For intermediate products entering the system (and listed on the input side of the inventory) a GWP100a value (carbon footprint, CO2 rucksack) must be available as a property
- For intermediate products leaving the system (and listed on the output side of the inventory) a GWP100a value (carbon footprint, CO2 rucksack) must be available as a property

Direct Emission GWP Values: When using the direct emission flows (elementary exchanges) that are provided in the ecoinvent GWP database (Direct Emissions – IPCC 2007 group), the official emission factors are readily available in the master data.

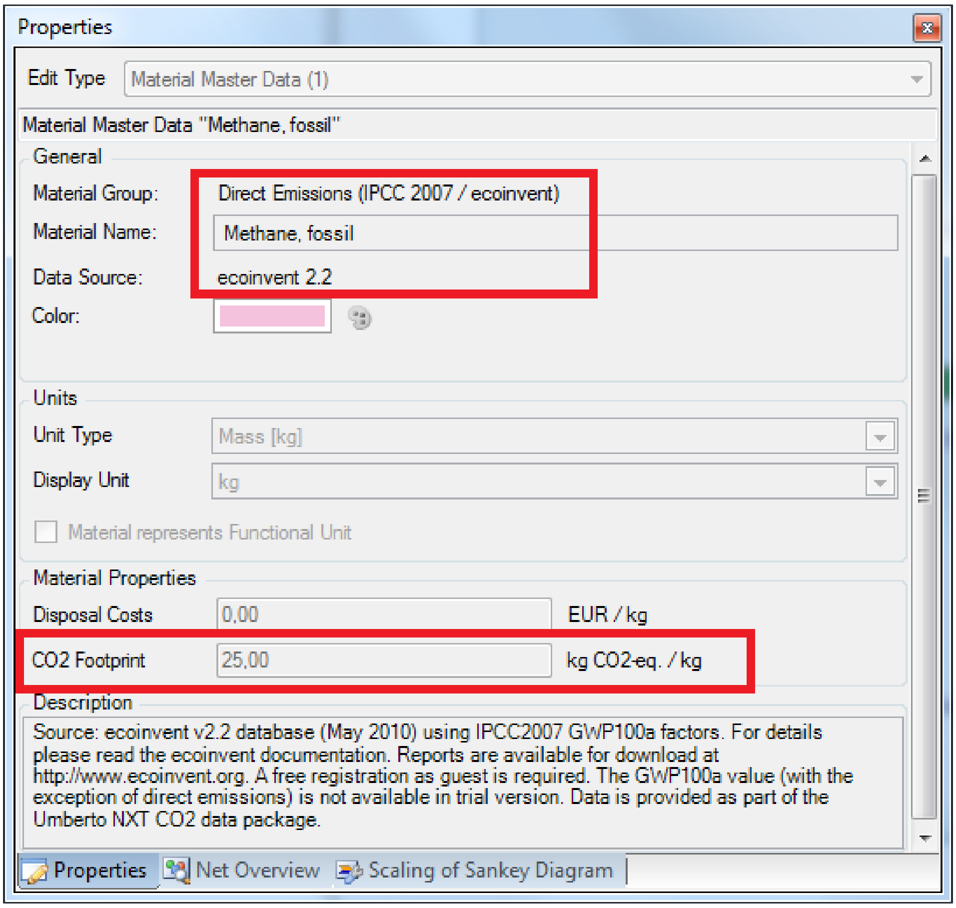


Figure 126: A direct emission entry ("methane") from the ecoinvent 2.2 master data with GWP100a value

Embodied Carbon GWP Values for Intermediates: As for the intermediates that figure on the input and output side of the inventory, you can use an entry from the ecoinvent GWP database 'Activities (ecoinvent Processes)' group as an approximation for the carbon footprint.

That value represents the overall emission of greenhouse gases along the supply chain and the production of one unit (e.g. 1 kg) of the intermediate (material, energy, etc).

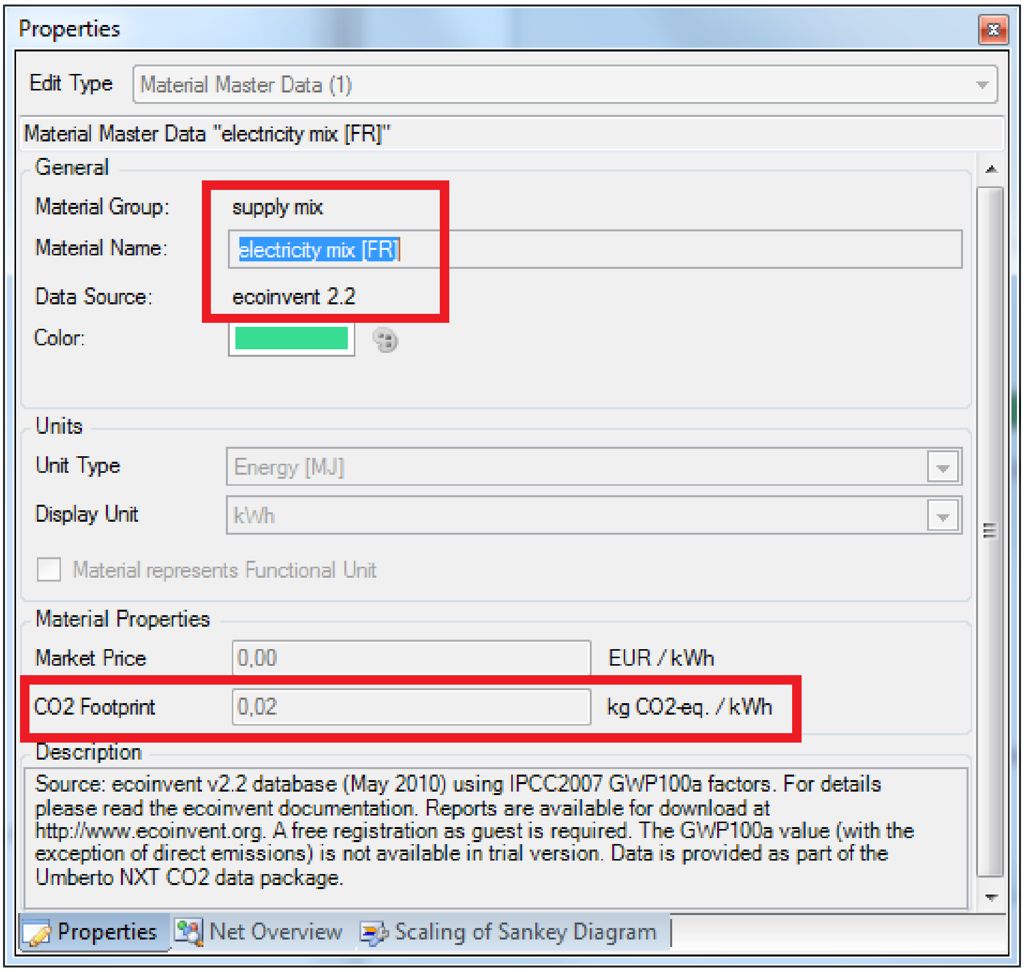


Figure 127: An entry from the ecoinvent database for an intermediate (supply mix "electricity mix [FR]") with its GWP100a value (carbon rucksack) for the production of 1 kWh in France

Note that all GWP values in the master databases are average values with a specific geographical validity. Read the ecoinvent v2.2 documentation to learn what assumptions were made and how the production process has been characterized. This is secondary data by third-party supplier, and preference should be given to primary data, if possible.

Embodied Carbon GWP Values for Intermediates: In case you have GWP100a values for specific materials you purchase (primary data from your supplier, third-party sources), you can enter this value as a property for the material yourself. This GWP data is then not drawn from the ecoinvent 2.2 master data, but rather a property of a material entry you use in your project

For a self-defined material entry in one of the groups under "Project Materials" enter a GWP100a carbon footprint value (embodied carbon vale, CO2 rucksack) in the "CO2 Footprint" entry field. Makes sure the value matches the respective basic unit.

The question where to obtain carbon footprint data for raw materials and energy is crucial for a carbon footprint calculation. If GWP100a values cannot be obtained from primary or secondary sources, you might want to derive the data from other, similar products, make estimations, or consider asking a consultant.

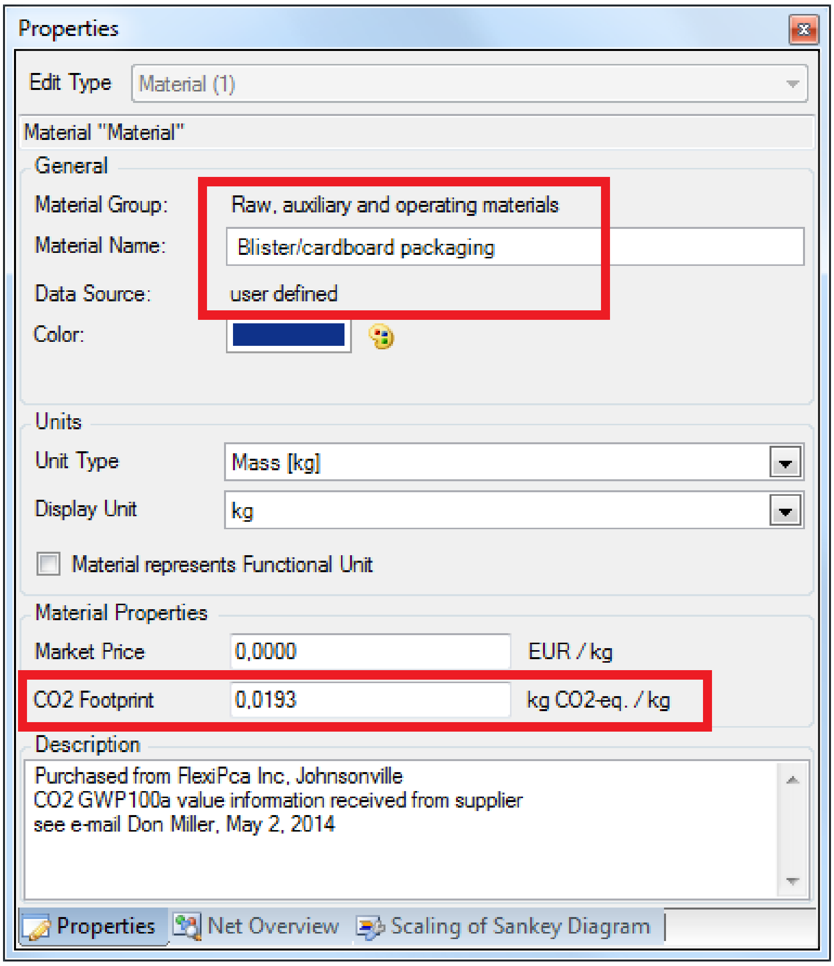


Figure 128: An entry for a self-defined material in the material list with its GWP100a value

To account for the carbon footprint of your system, make sure that all intermediate exchanges do have a GWP100a value assigned. Also verify that you are using the direct emissions from the master database ecoinvent v2.2 GWP in the process specification for releases into the environment.

For every calculation of the model, the carbon footprint values will be calculated and shown in a results view (see below).

If you are not interested in calculating a carbon footprint, just refrain from entering GWP100a values as material properties. Additionally you may want to disable the installed master database ecoinvent v2.2 that contains these values. To disable the master database, right mouse-click on the root folder of the database in the Project Explorer and select 'Disable Master Data Library'. Select the command 'Enable Master Data Library' to reactivate a disabled database again.

