Umberto® Efficiency+

(v10)

User Manual

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Information in this user manual is subject to change without notice. No liability for the correctness of the information in this manual. All figures are for illustration purposes only and contain fictitious data.

Contents

1 Introduction

Umberto Efficiency+ is a software tool that supports Material Flow Analysis (MFA), and Material Flow Cost Accounting (MFCA) as described in the international standard ISO 14051.

The software helps to model and understand production systems in regard to consumption of raw materials, resources and energy as well as to emissions and wastes. It has a special focus on material losses and the associated costs, but also supports a common managerial cost accounting perspective on costs.

Umberto Efficiency+ is a member of the Umberto software[1] family, and has been tailored specifically to be used for material flow cost accounting. It is targeted at the process engineer, plant manager, controller, and the environmental manager.

We find it important to have a visual approach for calculating the material and energy flows as well as the associated costs, rather than working with tables and grids. Therefore, the user starts by drawing the processes (the production system map). Specification of the processes and activities in the model is the next step, in order to be able to calculate all material and energy flows. Finally, after adding information on material and energy prices, and process costs, the calculation of costs and key performance indicators (KPIs) can be performed. Results are displayed graphically and in tables. The flows in the production system model can be displayed as Sankey diagrams, for material and energy flows, for costs and for the carbon footprint.

Typically, after first setting out to describe the situation "as is" in the production system, the practitioner then runs variations of the model to understand what consequences planned or actual changes in the production would cause in regard to material and energy consumption, as well as to emissions and wastes. The user can run parameter variations, think about substituting technical equipment, or replacing auxiliary materials.

We hope you enjoy working with Umberto Efficiency+!

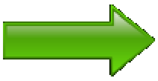
[1] http://www.umberto.de

About this User Manual

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

A brief introduction to the concept of 'Material Flow Analysis (MFA)' and method 'Material Flow Cost Accounting (MFCA)' with reference to further reading is 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 material and energy flow analysis (MFA) models are set up and how the material flow cost accounting can be performed. The tutorials can be used to self-study the software, and to get acquainted with the most important functionality.

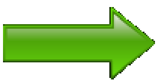
A keyword index allows you to quickly access the pages where specific functions of Umberto Efficiency+ are mentioned.

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. Also signals where the Umberto Efficiency+ version has limitations, e.g. in regard to size or complexity of the model.



Cross-reference to a related topic within the user manual or in the Umberto tutorials.

Reference to an ISO standard.

2 Installation

Administrator rights are required to install Umberto on your computer. Contact your administrator, if you have restricted user rights on your machine.

2.1 System Requirements

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

- Operating system Windows 7, Windows 8 or Windows 10
- Microsoft .NET Framework 4.6[2]
- Memory 4 GB RAM or higher
- Available hard disk space: 250 MB or more
- 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.

Hint for users of an Umberto 5 version: Umberto 5 and Umberto Efficiency+ can be run in parallel on the same computer without any problems.

2.2 Running Umberto Software Installer File

Run the Umberto installation file by clicking on the downloaded executable (the file is named either 'setup-umberto-efficiencyplus.exe' or 'umberto-efficiencyplus_trial-v10.x.x.xxx.exe' or 'umberto-efficiencyplus-v10.x.x.xxx.exe' where 'x' represents a digit). You need local administrator rights on your machine for the installation.

The installation is guided by a wizard and only requires some 60 to 90 seconds. If an older version of Umberto Efficiency+ 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\ifu Hamburg\Umberto EfficiencyPlus". You may of course opt to choose to install to a different directory by clicking on the 'Change…' button.

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[2] 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.

One additional folder "Umberto Efficiency+" 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.

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 don't enter license key, you can run Umberto as a trial version for 14 days from the date of first installation. The trial version almost has the same functionality as the full version, but the following limitations:

- No ecoinvent 2.2 GWP master database included (only stubs), instead 'Free Trial Datasets' database with 25 sample entries
- watermark over the model
- no print function
- no export to Excel

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

Users of the trial version of Umberto Efficiency+ can purchase a license key 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.

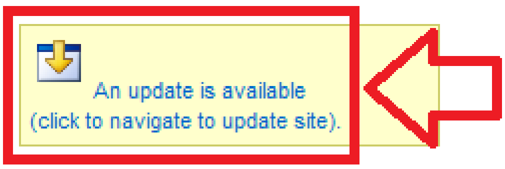


Figure 1: Information of the start page that an update of Umberto is available

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.

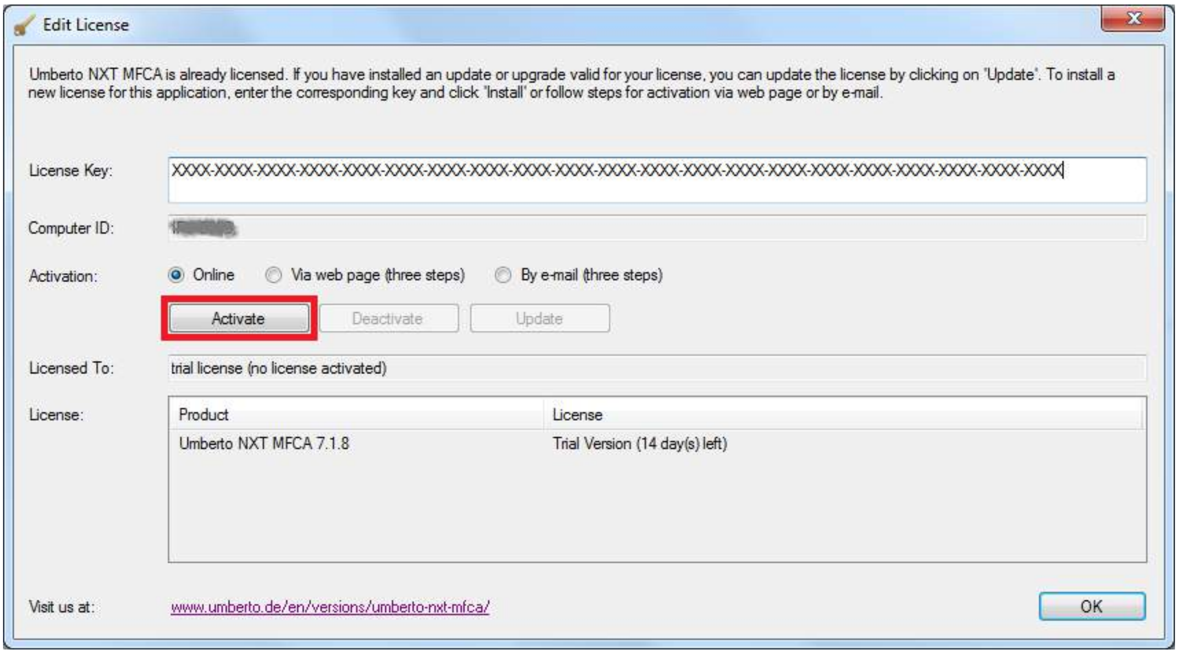


Figure 2: Entering the license key and activating the software.