17.3 Carbon Footprint Results

The results of the carbon footprint calculation are shown on the 'Results' tab in the Specification Editor area after a successful calculation.

Carbon Footprint Summary: A summary of the carbon footprint results is presented when clicking on one of the 'Carbon Footprint Summary' entries in the selection list on the left. Two different views are available

- MFCA: This 'Carbon Footprint Summary' view shows the carbon footprint burden distributed onto the actual product(s) as well as onto material losses. The MFCA perspective (described above in section 16.5.2) is extended onto the carbon footprint accounting. Material losses are considered like cost units ("products") and therefore they not only are responsible for a part of the costs, but also for a part of the GWP emissions.
- Classic: This 'Carbon Footprint Summary' view shows the carbon footprint burden for the product(s) in a conventional way. This means that material losses are expenses that are caused by the product creation and consequently these losses are expenses that are born by the product. Carbon footprint burdens of losses hence are included in the carbon footprint of the product.

The carbon footprint shows the GHG emissions of each product and material losses as horizontal bar charts, and the absolute values.

The carbon footprint logo on the right is displayed for the marked entry. Click on one of the products or material losses to view the logo.

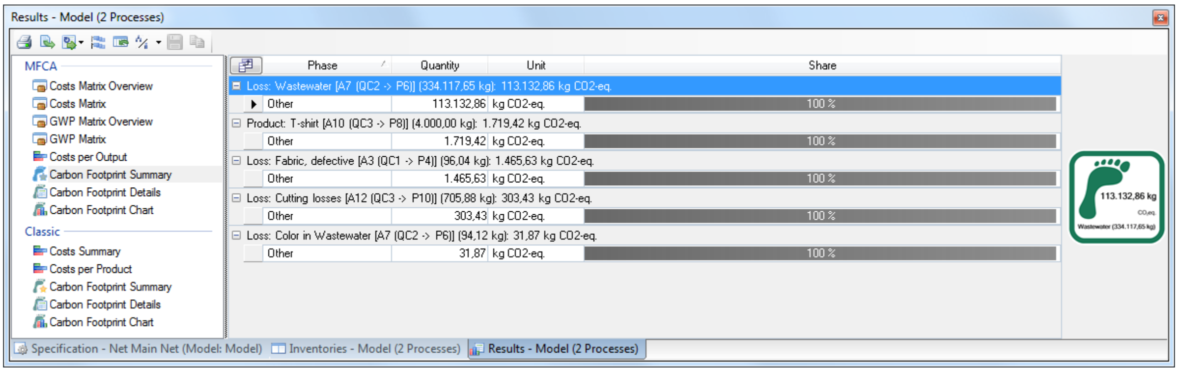


Figure 129: Carbon Footprint Summary, MFCA perspective

If model phases have been defined (see section 5.3), the horizontal bars are further broken down according to the phases. The assignment of the greenhouse gas emissions to a particular phase is done using the model phases frame: Depending on in which phase the place symbol that delivers the underlying flow to a process is located (indirect emission, carbon rucksack), or where the place symbol that takes up the direct emissions from a process is located, the calculated carbon footprint contribution is assigned to that particular stage. The color of the bar is synchronized with the color chosen for a particular model phase.

Values which do not lie within the life cycle phase frame are grouped under "Other". If no life cycle stages frame exists, this is the only bar that is shown.

Please note that these values do not automatically refer to one unit of the product, but rather to the manual flow quantity that has been entered before the start of the calculation. This might be, for example, the annual production quantity. Read more about the manual flow used for calculating the model in section 10.2.

If carbon footprint values are to be calculated for one unit of product, it is required to scale the calculation results to one functional unit of the product (see below).

Carbon Footprint Details: Details of the carbon footprint results can be viewed after a successful calculation on the 'Results' tab page.

Again, two different 'Carbon Footprint Details' views are available:

- MFCA: This 'Carbon Footprint Details' view shows the carbon footprint burden of the product(s) and material losses and their breakdown by material group.
- Classic: This 'Carbon Footprint Details' view shows the carbon footprint burden for the product(s) and their breakdown by material group.

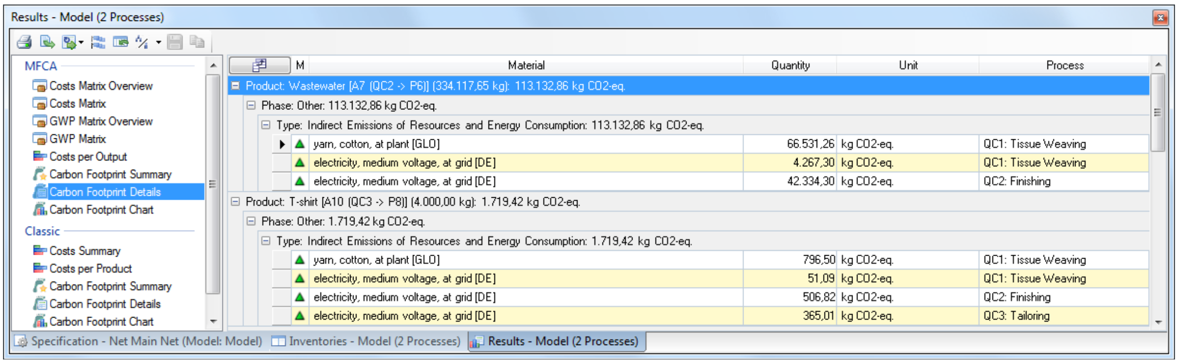


Figure 130: Carbon Footprint Details, MFCA perspective

A different grouping can be done the following way: First, open the group-by area by clicking on the button 'Toggle Group-By Box' in the toolbar. Then drag the column headers into the group-by area at the sort-order position.

Carbon Footprint Chart: Another chart for the carbon footprint results can be viewed after a successful calculation on the 'Results' tab page.

Two different 'Carbon Footprint Chart' views are available:

- MFCA: This 'Carbon Footprint Chart' shows the carbon footprint burden of the product(s) in green and material losses in red.
- Classic: This 'Carbon Footprint Details' view shows the carbon footprint burden for the product(s).

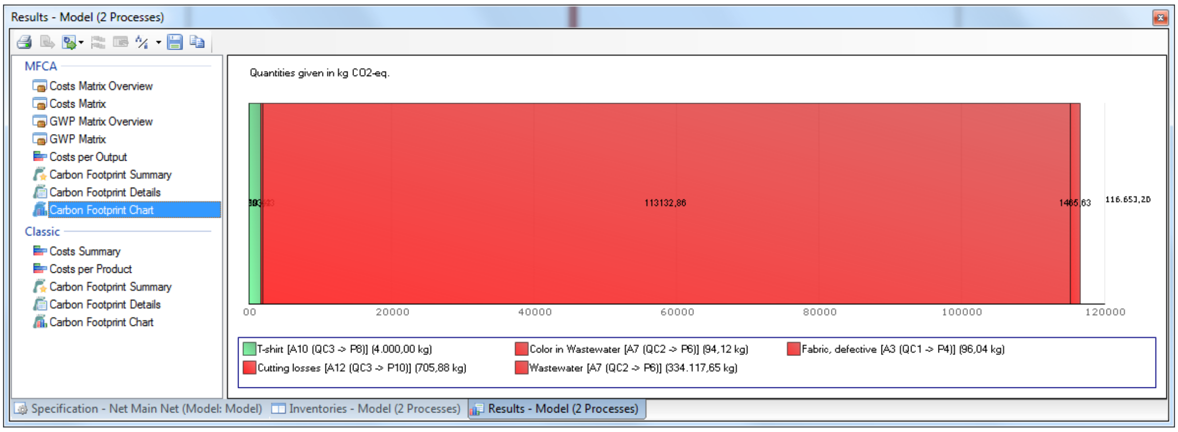


Figure 131: Carbon Footprint Chart, MFCA perspective

Use the buttons in the toolbar of each tab, to export, print or save the diagram. For more details refer to the section on printing and exporting below.

Scaling of Carbon Footprint Results: The results displayed on the page 'Carbon Footprint Summary' are scaled to the functional unit that has been defined.

If no functional unit has been defined the carbon footprint results are for the quantity of the reference flow, for which the model has been calculated (e.g. the yearly production). To switch between scaled and unscaled results, toggle the button 'Toggle Scaled/Normal Values'.

17.4 Carbon Footprint Sankey Diagrams

Just like for mass and energy flows, and for cost flows, Sankey diagrams can be used to display the model showing the carbon footprint. In the carbon footprint Sankey diagrams GHG loads are shown as arrows with increasing width along the process chain. The value shown represents the accumulated burdens of GHG emissions in CO2-equivalents.

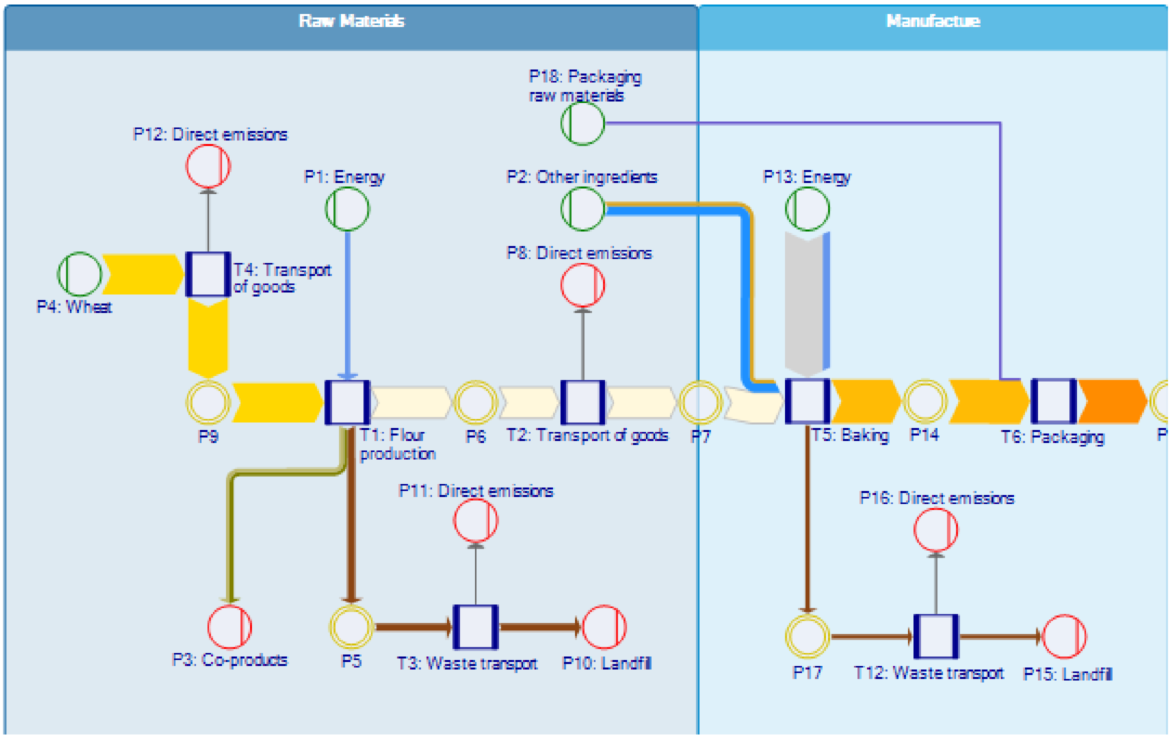


Figure 132: Section of a model showing contributions to the carbon footprint from material supplies and direct emissions

Two different cost Sankey diagrams area available: one for the conventional cost accounting perspective, and one for the MFCA perspective.