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 GWP Database Installer Files

Installation of GWP databases (databases with carbon footprint data for materials and activities) is only required if you intend to do carbon footprint calculations, as described in chapter 14.

In addition to the Umberto software installation, additional third-party GWP databases can be installed. These additional databases contain background data for doing carbon footprint calculations.

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

Any installed and up-to-date license for GWP databases on your computer is shown under the heading 'Databases'. If your license allows use of other GWP 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 GWP master databases is available for download on the server, a link will be provided to access the download page ("check online").

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

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

GWP Database	Installer File Name	
ecoinvent v2.2 GWP database	ecoinvent_2.2_GWP_for_umberto-efficiencyplus-v10.x.x.xxx.exe	included in licensed version of Umberto
ecoinvent v3.4 GWP	ecoinvent_3.4_GWP_for_umberto-	purchase license

database	efficiencyplus-v10.x.x.xxx.exe	
PAS 2050 GWP data	PAS_2050_for_umberto-efficiencyplus-v10.x.x.xxx.exe	included in licensed version of Umberto
BioGrace GWP data	BioGrace_for_umberto-efficiencyplus-v10.x.x.xxx.exe	included in licensed version of Umberto

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, and on modelling a production system or supply chain.

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 product version and version number (see About dialog) of Umberto 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\UmbertoEfficiencyPlus\%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 and discuss with them.

2.6 Uninstalling

To uninstall Umberto Efficiency+ 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 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.

3.1 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.

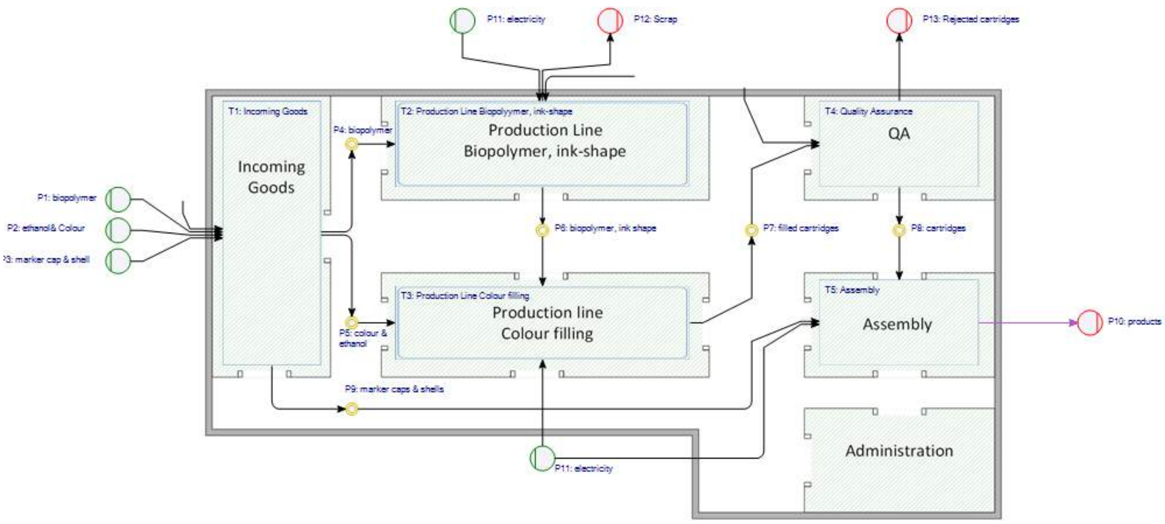


Figure 3: The model of the production system is the basis for determining all flows and analyse improvement measures in regard to material and energy consumption and reducing emissions.

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.

3.2 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)

3.3 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 3.1 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 Efficiency+, 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.

3.4 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.

4 General Functions of Umberto Efficiency+

4.1 Handling Windows

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

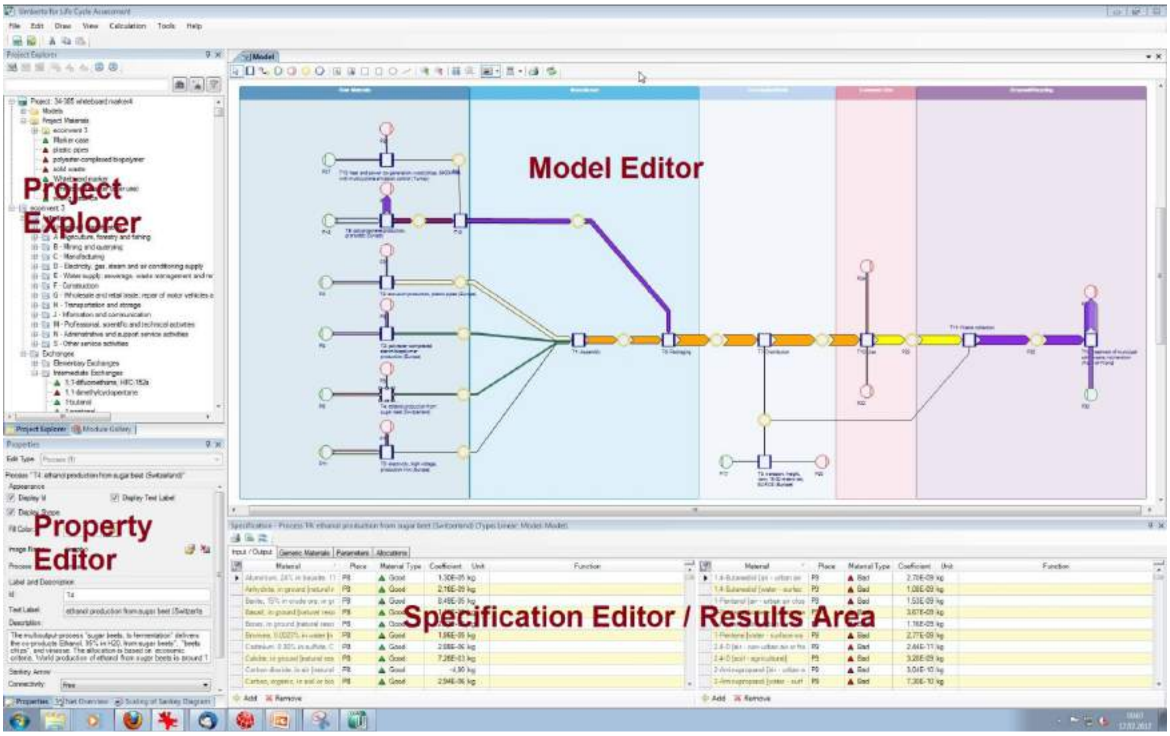


Figure 4: Typical windows layout of Umberto: Project Explorer with material list on the left, the Model Editor with the graphical model of the process system in the middle, and the Specification Editor/Results pane. The Property Editor in the bottom left area shows properties of the selected model element 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 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 model, while the main application windows are open on the other monitor.

4.2 Handling Grids

Most of the grids (tables) you find in Umberto 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', 'Parameters', 'Allocations'), and the calculation 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.

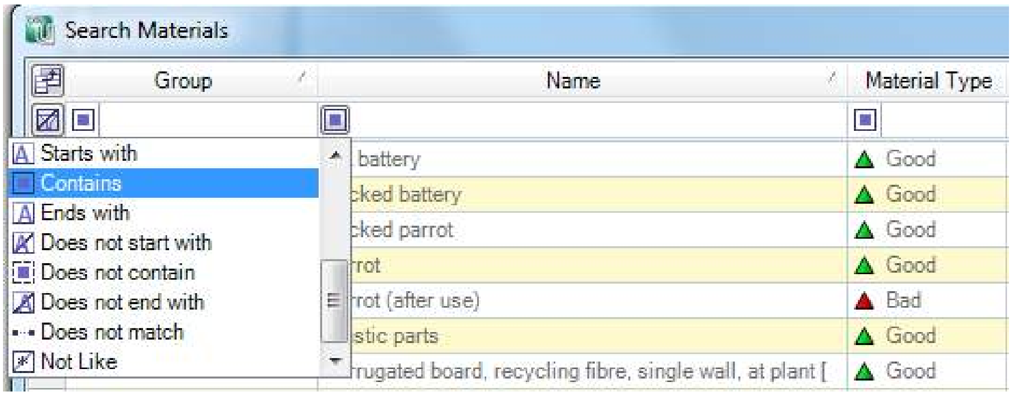


Figure 5: Filter setting in grid

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.

Grouping is helpful, e.g. to structure long inventory or result tables. There are also different pre-configured views available which can be used for the most common grouping of tables.

Reset Grid Layout: The configuration of the grids in specific windows (i.e. grouping, order of columns) will remain the same during a session and even if you close Umberto. Hence the user can configure the preferred grid layout.

The button "Reset Grid Layout" can be used to re-establish the original layout of the grid after having made changes.

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) must be done on the grey area on the left side of the grid, not on the entry directly. Dragging multiple items should start on the marker triangle.

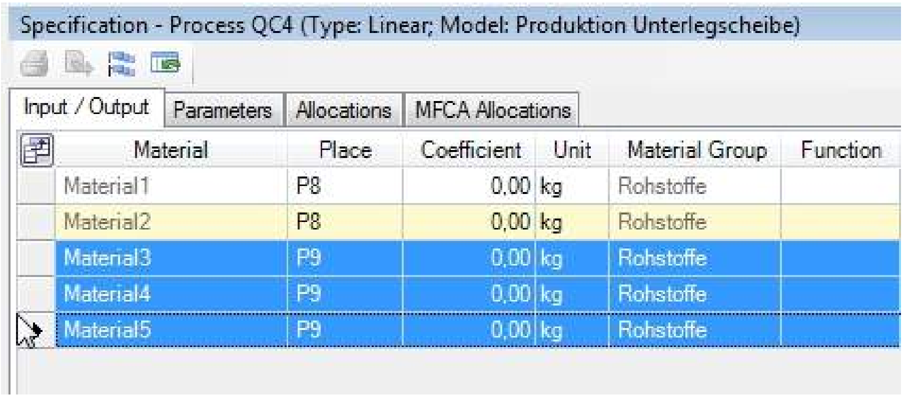


Figure 6: Selecting several entries in a grid, e.g. to drag them onto an element

4.3 Undo/Redo

Umberto has an Undo/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

4.4 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.

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).

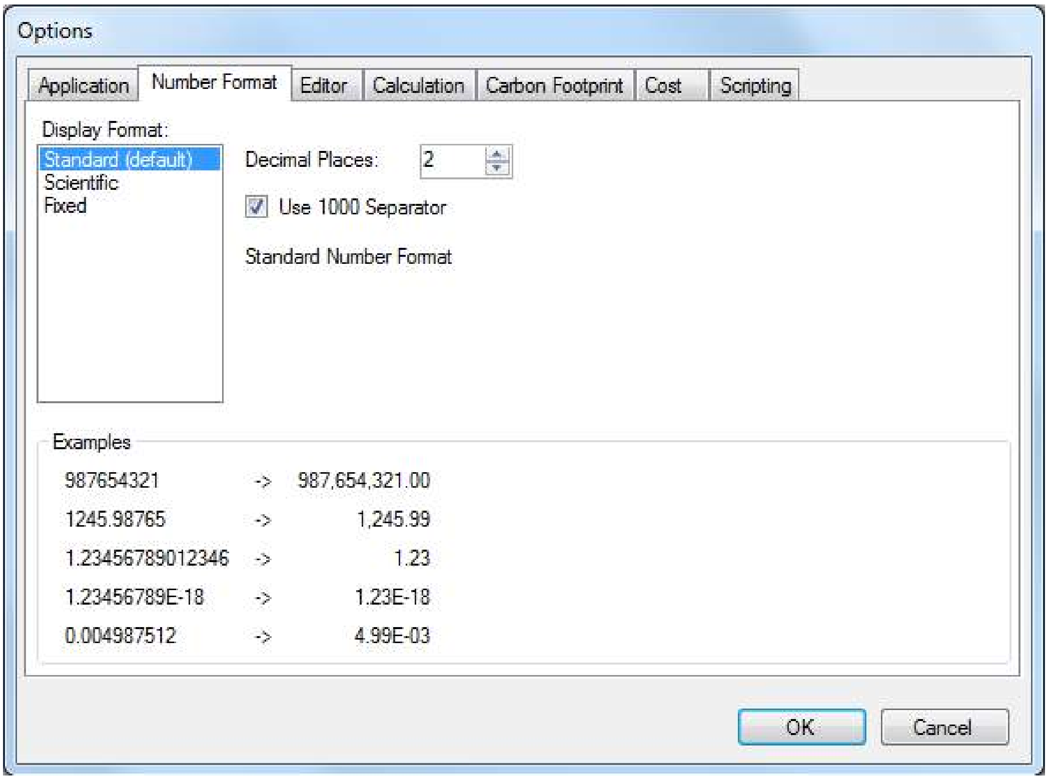


Figure 7: Number Format page of Options dialog

- **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 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.

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.

Read more about scripting in the chapter 15.

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 15.

5 Projects and Models

5.1 Projects

When no project is open in Umberto, 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.