In the conventional cost accounting perspective, only products or intermediates are identified as reference flows. Emissions and waste constitute expenses that are born by the products. For creating a Sankey diagram that only shows the allocated product-related cost flows, choose "Classic" from the 'Show Sankey Diagram' menu, and 'GWP: Carbon Footprint' from the cascading menu. Then choose one product in the next cascading menu.

In the material flow cost accounting (MFCA) perspective, material losses are also interpreted as reference flows that carry costs. For creating a Sankey diagram that shows the allocated costs per product and per material loss, choose "MFCA" from the 'Show Sankey Diagram' menu, and 'GWP: Carbon Footprint' from the cascading menu. Then choose a product or a material loss in the next cascading menu.

To switch between the Sankey diagram view and the normal net model view (with simple arrows) toggle the button 'Show Sankey Diagram' in the toolbar. To be able to view a Sankey diagram the network must already be calculated.

Should you not have used any material entries fro the ecoinvent 2.2 GWP master database or not have entered any GWP100a values as material properties, the Sankey diagram will not show any Sankey arrows.

17.5 Exporting Inventories and Results

Export Active Inventory: The inventories and tables shown on the tabs 'Input/Output Flows' and 'Input/Output per Product' can be exported to Microsoft Excel using the button 'Export Active Inventory Table'.

Export Carbon Footprint Data and Graphics: The result tables and graphics of the carbon footprint calculation on the tabs 'Carbon Footprint Summary', 'Carbon Footprint Details' and 'Carbon Footprint Chart' can be exported to Excel using the button 'Export Active Result Table'.

Export Inventory Raw Data: The inventory raw data can be exported to Microsoft Excel. This allows for creating any other customized table with selected results and diagrams based upon these.

Note that each entry has a time stamp, so that when results of several (different) calculations are exported and then copied into one Excel sheet together, comparisons over the differences can be performed.

Should you wish to create specific graphical analyses and diagrams, it is recommended to make an export of all calculated flow data as raw data and work with Pivot tables in Excel.

Copy Carbon Footprint Logo to Clipboard: Should you wish to use the footprint logo (featuring the name of the product and the calculated carbon footprint value) in another application, you can copy it to the clipboard using the 'Copy Image' entry from the context menu of the logo.

In the target application paste the content of the clipboard. The image can be resized.

Figure 133: The footprint logo can be copied and exported via the context menu

Export Carbon Footprint Logo: The carbon footprint logo can also be saved as a diagram file. From the context menu of the footprint logo on the 'Carbon Footprint Summary page, select the command 'Save Image as...". Choose a file format and the destination folder. The following graphic file formats are available: PNG, JPG, BMP, and GIF.

A default name made up from the model name and the product name is suggested, but any name can be chosen to save the file.

Choosing 'Copy Text' from the context menu of the footprint logo allows copying the value of the carbon footprint (in kg CO2-equivalents) and the name of the product to the clipboard as text.

Note that the carbon footprint value refers to either the quantity of the reference flow for which the model has been calculated (e.g. yearly production quantity), or for on unit of the product, if the results are viewed scaled to on unit of product (functional unit). Use the button 'Toggle Scaled/Normal View' to switch between the two values before exporting the footprint logo.

18 Scripting in Umberto

Advanced user can use scripting as an additional variant of describing process specifications.

The script language supported is IronPython.

In this chapter find a summary description of the scripting feature.

Scripting support is an integrated component of Umberto. It is not necessary to install any additional software. However, in some cases it might be helpful to have access to a full local installation of IronPython: This will enable you to verify code snippets or stepping through code.

The installation routine for IronPython can be downloaded at ironpython.net

Organizing Code: Program code can be organized in two different ways. Either the program code is fully written in the process specification, or Python modules are stored outside of the Umberto environment.

The latter allows maintaining a rather lean code in the process specification in Umberto that basically calls external code. Another advantage is that developer tools (IDEs, unit testing, etc.) for Python can be used, and code can be organized in modules, classes etc. A downside of this way or organizing your code is that handing over Umberto projects to other users requires that in addition to the .umberto file the external source code must also be delivered and copied to the correct location on the target machine.

There are two locations where external libraries and source code should be stored to make the accessible for scripts in process specifications:

Third party extensions delivered by ifu Hamburg and other third-party suppliers are by default stored in the subdirectory "python\dll" of the Umberto installation directory (typically "c:\Program Files\ifu Hamburg\Umberto LCAPlus\"). To make changes to this directory administrator rights might be required.

For extensions created by the user two additional search paths to directories can be defined. Call the 'Options' dialog from the 'Tools' menu and switch to the tab 'Scripting':

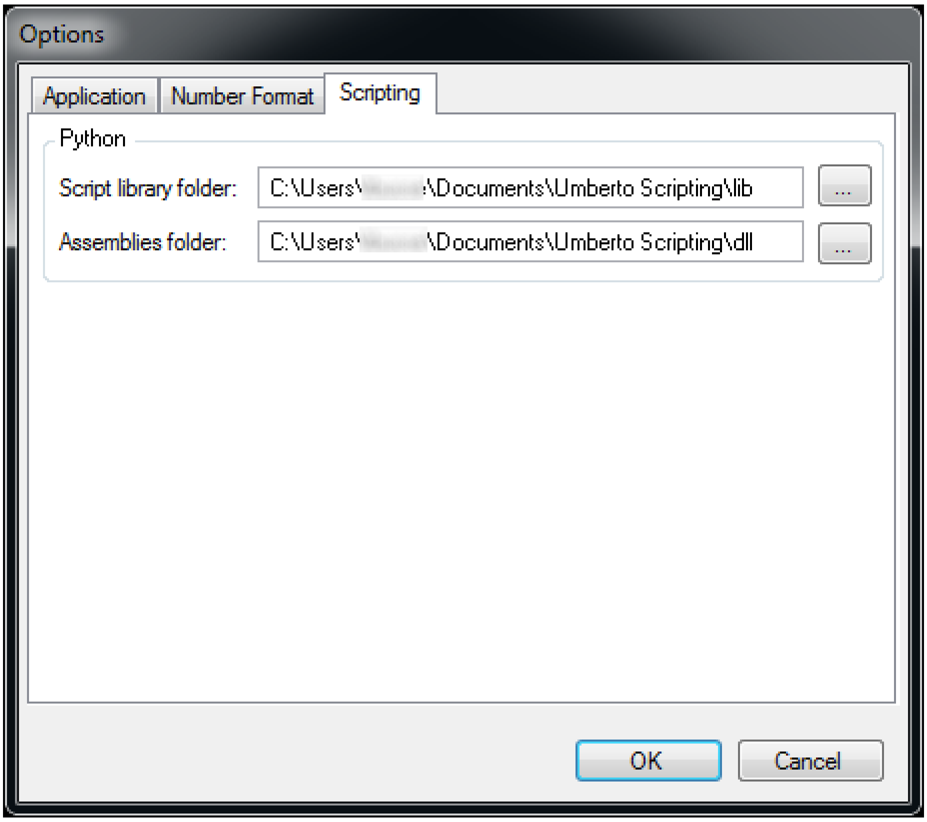


Figure 134: Setting directory path for script library folder and assemblies

The "Script Library Folder" can be used for storing Python modules. The "Assemblies Folder" can be used for.NET libraries (assemblies) that can then be included and used in scripts.

Process Specification with Scripting: To be able to specify a process with an IronPython script, it has first to be prepared to accept scripting code.

To do this, open the context menu of the process and choose "Python":

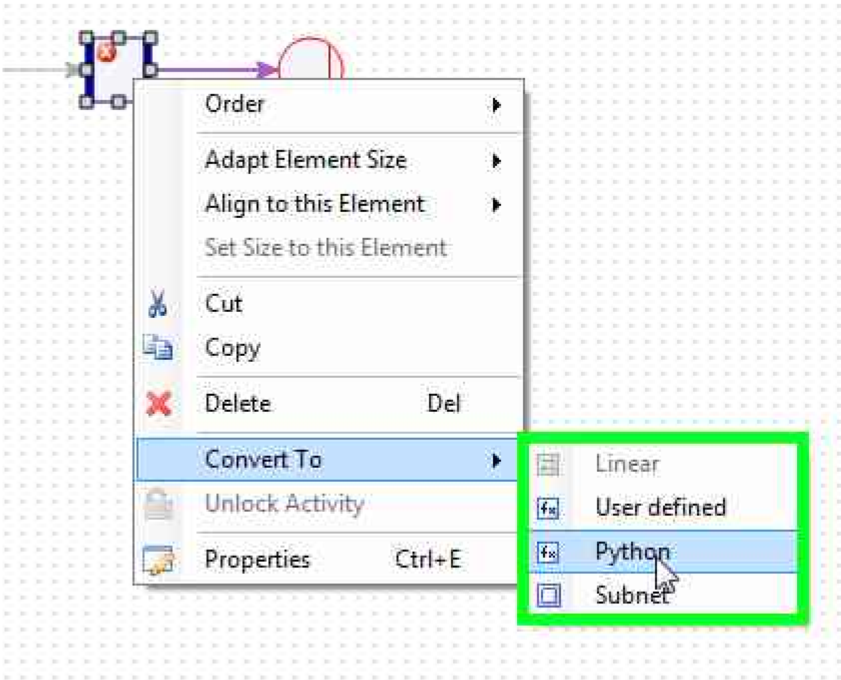


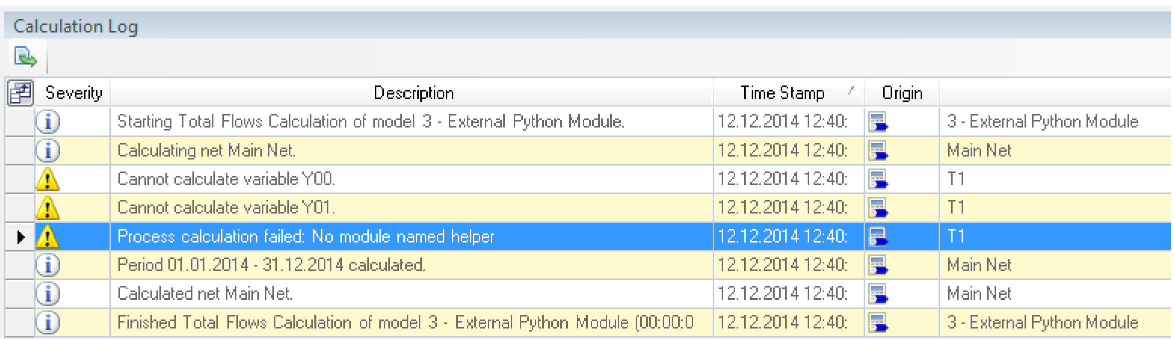
Figure 135: Context menu of the process, setting the specification type to "Python"

The other ("traditional") variants of process specification (linear input/output coefficient, user defined functions, subnet) are described in chapter 9 of the user.