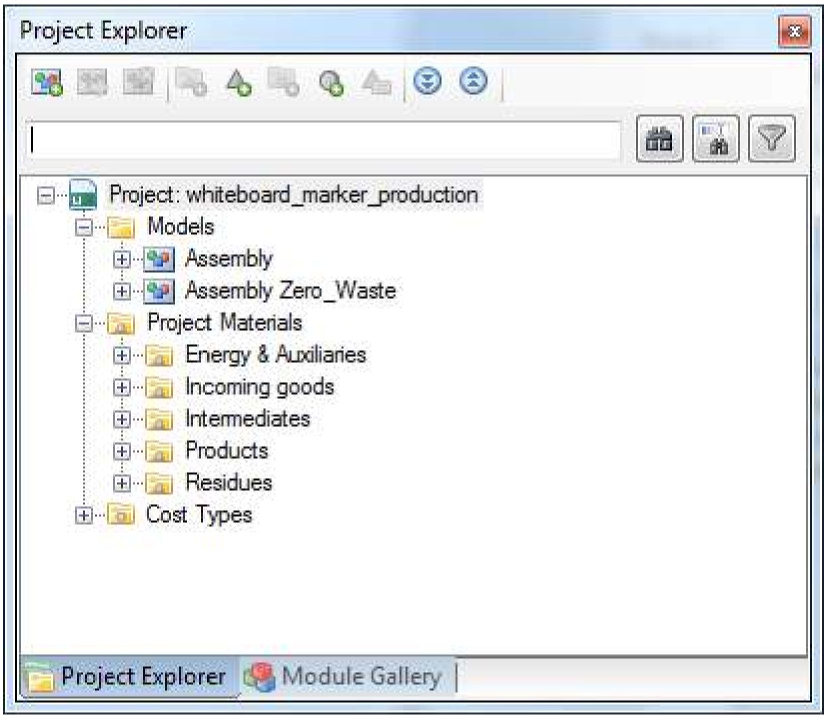


Figure 8: Project Explorer with open project Also visible are the root folders for models, materials and cost types.

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 Efficiency+), 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 project files created with other Umberto versions (Umberto LCA+, and the older Umberto NXT versions) also have the file extension ".umberto".

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 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 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 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 Efficiency+".

5.2 Models

Within a project several models can be created and opened. A model consists of a graphical representation of a process system (production system) or a supply chain. Models are made up from several elements, such as process, place and arrow. For further details see chapter 7 on network elements.

Different models within one project can either represent different production systems (or sections thereof), or variations of the same material flow model e.g. with different parameters, different upstream materials, or different transfer coefficients in a process.

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 9: 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 material flow 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 8.6).

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 Model Phases

In larger material flow models (e.g. of a complex production system, a supply chain model) it can be meaningful to separate the sections of the model.

In Umberto a breakdown of the result by phases (sections) is done using a graphical element overlay which helps to identify the limits of the individual phases in the editor.

Creating a 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 eight unnamed phases. Click on the entry you prefer then select 'OK'. If you click 'Cancel' no phases frame will be created. The phase frame can be created at a later stage via the 'Life Cycle Phases' command in the 'Draw' menu.

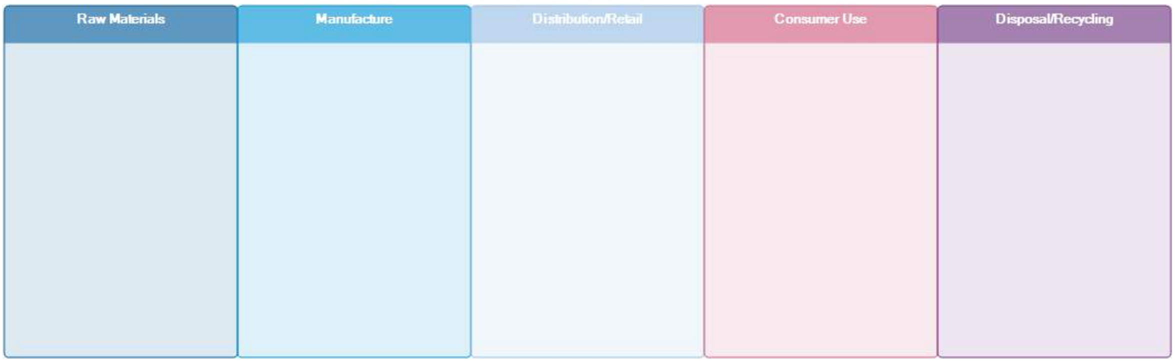


Figure 10: Phases frame with five phases. The preset colors and phase names can be adapted.

At present the model phases frame is only available with a left-to-right orientation. It is advisable to build up your material flow model with a general left-to-right direction too. Check for upcoming versions that have more flexibility for phases.

The phases frame has three 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 phase. The exchanges of the inventory and the associated costs will be assigned to the phase where the process symbol is located. For more details see below in the chapter 0 on results. Thirdly, when using the carbon footprint calculation feature, the phase frame can be used to understand from which part of the process system the contributions to the carbon footprint are shown. Read more about this in section 14.3.

Moving and Resizing Phases Frame: The 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 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.

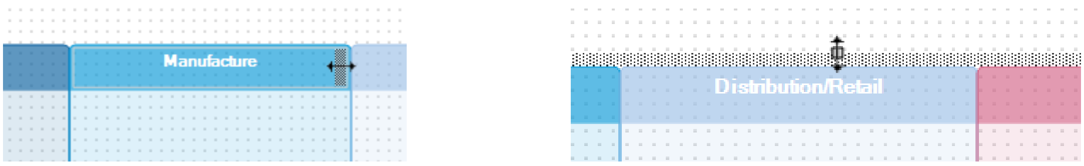


Figure 11: Change phase size and phase frame size

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

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

At the top the 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 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 0).

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.

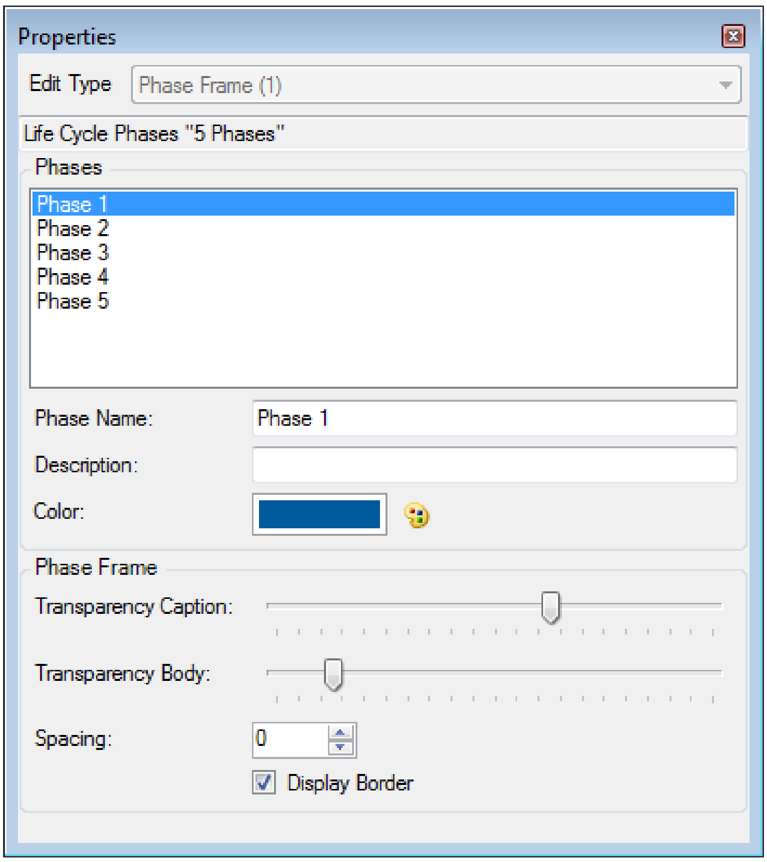


Figure 12: Phases properties

Deleting Phases Frame: To delete a phase 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 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

6.1 Material Groups

When a project is open, the Project Explorer window shows (at the top) a folder for models, and the folder 'Project Materials'. The 'Project Materials' group has a number of pre-defined material groups in a hierarchical structure.

6.1.1 Predefined Material Group Structure

The predefined material group structure provides a typical structure for producing companies. For MFCA studies it is essential to use these predefined groups, as the they allow to identify the role of a specific material.

If you do not wish to use these predefined groups, you can create your own material groups.

The names of the subgroups are used to classify materials in regard to their contribution to the product creation in the material flow model. The folder 'Losses' with its four sub-groups plays a specific role to determine costs of material losses (see section 7.3.2 for more details).

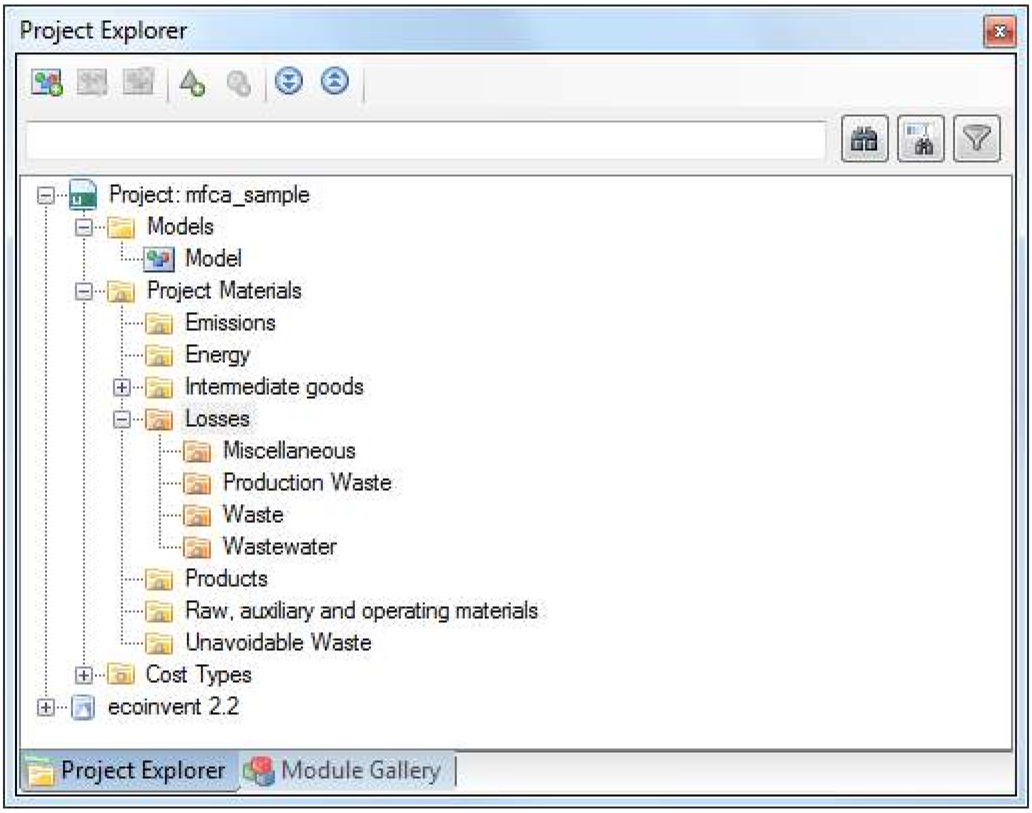


Figure 13: Root folder 'Project Materials' with predefined material groups

Groups to insert inputs into the production process

- Raw, auxiliary, and operating materials
- Energy

Groups to insert unavoidable outputs from the production process (not accounted for in material flow cost accounting)

- Unavoidable Waste
- Emissions

Groups to insert outputs from the production process that are accounted for in material flow cost accounting

- Losses
    - Defects
    - Waste
    - Wastewater
    - Miscellaneous

Groups to insert intermediate goods and final products

- Intermediate goods
- Products

6.1.2 Own Material Groups

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.

The "Group Type" is an important setting for each newly created group. The group type must be selected from the "Group Type" dropdown list on the material group properties.

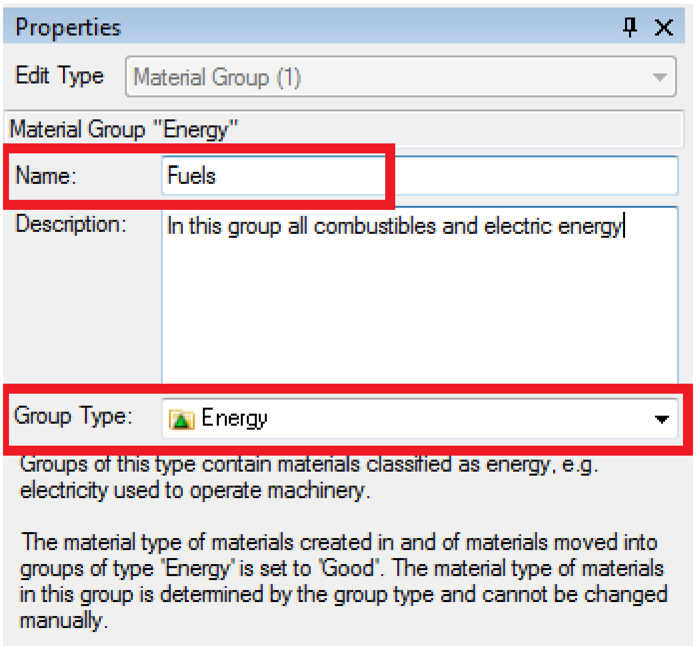


Figure 14: Setting the group type for a newly defined or renamed material group

Choose from one of the predefined material groups (see above section 6.1.1) to determine the role and contribution of any material in that group for cost calculation and Material Flow Cost Accounting (MFCA).

As a consequence of the "Group Type" selection the materials within the group all receive a specific material type "Good" or "Bad".

Group Type	Material Type
Raw, auxiliary, and operating materials	"Good" (green)
Energy	"Good" (green)
Emissions	"Bad" (red)
Losses	"Bad" (red)
Unavoidable Waste	"Bad" (red)
Intermediate goods	"Good" (green)
Products	"Good" (green)
Other	Default "Good" (green) but can be modified individually for all materials

Choose "Other" to signal a group that contains materials that have no specific role or contribution in the cost calculation or MFCA. For the materials in the groups with "Group Type" set to "Other" you must take care for yourself that the material type for each material is set properly to either "Good", "Bad" or "Neutral".