Use the command "Edit User Defined Functions" from the context menu to access and edit scripting code. An editor window opens where source code can be written and edited. Changes are saved as soon as you click outside the editor window in another area of Umberto.

It is possible to access information and data. Typically properties can be accessed using their identifiers. The scripting documentation details the interfaces to address properties and their values in a process specification.

Calculation Errors and Messages: In case running a script yields any errors, they will be written to the calculation log:


Calculation Log

Severity	Description	Time Stamp	Origin	
	Starting Total Flows Calculation of model 3 - External Python Module.	12.12.2014 12:40:		3 - External Python Module
	Calculating net Main Net.	12.12.2014 12:40:		Main Net
	Cannot calculate variable Y00.	12.12.2014 12:40:		T1
	Cannot calculate variable Y01.	12.12.2014 12:40:		T1
	Process calculation failed: No module named helper	12.12.2014 12:40:		T1
	Period 01.01.2014 - 31.12.2014 calculated.	12.12.2014 12:40:		Main Net
	Calculated net Main Net.	12.12.2014 12:40:		Main Net
	Finished Total Flows Calculation of model 3 - External Python Module (00:00:0	12.12.2014 12:40:		3 - External Python Module

Figure 136: Entries in the calculation log linked to the calculation of a process

It is also possible to write your own messages to the calculation log by using the function `log.Add("<TEXT>")`. For outputting values etc. the Python Format Operator `%` is useful.

Note that the scripting feature is in a first implementation stage and that further options and functionality will be added in future versions. Should you have comments or questions, please feel free to contact support@umberto.de

Annex A: LCIA Methods available from ecoinvent

The following list shoes the Life Cycle Impact Assessment methods (LCIA methods) shipped in Umberto LCA+. These methods and the individual characterization factors are provided by ecoinvent.

Please visit http:///www.ecoinvent.org and read the ecoinvent report No. 3 Roland Hischier, Bo Weidema (Editors):'Implementation of Life Cycle Impact Assessment Methods Data v2.2 (2010)' for further details.

LCIA Method	Short Description
CML2001	Developed by Center of Environmental Science of Leiden University (http://www.cml.leiden.edu/) see Guinée et al. 2001 and ecoinvent report No. 3 (2010), pp. 24-32. *Mind that this LCIA Method has been updated several times since its first release and that version published by ecoinvent does not necessarily reflect the latest published version. Please check the ecoinvent documentation for details.*
CML2001 w/o LT	As above for CML2001, but without long-term (LT) effects see Guinée et al. 2001 ecoinvent report No. 3 (2010), pp. 24-32.
cumulative energy demand	LCIA method "Cumulative Energy Demand (CED)" Own concept by ecoinvent, see ecoinvent report No. 3 (2010), pp. 33-40. *In ecoinvent v2.2 there were 14 elementary exchanges considered in this impact method. Mind that some of these elementary exchanges do not exist anymore in ecoinvent v3. Please check the ecoinvent documentation for details.*
cumulative exergy demand	LCIA method "Cumulative Exergy Demand (CExD)" see Boesch et al. 2007 and ecoinvent report No. 3 (2010), pp. 41-45. *Mind that some of the elementary exchanges available on ecoinvent v2.2 do not exist anymore in ecoinvent v3. Please check the ecoinvent documentation for details.*
eco-indicator 99 (E,E)	LCIA method developed by a group of scientists and available in different perspectives/weighting sets: (E,E) = Egalitarian, Egalitarian weighting. see Goedkoop & Spriensma 2000 and ecoinvent report No. 3 (2010), pp. 46-60.
eco-indicator 99 (E,E) w/o LT	As above for eco-indicator 99 (E,E), but without long-term (LT) effects.
eco-indicator 99 (H,A)	LCIA method developed by a group of scientists and available in different perspectives/weighting sets: (H,A) = Hierarchist, Average weighting. see Goedkoop & Spriensma 2000 and ecoinvent report No. 3 (2010), pp. 46-60.
eco-indicator 99 (H,A) w/o LT	As above for eco-indicator 99 (H,A), but without long-term (LT) effects.
eco-indicator 99 (I,I)	LCIA method developed by a group of scientists and available in different perspectives/weighting sets: (I,I) = Individualist, Individualist weighting.

	see Goedkoop & Spriensma 2000 and ecoinvent report No. 3 (2010), pp. 46-60.
ecological footprint	see Huijbregts et al. 2006 and ecoinvent report No. 3 (2010), pp. 73/74.
ecological scarcity 1997	LCIA Method also known as 'Umweltbelastungs-punkte (UBP'97)' see Brand et al. 1998 and ecoinvent report No. 3 (2010), pp. 75-86.
ecological scarcity 2006	see Frischknecht et al. 2009 and ecoinvent report No. 3 (2010), pp. 87/88.
ecological scarcity 2013	Updates to ecological scarcity 2006
ecosystem damage potential	see Köllner & Scholz 2007 and ecoinvent report No. 3 (2010), pp. 62-71.
EDIP	LCIA method from Denmark, "Environmental Design of Industrial Products". see Hauschild & Wenzel 1997, DK LCA Center 2007 and ecoinvent report No. 3 (2010), pp. 89-96.
EDIP w/o LT	As above for EDIP, but without long-term (LT) effects. see Hauschild & Wenzel 1997, DK LCA Center 2007 and ecoinvent report No. 3 (2010), pp. 89-96.
EDIP 2003	LCIA method from Denmark. see Hauschild & Potting 2005 and ecoinvent report No. 3 (2010), pp. 97-101.
EDIP 2003 w/o LT	As above for EDIP 2003, but without long-term (LT) effects. see Hauschild & Potting 2005 and ecoinvent report No. 3 (2010), pp. 97-101.
EPS 2000	LCIA method from Sweden see Steen 1999 and ecoinvent report No. 3 (2010), pp. 102-118.
IMPACT 2002+ Midpoint	see Jolliet et al. 2003 and ecoinvent report No. 3 (2010), pp. 119-124.
IMPACT 2002+ Endpoint	see Jolliet et al. 2003 and ecoinvent report No. 3 (2010), pp. 119-124.
IPCC 2001	see Albritton & Meira-Filho 2001; IPCC 2001 and ecoinvent report No. 3 (2010), pp. 126-134.
IPCC 2007	IPCC 2007 and ecoinvent report No. 3 (2010), pp. 136-142. Updated again with ecoinvent v3.2 in November 2015 (see Bourgault G (2015). Implementation of IPCC impact assessment method 2007 and 2013 to ecoinvent database 3.2)
IPCC 2007 no LT	Implementation of IPCC 2007 without long-term effects. Updated again with ecoinvent v3.2 in November 2015 (see Bourgault G (2015). Implementation of IPCC impact assessment method 2007 and 2013 to ecoinvent database 3.2)
IPCC 2013	Updates to IPCC2007, reflecting data from Fifth Assessment Report (AR5). GWP20a, GTP20a, GWP100a, GTP100a. Updated again with ecoinvent v3.2 in November 2015 (see Bourgault G (2015). Implementation of IPCC impact assessment method 2007 and 2013 to ecoinvent database 3.2)
IPCC 2013 no LT	Implementation of IPCC 2013 without long-term effects. Updated again with ecoinvent v3.2 in November 2015 (see Bourgault G (2015).

	Implementation of IPCC impact assessment method 2007 and 2013 to ecoinvent database 3.2)
ReCiPe Endpoint (E,A)	ReCiPe LCIA Method with results available as midpoints and endpoints, and with different perspectives/ weighting sets: (E,A) = Egalitarian, Average weighting see Goedkoop M., Heijungs R., de Schryver A., Struijs J. and van Zelm R. (2009): ReCiPe 2008 - A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level / Report I: Characterisation. Ministerie van VROM, Den Haag. Online-Version under: www.lcia-recipe.net. and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Endpoint (E,A) w/o LT	As above for ReCiPe Endpoint (E,A), but without long-term (LT) effects. see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Endpoint (H,A)	ReCiPe LCIA Method, results on endpoints level (H,A) = Humanitarian, Average weighting see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Endpoint (H,A) w/o LT	As above for ReCiPe Endpoint (H,A), but without long-term (LT) effects. see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Endpoint (I,A)	ReCiPe LCIA Method, results on endpoints level (I,A) = Individualist, Average weighting see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Midpoint (E)	ReCiPe LCIA Method, results on midpoints level (E) = Egalitarian see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Midpoint (E) w/o LT	As above for ReCiPe Midpoint (E), but without long-term (LT) effects. see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Midpoint (H)	ReCiPe LCIA Method, results on midpoints level (H) = Humanitarian see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Midpoint (H) w/o LT	As above for ReCiPe Midpoint (H), but without long-term (LT) effects. see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
ReCiPe Midpoint (I)	ReCiPe LCIA Method, results on midpoints level (I) = Individualist see Goedkoop et al. 2009 and ecoinvent report No. 3 (2010), pp. 143-148.
selected LCI results	A collection of inventory elements, by ecoinvent See ecoinvent report No. 3 (2010), pp. 161-163.
selected LCI results, additional	A collection of inventory elements, by ecoinvent See ecoinvent report No. 3 (2010), pp. 161-163.
TRACI	Tool for the Reduction and Assessment of Chemical and other environmental Impacts. A midpoint-

	oriented methodology developed specifically for the US. http://www.epa.gov/nrmrl/std/traci/traci.html see Bare 2004; Bare J. C. et al. 2007 and ecoinvent report No. 3 (2010), pp. 149-155. *Note: The ecoinvent implementation of TRACI excludes the impact categories 'fossil fuel depletion', 'land use' and 'water use'.* *Note: The version delivered in ecoinvent is TRACI 2.0, last changes 2010.*
UseTox	LCIA Method that comprises primarily human toxicity and ecotoxicity effects: see Rosenbaum et al. 2008 and ecoinvent report No. 3 (2010), pp. 156-160.
UseTox w/o LT	As above for UseTox, but without long-term (LT) effects. see Rosenbaum et al. 2008 and ecoinvent report No. 3 (2010), pp. 156-160.

Note that additional or new impact assessment methods are once provided in Umberto LCA+ once they are added officially to the ecoinvent database. Therefore these LCIA methods do not always represent the latest published version.

Warning: Mind that some published updates to the impact assessment methods have not been implemented by ecoinvent. Hence the practitioner should check the characterization factors carefully, to see whether the factors represent the latest published values or not.

Annex B: LCIA Methods available from GaBi database

The following list contains the Life Cycle Impact Assessment methods (LCIA methods) shipped with the GaBi databases. These methods and the individual characterization factors are provided by the makers of the GaBi databases.

The following list of impact assessment methods is specific to GaBi LCI databases. They can only be used for Umberto LCA+ projects, where the exchanges from GaBi databases have been used. Impact assessment for exchanges from the ecoinvent databases will not work for these.

<table>
<tr><th>LCIA Method</th><th>Short Description</th></tr>
<tr><td>CML 2001</td><td>CML 2001 LCIA method with updates made up to April 2013.
<table>
<tr><td>CML2001 - Apr. 2013, Abiotic Depletion (ADP elements)</td><td>kg Sb-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Abiotic Depletion (ADP fossil)</td><td>MJ</td></tr>
<tr><td>CML2001 - Apr. 2013, Acidification Potential (AP)</td><td>kg SO2-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Eutrophication Potential (EP)</td><td>kg Phosphate-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.)</td><td>kg DCB-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Global Warming Potential (GWP 100 years)</td><td>kg CO2-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Global Warming Potential, excl biogenic carbon (GWP 100 years)</td><td>kg CO2-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Human Toxicity Potential (HTP inf.)</td><td>kg DCB-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Marine Aquatic Ecotoxicity Pot. (MAETP inf.)</td><td>kg DCB-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Ozone Layer Depletion Potential (ODP, steady state)</td><td>kg R11-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Photochem. Ozone Creation Potential (POCP)</td><td>kg Ethene-Equiv.</td></tr>
<tr><td>CML2001 - Apr. 2013, Terrestric Ecotoxicity Potential (TETP inf.)</td><td>kg DCB-Equiv.</td></tr>
</table>
For more information visit http://www.cml.leiden.edu/software/data-cmlia.html</td></tr>
<tr><td>EDIP 2003</td><td>The LCIA method EDIP 2003 as provided in the GaBi database:
<table>
<tr><td>EDIP 2003, Acidification potential</td><td>m2 UES</td></tr>
<tr><td>EDIP 2003, Aquatic eutrophication</td><td>kg NO3-Equiv.</td></tr>
<tr><td>EDIP 2003, Global warming</td><td>kg CO2-Equiv.</td></tr>
<tr><td>EDIP 2003, Photochemical ozone formation - impact on human health and materials</td><td>pers*ppm*hours</td></tr>
<tr><td>EDIP 2003, Photochemical ozone formation - impact on vegetation</td><td>m2 UES*ppm*hours</td></tr>
<tr><td>EDIP 2003, Stratospheric ozone depletion</td><td>kg R11-Equiv.</td></tr>
<tr><td>EDIP 2003, Terrestrial eutrophication</td><td>m2 UES</td></tr>
</table></td></tr>
<tr><td>Impact 2002+</td><td>The LCIA method Impact 2002+ (released 2012), v2.1 as provided in the GaBi database:</td></tr>
</table>

	I02+ v2.1 - Aquatic acidification - Midpoint	kg SO2-Eq. to air
	I02+ v2.1 - Aquatic ecotoxicity - Midpoint	kg TEG-Eq. to water
	I02+ v2.1 - Aquatic eutrophication - Midpoint	kg PO4-Eq. to water
	I02+ v2.1 - Carcinogens - Midpoint	kg C2H3Cl-Eq. to air
	I02+ v2.1 - Global warming 500yr - Midpoint	kg CO2-Eq. to air
	I02+ v2.1 - Ionizing radiation - Midpoint	Bq C-14-Eq. to air
	I02+ v2.1 - Land occupation - Midpoint	m2*yr-Eq.
	I02+ v2.1 - Mineral extraction - Midpoint	MJ surplus
	I02+ v2.1 - Non-carcinogens - Midpoint	kg C2H3Cl-Eq. to air
	I02+ v2.1 - Non-renewable energy - Midpoint	MJ
	I02+ v2.1 - Ozone layer depletion - Midpoint	kg CFC-11-Eq. to air
	I02+ v2.1 - Photochemical oxidation - Midpoint	kg C2H4-Eq. to air
	I02+ v2.1 - Respiratory effects - Midpoint	kg PM2.5-Eq. to air
	I02+ v2.1 - Terrestrial acidification/nutrification - Midpoint	kg SO2-Eq. to air
	I02+ v2.1 - Terrestrial ecotoxicity - Midpoint	kg TEG-Eq. to soil
Impacts ILCD/PEF recommendation	A set of 15 LCIA factors for different impact categories, taken from different LCIA methods as described in the ILCD Handbook. Acidification, accumulated exceedance Ecotoxicity for aquatic fresh water, USEtox (recommended) Freshwater eutrophication, EUTREND model, ReCiPe Human toxicity cancer effects, USEtox (recommended) Human toxicity non-canc. effects, USEtox (recommended) IPCC global warming, excl biogenic carbon IPCC global warming, incl biogenic carbon Ionising radiation, human health effect model, ReCiPe Marine eutrophication, EUTREND model, ReCiPe Ozone depletion, WMO model, ReCiPe Particulate matter/Respiratory inorganics, RiskPoll Photochemical ozone formation, LOTOS-EUROS model, ReCiPe Resource Depletion, fossil and mineral, reserve Based, CML2002 Terrestrial eutrophication, accumulated exceedance Total freshwater consumption, including rainwater, Swiss Ecoscarcity see: Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors (International Reference Life Cycle Data System - ILCD handbook)	
Land use quantities	A set of 12 indicators for land use (occupation and transformation) Biotic Production Indicator (BP (Occ.)) Biotic Production Indicator (BP (Transf.)) Erosion Resistance Indicator (ER (Occ.)) Erosion Resistance Indicator (ER (Transf.)) Groundwater Replenishment Indicator (GWR (Occ.)) Groundwater Replenishment Indicator (GWR Transf.)) Land Occupation Indicator Land Transformation Indicator Mechanical Filtration Indicator (MF (Occ.)) Mechanical Filtration Indicator (MF (Transf.)) Physicochemical Filtration Indicator (PCF (Occ.)) Physicochemical Filtration Indicator (PCF (Transf.))	

<table>
<tr><td></td><td>For further information see:
Documentation of Land Use Indicator Values in GaBi http://www.gabi-software.com/fileadmin/Documents/landuse.pdf</td></tr>
<tr><td>Primary energy</td><td>A set of six indicators for primary energy consumption, distinguished as renewable/non-renewable, and using gross/net calorific values:

Primary energy demand from ren. and non ren. resources (gross cal. value)
Primary energy demand from ren. and non ren. resources (net cal. value)
Primary energy from non renewable resources (gross cal. value)
Primary energy from non renewable resources (net cal. value)
Primary energy from renewable resources (gross cal. value)
Primary energy from renewable resources (net cal. value)

For further information see Supplement A in:
GaBi Database & Modelling Principles 2013, http://www.gabi-software.com/uploads/media/GaBi_Modelling_Principles_2013.pdf</td></tr>
<tr><td>ReCiPe 1.08 (H)</td><td>ReCiPe LCIA Method, results on midpoints level
(H) = Humanitarian

<table>
<tr><td>ReCiPe 1.08 Midpoint (H) - Agricultural land occupation</td><td>m2a</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Climate change, default, excl biogenic carbon</td><td>kg CO2-Equiv.</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Climate change, incl biogenic carbon</td><td>kg CO2-Equiv.</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Fossil depletion</td><td>kg oil eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Freshwater ecotoxicity</td><td>kg 1,4-DB eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Freshwater eutrophication</td><td>kg P eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Human toxicity</td><td>kg 1,4-DB eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Ionising radiation</td><td>kg U235 eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Marine ecotoxicity</td><td>kg 1,4-DB eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Marine eutrophication</td><td>kg N-Equiv.</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Metal depletion</td><td>kg Fe eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Natural land transformation</td><td>m2</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Ozone depletion</td><td>kg CFC-11 eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Particulate matter formation</td><td>kg PM10 eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Photochemical oxidant formation</td><td>kg NMVOC</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Terrestrial acidification</td><td>kg SO2 eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Terrestrial ecotoxicity</td><td>kg 1,4-DB eq</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Urban land occupation</td><td>m2a</td></tr>
<tr><td>ReCiPe 1.08 Midpoint (H) - Water depletion</td><td>m3</td></tr>
</table></td></tr>
<tr><td>ReCiPe 1.08 (H,A)</td><td>ReCiPe LCIA Method, results on endpoint level
(H, A) = Humanitarian, Average

<table>
<tr><td>ReCiPe 1.08 Endpoint (H) - Agricultural land occupation</td><td>species.yr</td></tr>
<tr><td>ReCiPe 1.08 Endpoint (H) - Climate change Ecosystems, default, excl biogenic carbon</td><td>species.yr</td></tr>
</table></td></tr>
</table>

	ReCiPe 1.08 Endpoint (H) - Climate change Ecosystems, incl biogenic carbon — species.yr ReCiPe 1.08 Endpoint (H) - Climate change Human Health, default, excl biogenic carbon — DALY ReCiPe 1.08 Endpoint (H) - Climate change Human Health, incl biogenic carbon — DALY ReCiPe 1.08 Endpoint (H) - Fossil depletion — $ ReCiPe 1.08 Endpoint (H) - Freshwater ecotoxicity — species.yr ReCiPe 1.08 Endpoint (H) - Freshwater eutrophication — species.yr ReCiPe 1.08 Endpoint (H) - Human toxicity — DALY ReCiPe 1.08 Endpoint (H) - Ionising radiation — DALY ReCiPe 1.08 Endpoint (H) - Marine ecotoxicity — species.yr ReCiPe 1.08 Endpoint (H) - Metal depletion — $ ReCiPe 1.08 Endpoint (H) - Natural land transformation — species.yr ReCiPe 1.08 Endpoint (H) - Ozone depletion — DALY ReCiPe 1.08 Endpoint (H) - Particulate matter formation — DALY ReCiPe 1.08 Endpoint (H) - Photochemical oxidant formation — DALY ReCiPe 1.08 Endpoint (H) - Terrestrial acidification — species.yr ReCiPe 1.08 Endpoint (H) - Terrestrial ecotoxicity — species.yr ReCiPe 1.08 Endpoint (H) - Urban land occupation — species.yr
ReCiPe 1.08 (E)	ReCiPe LCIA Method, results on midpoints level (E) = Egalitarian Same 19 impact categories as above in ReCiPe 1.08 (H)
ReCiPe 1.08 (E,A)	ReCiPe LCIA Method, results on endpoint level (E, A) = Egalitarian, Average Same 19 impact categories as above in ReCiPe 1.08 (H, A)
ReCiPe 1.08 (I)	ReCiPe LCIA Method, results on midpoints level (I) = Individualist Same 19 impact categories as above in ReCiPe 1.08 (H)
ReCiPe 1.08 (I,A)	ReCiPe LCIA Method, results on endpoint level (I, A) = Individualist, Average Same 19 impact categories as above in ReCiPe 1.08 (H, A)
TRACI 2.0	The method TRACI 2.0 (2011) TRACI 2.0, Eutrophication — kg N-Equiv. TRACI 2.0, Ecotoxicity Water — CTUeco TRACI 2.0, Human Health Cancer Water — cases TRACI 2.0, Ecotoxicity Air — CTUeco TRACI 2.0, Human Health Non Cancer Air — cases TRACI 2.0, Global Warming Air — kg CO2-Equiv. TRACI 2.0, Ecotoxicity Soil — CTUeco TRACI 2.0, Human Health Cancer Soil — cases TRACI 2.0, Human Health Non Cancer Soil — cases TRACI 2.0, Smog Air — kg O3-Equiv. TRACI 2.0, Acidification Air — H+ moles-Equiv. TRACI 2.0, Human Health Criteria Air — kg PM10-Equiv. TRACI 2.0, Human Health Cancer Air — cases TRACI 2.0, Human Health Non Cancer Water — cases TRACI 2.0, Ozone Depletion Air — kg CFC 11-Equiv.