For a description of material types and their role please see section 10.2 of this user manual

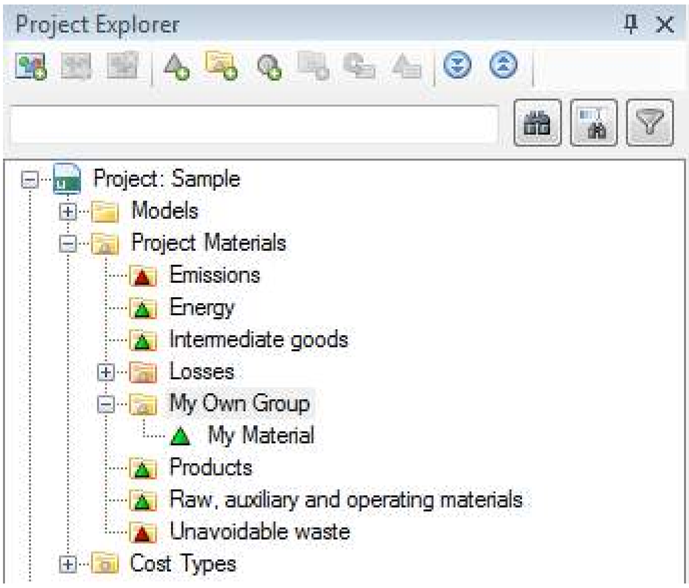


Figure 15: A material group has been defined next to the existing predefined groups

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.

A 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.

6.2 Materials

Materials (also sometimes referred to as flows or exchanges) is the term for the flows that run within material flow model, 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 input flows to a process (in the MFCA vocabulary: a "quantity centre") from other processes (from other quantity centres).

Materials can be defined by the user in the project as individual flows. They have to be inserted in one of the material groups that signal their role or contribution in the production process.

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 service. It does not necessarily have to be a physical item, but may also be used for energy, people, work, service, area, etc.

New Material: To define a new material in one of the material groups, mark the folder in the 'Project Explorer', then click on the button 'New Material'. Alternatively, use the command 'New Material' (CTRL+M) from the context menu of the material group folder. The material will be inserted in the material group that is currently marked, or in which a material is currently marked.

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

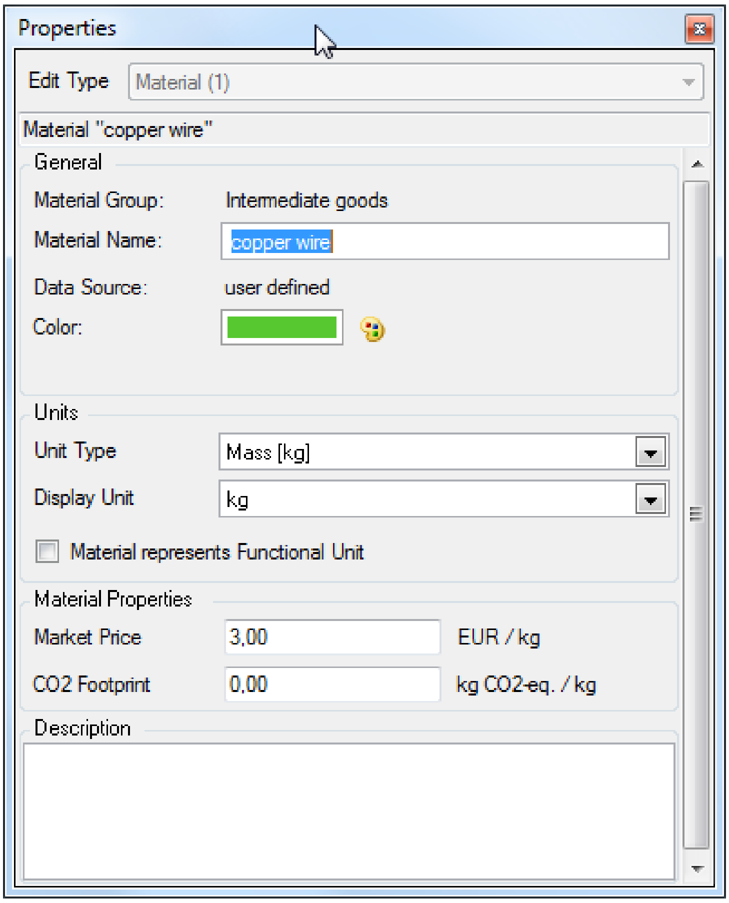


Figure 16: Properties of a material

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 one 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.

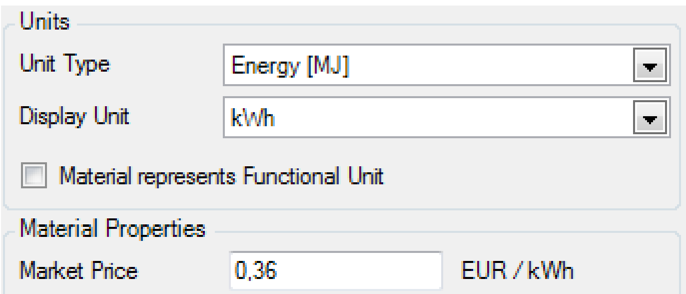


Figure 17: For a material entry with "energy" unit type the basic unit is "MJ", the display unit is set to the more common "kWh". Market price and CO2 footprint are shown per one display unit.

Typically, the result of the model calculation will present the input and output flows of the system in regard to the production volume in a certain period of time (e.g. a business year). If a material is used as a product to which the inventories of the product model are to be scaled, 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 model calculation to one unit of product in section 12.

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 more about the reference flow in section 10.2. Read more about allocation in section 9.4

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.

In the 'Material Properties' panel the first field is labelled "Market Price" for materials or "Disposal Costs" depending on in which material group they are located. A cost value can be entered in EUR per one display unit. Examples: 2,80 EUR/kg of material, 0,00012 EUR/MJ of energy. The market price is used to determine material direct costs (see section 7.1).

Edit Material Properties: To edit properties of a material in the project, mark it in the 'Project Materials' folder. Then edit its properties, such as name, description, or display unit in the Property Editor.

Move Material: If you wish to move a material entry into another group in the material hierarchy, just drag&drop it from one folder onto another material group folder.