	TRACI 2.0, Global Warming Air, excl biogenic carbon kg CO2-Equiv.
TRACI 2.1	The updated method TRACI 2.1 (2012) as provided in the GaBi database: TRACI 2.1, Acidification — kg SO2-Equiv. TRACI 2.1, Ecotoxicity (recommended) — CTUe TRACI 2.1, Eutrophication — kg N-Equiv. TRACI 2.1, Global Warming Air, excl. biogenic carbon — kg CO2-Equiv. TRACI 2.1, Global Warming Air, incl. biogenic carbon — kg CO2-Equiv. TRACI 2.1, Human Health Particulate Air — kg PM2,5-Equiv. TRACI 2.1, Human toxicity, cancer (recommended) — CTUh TRACI 2.1, Human toxicity, non-canc. (recommended) — CTUh TRACI 2.1, Ozone Depletion Air — kg CFC 11-Equiv. TRACI 2.1, Resources, Fossil fuels — MJ surplus energy TRACI 2.1, Smog Air — kg O3-Equiv. For further information see: GaBi Database & Modelling Principles 2013, http://www.gabi-software.com/uploads/media/GaBi_Modelling_Principles_2013.pdf
Technical quantities	Two summary indicators for energy: Energy (gross calorific value) Energy (net calorific value)
USETox	USEtox LCIA method, published 2010 by researchers from the task force on toxic impacts under the UNEP SETAC Life Cycle Initiative. USEtox, Ecotoxicity (recommended) — CTUe USEtox, Human toxicity, cancer (recommended) — CTUh USEtox, Human toxicity, non-canc. (recommended) — CTUh
Water	Four water quantities for water foot printing and water assessments available for GaBi datasets: Blue water consumption Blue water use Total freshwater consumption (including rainwater) Total freshwater use For further information see Supplement A in: GaBi Database & Modelling Principles 2013, http://www.gabi-software.com/uploads/media/GaBi_Modelling_Principles_2013.pdf

Annex C: Migration of projects from Umberto 5.6 LCA to Umberto LCA+

Many Umberto users have been working with Umberto for Life Cycle Assessment 5.6 (or predecessor versions) for years. This section gives advice on how to make step from an old Umberto 5 version to the newest version, carrying over models from the old version.

Umberto LCA+ is implemented on a completely new technical platform. Many adaptations have been made to cater for the new EcoSpold v2 data format and to be able to use all the new features of the ecoinvent v3 datasets. It is therefore not possible to directly continue working with projects created in Umberto 5.6. The projects have to be migrated (i.e. converted) so that they can be opened in Umberto LCA+.

A migration tool is available to handle the conversion task. It is made available to Umberto 5.6 customers as a separate installer. This section briefly explains how the migration tool is used and how the conversion procedure works. It also points out some of the points that might require attention of the user after a successful migration of the projects to Umberto LCA+.

Given the changes between ecoinvent v2.2 datasets (EcoSpold v1 data format) and ecoinvent v3 datasets (EcoSpold v2 data format) described partially in Annex B, the conversion might in some cases not be lossless.
Users who need support for the migration of their Umberto 5.6 LCA projects to Umberto LCA+ should contact us for advice: support@umberto.de

Migration is possible for project databases of Umberto 5.5 and Umberto 5.6. If you are still running older versions of the software, please update to the latest version of the Umberto 5 product line first.

Installation
The migration tool is shipped as a separate installer file. It requires an existing Umberto LCA+ installation. Make sure that the Umberto LCA+ installation is the newest one and corresponds to the version of the migration tool:

- Umberto LCA+: version 7.0.8.XXXX or higher
- Migration tool: model_migration_tool_for_umberto-lcaplus-vXXXX.exe

The installation of the migration tool is done by clicking on the executable file. It is recommended that Umberto 5.6 is also installed on the same computer. If there is an existing Umberto 5.6 installation, the migration tool can access the project database using the installed Firebird server. Otherwise it will use the embedded Firebird driver.

On 32-bit Windows operating system users can choose to use the installed Firebird server or the embedded Firebird driver. On 64-bit Windows operating system the embedded Firebird driver is not available and users must use an installed 32-bit Firebird server. Contact our support if in doubt.

After installation the migration tool is integrated into the Umberto LCA+ installation and can be run with the command "Migrate a Umberto 5 Database" from the File menu.

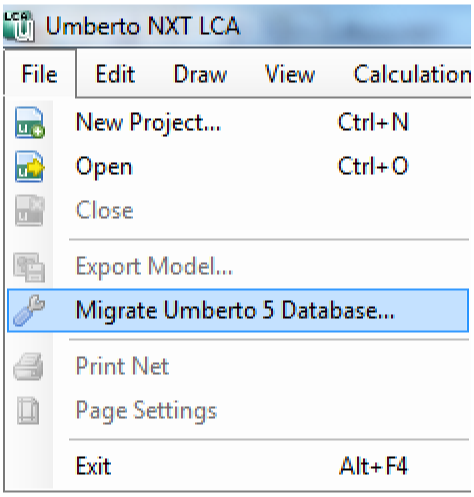


Figure 137: After installing the migration tool, it can be called from the File menu

The source file for the migration is an Umberto 5.6 for Life Cycle Assessment database (Firebird database file, .gdb file). The user selects the projects that need to be migrated from the project database. The target files are .umberto files that can be opened in Umberto LCA+.

The source file (the original Umberto 5.6 project database) will not be modified during the migration process. It can still be used with Umberto 5.6. Nevertheless we suggest that you make a backup copy of the project database (.gdb file).

Preparation for Migration of Projects

Since the migration is a time-consuming process, we recommend that you first identify the projects from your Umberto 5.6 project database that need to be migrated to Umberto LCA+. You might want to consider whether a project has already been terminated, or if it will still be worked on (extended, modified). We remember that – in case you have an indefinite Umberto 5.6 license – it will still be possible to open, run and modify models in the old software version. You can still decide to migrate legacy projects at a later point in time (given that the .gdb file is still available/accessible).

Running the Migration

The migration procedure is described hereafter step-by-step:

- Make sure the source Umberto 5.6 project database file (.gdb file) is accessible on your computer or on an external drive (Note that having the .gdb file locally on your drive allows for a faster migration).
- Launch the migration tool in Umberto LCA+ with the command "Migrate a Umberto 5 Database" from the File menu.
- You will be prompted for a name for the new (target) project.
- The migration tool dialog (window) opens. It allows selecting the Umberto 5.6 project database file (.gdb file). Use the button with three dots to browse for the file on your file system.

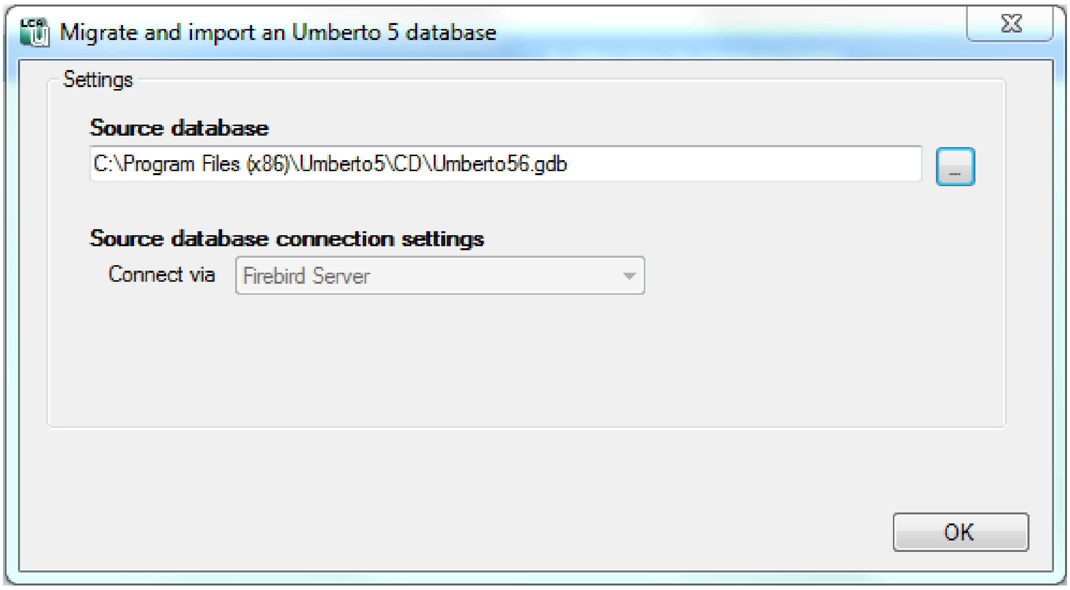


Figure 138: Migration tool, choosing the source Umberto 5.6 project database

- If a Firebird Server is installed on the computer, the migration will use it to access the Umberto 5.6 project database. On 32-bit machines there is also the option to use choose the Embedded Firebird Driver. On 64-bit machines it is indispensable to use the Firebird Server for the connection, as 64-bit Embedded Firebird drivers are not available.
- Click 'OK' to connect to the database. The migration tool will analyse the content of the project database. Note that for very large Umberto project databases this process may take 1 or 2 minutes.

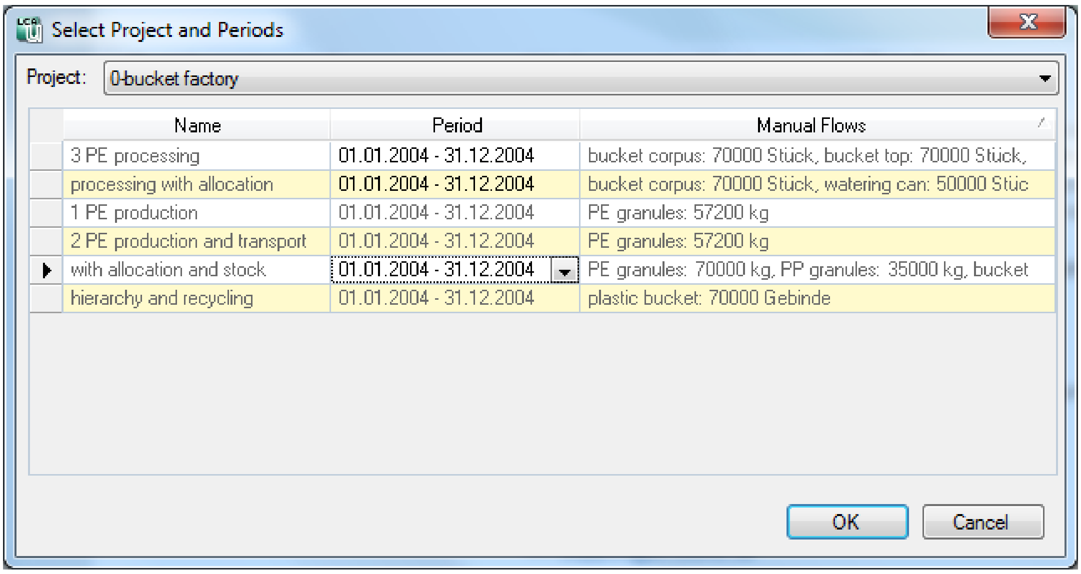


Figure 139: Migration tool, selecting one project from the Umberto 5.6 project database

- The next window that appears in the migration process is "Select Project and Periods". Since in Umberto LCA+ each project file (.umberto file) contains exactly one project, it is necessary to choose one project to migrate at this point. Use the dropdown list "Project" to select the project. Note that if you want other projects to be converted, the process has to be repeated. Projects are migrated one-by-one.