Mind that the role of the material in the production processes is interpreted depending on the group in which the material is located. So, while it might make sense to move a material from group "Losses/Production Waste" to group "Losses/Waste", moving a material from group "Intermediate Goods" to "Losses/Miscellaneous" can result in different results in the material flow cost accounting (MFCA) calculations

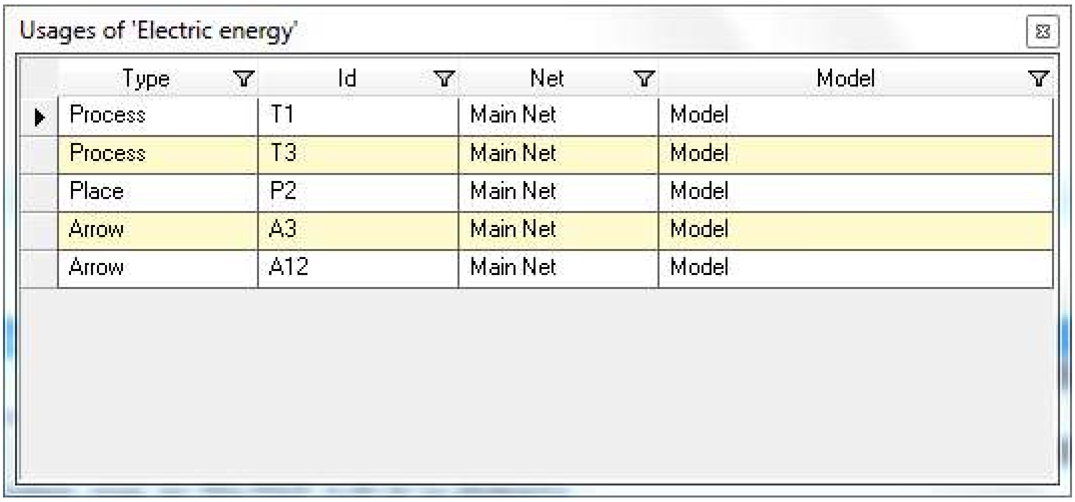
Search Project Material Entry: To be able to detect a specific material entry, use the search bar at the top of the Project Explorer.

- Full Text Search
- Incremental Search
- Filter

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

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 Material: To find out in which element of a model a specific material is being used, right mouse-click the entry in the material list in the Project Explorer and choose the command 'Find Usages…' 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 18: The 'Find Usages…' command will yield a list of network elements where the material is being used, along with information on the model and the net.

Delete Material: To delete a 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.

7 Costs

Umberto Efficiency+ has a managerial cost accounting feature that allows calculation of costs based on the calculated materials and energy flows (material direct costs) and other costs that incur in the cost centers i.e. processes (process costs). Fixed costs can also be handled.

Umberto Efficiency+ additionally supports a material flow cost accounting (MFCA) perspective. The MFCA cost accounting approach is described in section 7.3.2

7.1 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.

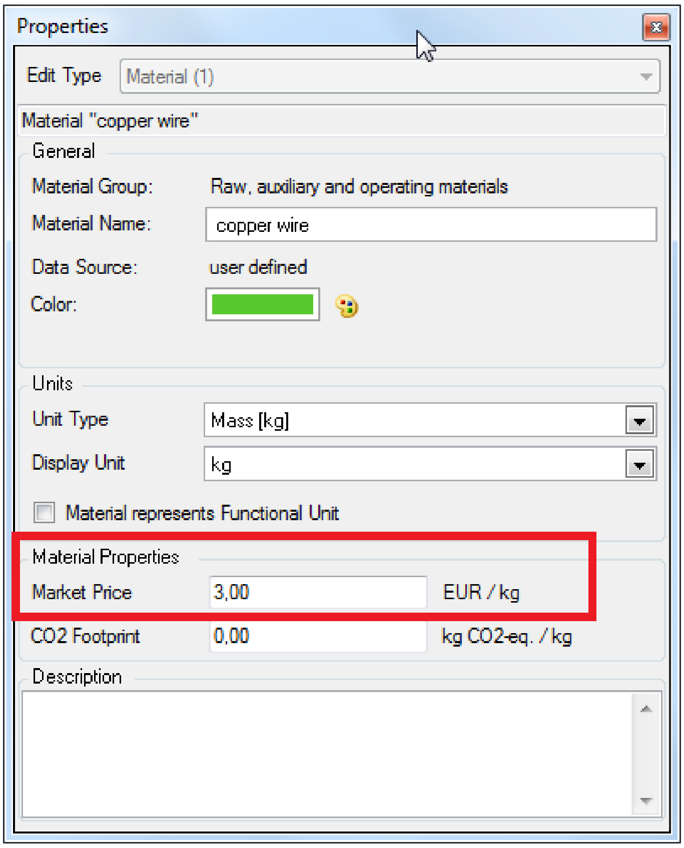


Figure 19: Market price is defined for a material in the properties panel.

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 13 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.

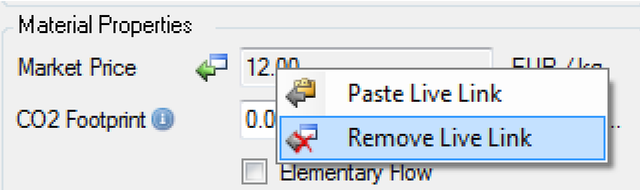
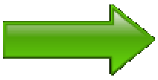


Figure 20: Context menu for market price field in material properties.

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 9.2 for details on use of materials in process specifications and inclusion of material direct costs in the calculation of costs.

7.2 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.

7.2.1 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).

In Umberto Efficiency+ the creation of individual new cost type groups and the editing of cost type groups have been disabled.

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".

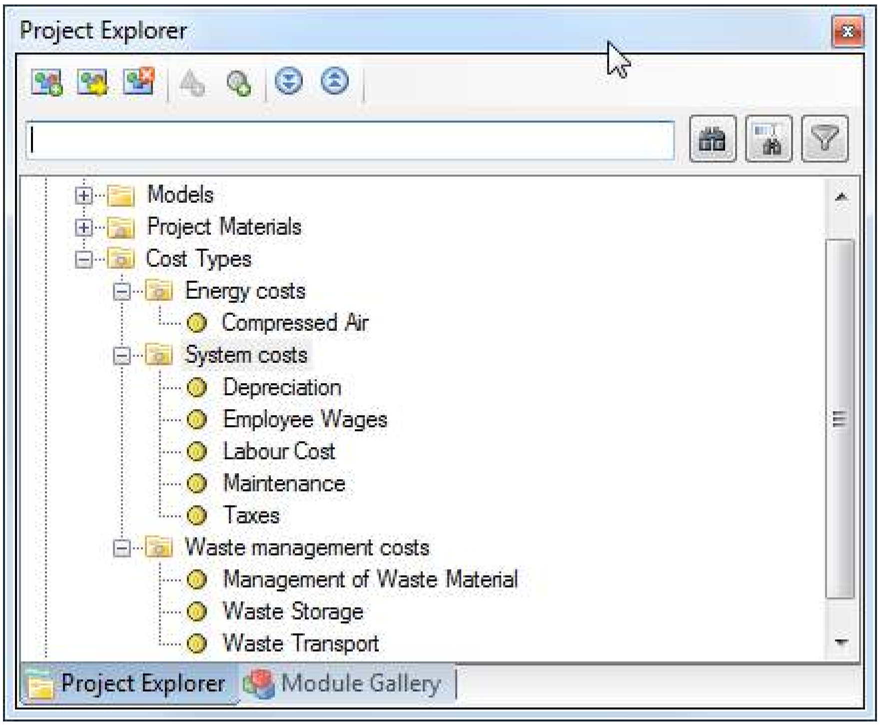


Figure 21: Cost type groups with cost type entries

Calculated cost data is presented in the cost inventory (see section 11.2) broken down into the cost type groups. For each quantity centre the material flow cost matrix shows the respective costs.