- All scenarios of the selected project are migrated. They are shown in the list with their name and the periods that have been defined in the scenario. In case there is only one period defined, it is shown in grey font. If there is more than one period, it is shown in black font and the user can select the period for which he/she wishes to migrate the manual flow. The manual flow(s) are shown for the selected period in the third column. Note that the scenarios in Umberto 5.6 are the same for all periods defined. The difference is only in the manual flow that might be different from period to period.
- Click 'OK' to start the migration of the selected project. Note that for large Umberto project databases this process may take 1 or 2 minutes.
- The next dialog "Assign Import Units to Unit Types" only appears, if there are unknown material basic units in the selected project file that is migrated. The default basic units (e.g. the units used in the ecoinvent v2.2 database in Umberto 5.6) are automatically matched to the units and unit types that exist in Umberto LCA+ with ecoinvent v2.2 and/or ecoinvent v3 database (see Annex D for a complete list).
  However, the user might have defined new basic units in Umberto 5.6 that cannot be automatically matched to the basic units defined as master data in Umberto LCA+. Only these will be listed in the dialog. Display units are not migrated since unit types already have display units defined. Units of parameters are added automatically. Note that units that have already been assigned once are added to the assignment list in the background and will not be shown again next time.

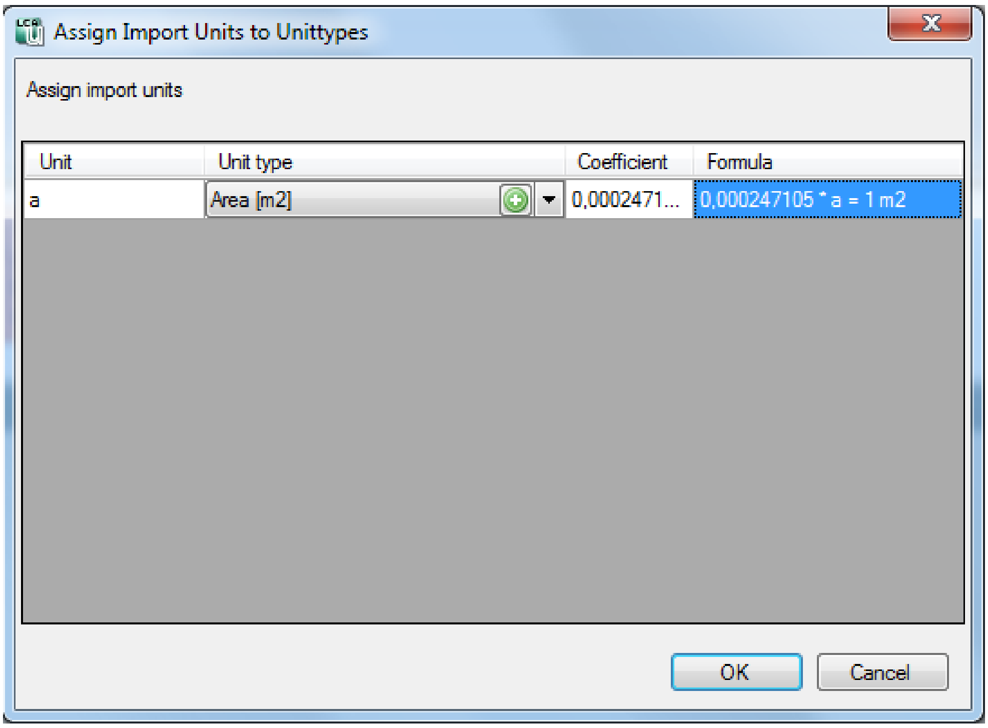


Figure 140: Migration tool, assigning new units from the Umberto 5.6 project

- It is required that for each unknown material basic unit an assignment is made to an existing unit type, or, a unit type is defined in Umberto LCA+ and the unknown basic unit assigned to it.
  To assign to an existing unit type, select one from the dropdown list.

The conversion formula can be checked in the "Formula" column.
Example: The user defined basic unit "Pounds" ('lbs') can be assigned to unit type "Mass" (with basic unit 'kg'). The conversion coefficient is "2.2046226218487757" (2.2046226218487757 lbs = 1.00 kg).
If no appropriate unit type can be found among the pre-defined existing unity types in the dropdown list, it might be an option to add a unit type in Umberto LCA+ and assign the unit to this new unit type.
To do this, click on the button with the green "plus" icon in the "Coefficient" column. Enter a name for the new unit type in the dialog box. The new unit type will be added to the list of unit types in Umberto LCA+, with the basic unit from the Umberto 5.6 project as basic unit.

- Click 'OK' when all units have been assigned to complete the preparation, and actually start the migration of the selected project. Note that for large Umberto projects, especially those containing many net elements and many ecoinvent datasets, the migration process may take up to 20 minutes (depending on the memory of your computer). Please be patient, and remember that this process has to be executed only once to be able to use the model in Umberto LCA+ in the future.
- The migrated and converted project will be stored under the name and in the path you chose for the target file at the beginning (typically the directory C:\Users\<username>\Documents\Umberto LCA+). Alongside in same the same directory a log file in three different formats (CSV, TXT, and XLSX) will be stored. It is named "<projectname>_migrationreport_130522-1029.xlsx". You will be offered to view the migration report in Excel. It contains "infos" and "warnings" and some statistics (e.g. information on dropped objects). The log file can be filtered, e.g. to view only the messages for one specific model of the migrated project.
- The converted project file will not be opened automatically. Use the "Open Project" command in Umberto LCA+, or double click on the .umberto file.

The migration tool aims to convert Umberto 5.6 LCA projects in such a way that the graphical structure of the model is maintained and that the specification of the model remains identical.

For each project all scenarios (called models in Umberto LCA+) are migrated with the manual flow of the period that has been selected. The hierarchical model structure is maintained and subnets of a model are transferred.

Ecoinvent v2.2 modules used in the Umberto 5.6 model will be matched with the corresponding process module from the ecoinvent v2.2 master material database in Umberto XT LCA and materials (intermediate and elementary exchanges) will be assigned correctly.

The calculation algorithm in Umberto 5.6 and in Umberto LCA+ is the same, so that the migrated model produces the same results.

Objects that are not migrated to Umberto LCA+
There are however, some differences between Umberto 5.6 and Umberto LCA+. This is due to the fact that the Umberto LCA+ version does not support

some features of Umberto 5.6, and in some cases handles them in a different way.

The data migration has the following limitations:

- Only one period is migrated, since Umberto LCA+ doesn't support multiple periods for models.
- The places of the combined type "Input/Output" are split into two separate places (one input place and one output place) since this place type ceases to exist in Umberto. Should there be a stock of material in the Input/Output place, it will be transferred as initial stock onto the Input place.
- Synonyms of materials (in Umberto 5.6 on the "Synonyms" tab of the "Edit Material" window) are not migrated.
- Display units are not migrated. The unit types defined in Umberto LCA+ have their own unit types. The handling of the functional unit in Umberto LCA+ is different from the definition of the Functional Unit in Umberto 5.6. See sections 6.3 and 10.1 in this user manual.
- Sankey colors defined for materials in the Umberto 5.6 LCA models will not be migrated. Instead a new color will be assigned.
- Images on frames are not supported by the migration tool
- The layer order of elements when having overlapping graphical elements in the model may possibly not be the same in the migrated model. Use the "Element Order" commands in Umberto LCA+ to modify the order.

The following objects are (at present) not supported by the data migration tool:

- Self defined impact assessment methods (valuation systems). In contrast to the handling of the LCA step in Umberto 5.6, impact assessment is now handled via material properties (characterization factors are defined as properties of elementary exchanges, see section 6.5 and chapter 12 in this user manual). In Umberto LCA+ it is at present only possible to use the impact assessment methods supplied by ecoinvent (see Annex A). In the future there will be a possibility to define own characterization factors and key performance indicators.
- Input vectors defined in the Input Monitor are not supported in Umberto LCA+.
- Stored balance sheets (inventories) are not transferred to Umberto LCA+. Users should export stored inventories to Excel.
- Individual user rights to one project ("Project Authority") and encryption of scenario or transition are not supported by the migration tool.
- Literature sources are not are not supported by the migration tool.

Using the Migrated Project in Umberto LCA+

For typical LCA models built in Umberto 5.6 the migrated Umberto LCA+ will calculate immediately after being opened in the new software.

The user should verify the migration, and check the model for processes that show red markers as warning. The log file of the migration also highlights processes that could not be migrated properly.
These processes typically need manual adaptation in order to make them calculable. Two cases are known to require manual intervention:

- One-sided generic materials (i.e. transitions where a generic material is used only on the input or on the output side) will be marked as process warning in Umberto LCA+.
- Processes that didn't have a reference flow could still be calculated in Umberto 5.6 but the calculation in Umberto LCA+ is more strict in its requirement that every process must have a reference flow (see section 10.1, a reference flow of a process is automatically identified as the output flow that has a green material type, or an input flow that has a red material type).

Example of a modelling structure that is not allowed in Umberto LCA+ anymore, but was possible in Umberto 5.6. The disposal or waste treatment process is an input with the same quantity as the material to be disposed of. The output side is empty. This is a sink of material.

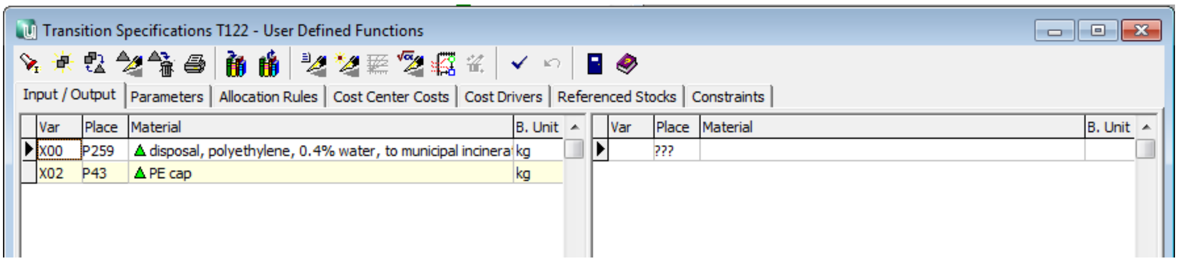


Figure 141: "Dead end" waste treatment modelling in Umberto 5.6 with no output.

Such a situation must now be modelled either as a process with a virtual reference flow (that describes the benefit, the service of the treatment process), or, requires the material to be disposed of to have a red material type.

Support for Migration

Users who need support for the migration of their Umberto 5.6 LCA projects to Umberto LCA+ should contact us for advice: support@umberto.de

Annex D: Unit Types and Units in Umberto LCA+

The following is a list of unit types for materials (exchanges), and the units contained within the unit type and their conversion factor.

This list is derived from the unit types provided in ecoinvent v2.2 and v3. Some alternative ways of writing have been introduced allowing to match materials which have slightly different unit names.

Unit Type	Unit	Coefficient	
Amount	unit	1	Basic Unit
Area	m2	1	Basic Unit
	m**2	1	
	m²	1	
	acre	4046856	
	cm2	0.0001	
	dm2	0.01	
	ha	10000	
	km2	1000000	
	mm2	0,000001	
	sq.ft	0.09290304	
	sq.in	0.00064516	
	sq.mi	2589988	
	sq.yd	0.8361273	
Area per year	m2*year	1	Basic Unit
	cm2a	0.0001	
	haa	10000	
	km2a	1000000	
	mm2a	0.000001	
Currency	EUR	1	Basic Unit
	EUR2004	1	
	EUR2005	1	
	EUR2005basic	1	
	EUR2006	1	
	EUR2007	1	
	EUR2008	1	
	EUR2009	1	
	EUR2010	1	
	DM	0.51129	
	USD	0.8	
Dimensionless	n	1	Basic Unit
	pcs	1	
	piece	1	
	units	1	
	%	0.01	
Energy	MJ	1	Basic Unit

	Btu	0.001055696	
	GJ	1000	
	J	0.000001	
	kcal	0.0041855	
	kJ	0.001	
	kWh	41428	
	MWh	3600	
	PJ	1000000000	
	TJ	1000000	
	Wh	0.0036	
Length	m	1	Basic Unit
	æm	0.000001	
	cm	0.01	
	dm	0.1	
	ft	0.3048	
	inch	0.0254	
	km	1000	
	mile	1609.35	
	mm	0.001	
	yard	0.9144	
Length-Time	my	1	Basic Unit
	m*year	1	
	km*year	1000	
	miy	1609.35	
Mass	kg	1	Basic Unit
	æg	0.000000001	
	g	0.001	
	kton	1000000	
	lb	0.4535924	
	mg	0.000001	
	Mtn	1000000000	
	ng	1E-12	
	oz	0.02834952	
	pg	1E-15	
	t	1000	
	tn.lg	1016047	
	tn.sh	9071848	
	ton	1000	
Mass-Time	kg*day	1	Basic Unit
Mass Flow Rate	kg/s	1	Basic Unit
	µg/s	1E-09	
	g/h	2.77777778E-07	
	g/s	1E-03	
	kg/a	3,16880878E-08	new
	kg/h	2.77777778E-04	
	kton/h	277.77777778	

	lb/h	1.26111111E-04	
	lb/s	0.454	
	mg/h	2.77777778E-10	
	mg/s	1E-06	
	Mt/h	277777.77777778	
	ng/s	1E-12	
	oz/h	0.000007875	
	oz/s	0.02835	
	t/a	3,16880878E-05	new
	t/h	2.77777778E-01	
	t/s	1000	
Power	kW	1	Basic Unit
	Btu/h	3798	
	Btu/s	1.055	
	GW	1E09	
	hp	0.7457	
	kcal/s	4.186	
	MW	1000	
	TW	1E06	
	W	0.001	
Radioactivity	kBq	1	Basic Unit
	Bq	0.001	
Time	s	1	Basic Unit
	day	86400	
	hour	3600	
	min	60	
	week	604800	
	year	31557600	
Transport Mass	metric ton*km	1	Basic Unit
	kgkm	0.001	
	ktkm	1000	
	tmi	145997	
Transport Persons	person*km	1	Basic Unit
Volume	m3	1	Basic Unit
	m**3	1	
	m³	1	
	Nm3	1	
	cm3	0.000001	
	cu.ft	0.02831685	
	cu.in	1.63871	
	cu.yd	0.7645549	
	dm3	0.001	
	gal (UK)	0.004546092	
	gal (US)	0.003785412	
	l	0.001	
	mm3	0.000000001	

Volume per year	m3*year	1	Basic Unit
Groundwater Replenishment (Occ.)	mm*m2	1	GaBi specific
Mechanical Filtration (Occ.)	cm*m3	1	GaBi specific
Physicochemical Filtration (Occ.)	(cmol*m2*a)/kg	1	GaBi specific
Groundwater Replenishment (Transf.)	(mm*m2)/a	1	GaBi specific
Mechanical Filtration (Transf.)	cm*m2/d	1	GaBi specific
Physicochemical Filtration (Transf.)	(cmol*m2)/kg	1	GaBi specific

The following are pre-defined units used for parameters. These are merely text strings as units of parameters and are not used for calculation.

Parameter Units		
	BTU/kg	
	g/mol	
	hour/m3	
	hour/year	renamed from "h/year" in ecoinvent 3 (v3.00)
	K	
	kg N/ha	
	kg N2O-N/kg N	
	kg N2O-N/kg NH3-N	
	kg N2O-N/kg NO3-N	
	kg NH3-N	
	kg NO3-N/ha.year	
	kg NOx/kg N2O	
	kg P/ha.year	
	kg P2O5/ha	
	kg PO4/ha	
	kg TAN/kg TAN	
	kg/(head.d)	
	kg/(kg vehicle*km)	
	kg/(m2*year)	renamed from "kg/(m2*yr)" in ecoinvent 3 (v3.00)
	kg/GJ	
	kg/ha	
	kg/kg	
	kg/kg vehicle	
	kg/kWh	
	kg/l	
	kg/m	
	kg/m2	
	kg/m3	
	kg/s	
	kg/unit	
	km/hour	
	kW	
	kW/TEU	
	kWh/km	
	kWh/kWp	
	kWh/s	
	kWh/year	
	kWp	
	l/hour	
	l/m2	
	l/m3	

	m2*K/W	
	m2/kg	
	m2/unit	
	m2/year	
	m3/head/yr	
	m3/kg	
	metric ton/(ha*year)	renamed from "t/(ha*yr)" in ecoinvent 3 (v3.00)
	metric ton/ha	renamed from " t/ha" in ecoinvent 3 (v3.00)
	MJ/kg	
	MJ/kWh	
	MJ/m3	
	MJ/Nm3	
	mm/year	
	MW	
	unit/kWh	

The following are pre-defined units used for LCIA factors. These are merely text strings used as units of weighted impact assessment results. No conversion to other units is available.

Units used in LCIA	
	kg 1,4-DCB-Eq
	kg 2,4-D-Eq
	kg antimony-Eq
	kg benzene-Eq
	kg CFC-11-Eq
	kg CO2-Eq
	kg ethylene-Eq
	kg Fe-Eq
	kg formed ozone
	kg N
	kg N-Eq
	kg NMVOC
	kg NO3-
	kg NOx-Eq
	kg oil-Eq
	kg P
	kg P-Eq
	kg PM10-Eq
	kg PM2.5-Eq
	kg PO4-Eq
	kg SO2-Eq
	kg toluene-Eq
	kg U235-Eq
	kg waste

MJ-Eq	
moles of H+-Eq	
m2.ppm.h	
m2a	
m3 air	
m3 soil	
m3 waste water	
m3 water	
person.ppm.h	
points	
ELU	
DALYs	
CTU	
UBP	
kg NO3-Equiv.	used in GaBi for NEP (EDIP)
kg C2H3Cl-Eq. to air	used in GaBi
kg TEG-Eq. to water	used in GaBi for Aquatic ecotoxicity - Midpoint (I02+)
kg TEG-Eq. to soil	used in GaBi for Terrestrial ecotoxicity - Midpoint (I02+)
Bq C-14-Eq. to air	used in GaBi for Ionizing radiation - Midpoint (I02+)
CTUe	used in GaBi for Ecotoxicity (USEtox)
CTUh	used in GaBi for Human toxicity (USEtox)
Mole of N eq.	used in GaBi for Accumulated Exceedance (EP)
species.yr	used in GaBi for Ecosystems - ReCiPe
$	used in GaBi for Fossil depletion - ReCiPe (Endpoint) and for Metal depletion - ReCiPe (Endpoint)

Annex E: Valid Expressions in Formulas

a) Basic Mathematical Operations

Addition
expr1+expr2
Examples: 3400+23.7
64+100

Subtraction
expr1-expr2
Examples: 4000-500
64-(5+9.6)

Multiplication
expr1*expr2
Examples: 930*5.976
(55+x)*66

Division
expr1/expr2
Examples: 780/32
9000/(88*6.23)
Note that division by zero is not defined. The expression used as denominator ("expr2") must not to be "0"!

b) Comparison Operators

TRUE and FALSE are represented by numerical values. The result of the comparison operators on this page is either 1 (for TRUE) or 0 (for FALSE).

>(expr1,expr2)
is TRUE, if expr1 is greater than expr2, else FALSE.
Examples: >(234,X01*4)
>(MAX(x,y),134)

<(expr1,expr2)
is TRUE, if expr1 is smaller than expr2, else FALSE.
Examples: <(56.9,X02/.8)
<(SQR(A33),4)

=(expr1,expr2)
is TRUE, if expr1 equals expr2, else FALSE.
Examples: =(400,23.7) FALSE
=(4*100,500-100) TRUE

c) Exponential- and Logarithmic Functions

EXP(expr)

calculates Euler figure (e=2.71828) with exponent expr.
Example: EXP(3) is 20.085

LN(expr)
calculates natural logarithm of expr
Example: LN(5+y3) is 2.19722 for y3 = 4

d) Square and Square Root Function

SQR(expr)
square (quadratic) function of expr
Example: SQR(2*4) is 64

To perform exponential calculations with an exponent larger than 2, please use the function EXP. EXP(expr2*LN(expr1)) is a way of calculating "expr1 to the power of expr2".

SQRT(expr)
square root of expr
Example: SQRT(100+11*4) is 12

e) Extreme- and Absolute Values

MAX(expr1,expr2)
delivers the maximum value of expr1 and expr2
Example: MAX(3*SQR(x),22) is 27 for x=3

MIN(expr1,expr2)
delivers the minimum value of expr1 and expr2
Example: MIN(1000, 4*d01) is 800 for d01=200

ABS(expr)
delivers absolute value
Example: ABS(-0.98) is 0.98

INT(expr)
delivers integral part of expr
Example: INT(3/2) is 1

ROUND(expr1,expr2)
divides expr1 by expr2, rounds the result to the next integral figure and multiplies with expr2.
Examples: ROUND(12.345,0.01) is 12.35
ROUND(123,10) is 120

RANGE(expr1,expr2,expr3)
if the value of expr1 lies within the range set up by expr2 and expr3, the result "0" is delivered. If the value lies below the value range (expr1<expr2), the result of the function is "-1". If expr1 lies above the range (expr1>expr2),

the result of the function is "1". Note that the RANGE function can also be built using several IF-functions.

f) Boolean Functions

TRUE stands for any figure unequal zero (not Null), FALSE has the value 0 (Null, zero).

AND(expr1,expr2)
delivers TRUE (1), if expr1 and expr2 are both not Null, else FALSE (0)
Example: AND(>(x1,x2),=(y1,y2))

OR(expr1,expr2)
delivers logical value TRUE (1), if expr1 or expr2 are TRUE, else FALSE (0)
Example: OR(>(x1,x2),=(x1,x2))

NOT(expr)
delivers negative logical value
Example: NOT(=(x,3))

IF(expr1,expr2,expr3)
conditional query for logical value of expr: if expr1 not Null (i.e. TRUE), the result is expr2, else expr3.
Example: IF(>(d4,e3),1,-1) is 1 for d4=5 and e3=4

FALSE()
delivers logical value FALSE, i.e. 0

TRUE()
delivers logical value TRUE, i.e. 1

g) Trigonometric Functions

The trigonometric functions use the radian measure (multiple of *=3.14159..., delivered by PI()).

COS(expr)
Cosinus of expr
Example: COS(2*PI()) is 1

SIN(expr)
Sinus of expr
Example: SIN(1.5) is 0.99749

TAN(expr)
Tangens of expr.
Example: TAN(1) is 1.557407

ARCTAN(expr)

Arcustangens of expr
Example: ARCTAN(1) is 0.7853

PI()
the constant ∏ (3.141592654...)

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