7.2.2 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 11.4)

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 9.2 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 11.2). Fixed costs are not displayed in the cost Sankey diagrams (see section 11.4).

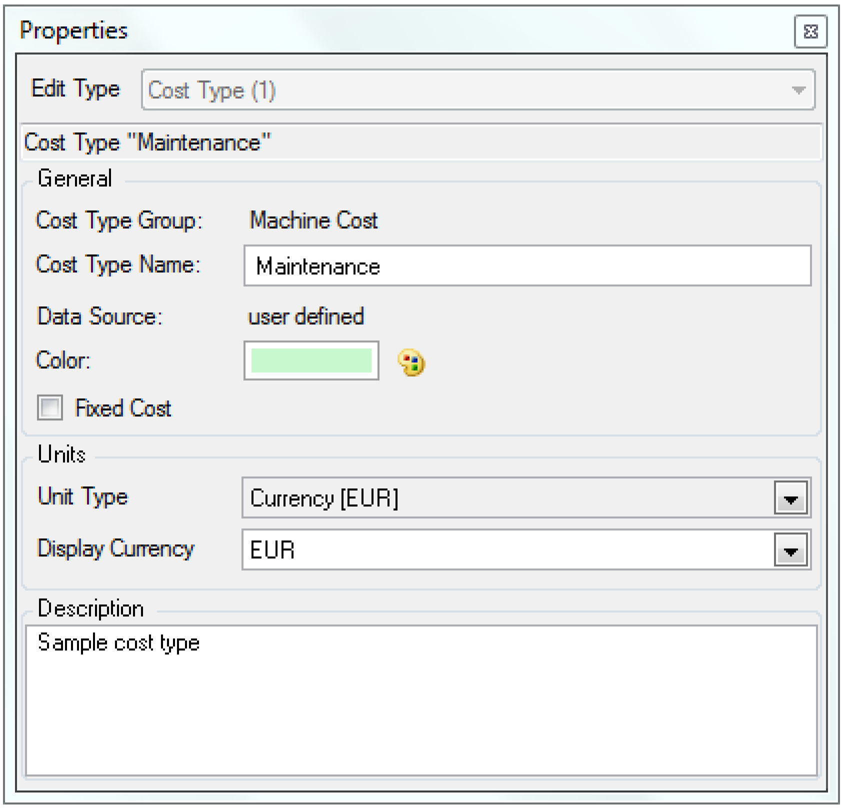


Figure 22: Cost type properties panel

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.

7.3 Cost Accounting in Umberto

Umberto Efficiency+ 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.

7.3.1 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.

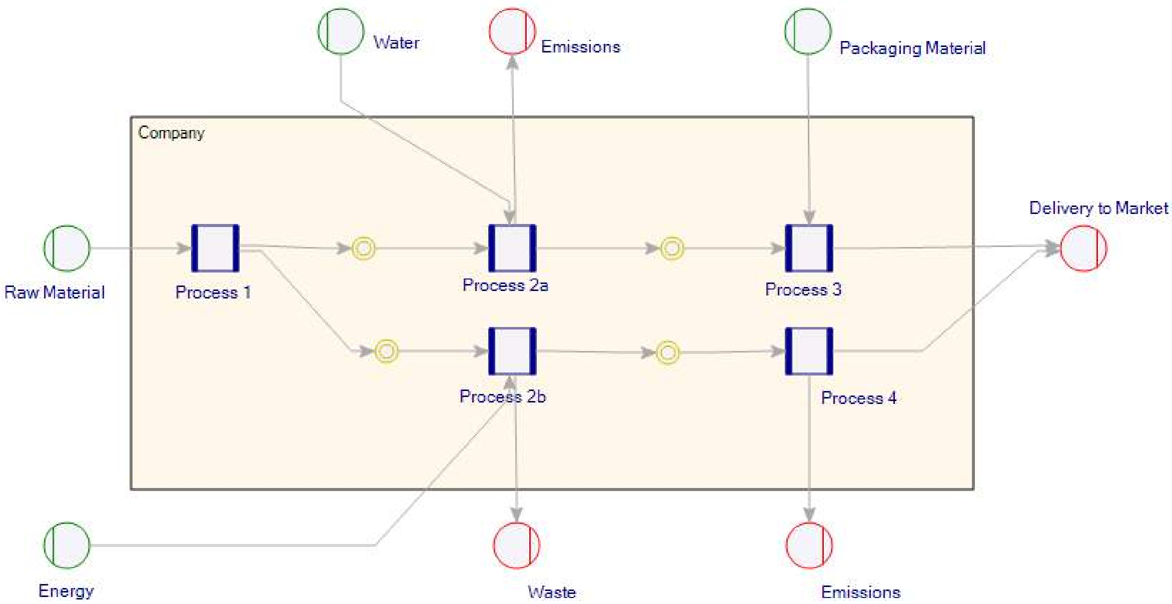


Figure 23: Schematic sample material flow model representing a company with a number of production steps. The input places deliver from outside the system boundary (from the market) to the company. The output places take up product and emission/waste outputs from the system. These input output flows 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 (see chapter 11). 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 7.3.2.

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 10.1.

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 9.2

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 Relation', see section 9.1). It can also be defined non-linearly with mathematical functions (process specification type 'User Defined Functions', see section 9.4.2).

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 9.4 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 0 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 11.2 for details on cost inventories and cost details.

Another presentation of calculated cost information can be with cost Sankey diagrams.

Read section 11.4 for more information on how cost data in a production system can be displayed in a Sankey diagram.

7.3.2 Material Flow Cost Accounting

Umberto Efficiency+ support 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 7.3.1)

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 <u>not</u> 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 (see section 6.1). 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 9.4.

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 0 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 11.2 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 11.4 for more information on how cost data from the material flow cost calculation can be displayed in a Sankey diagram.

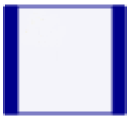
Read more about the ISO standard on Material Flow Cost Accounting (MFCA). Refer to the official ISO 14051 document.

8 Material Flow Model

The Modelling Editor covers the main area of the application. It serves to graphically build the material flow model, and to specify the processes.

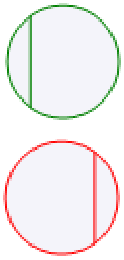
Get a practical idea on how to build up a material flow model by working through the examples of the Umberto tutorials.

The material flow 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 8.2
→ for details on defining the process see chapter 9 '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 8.3

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 8.4

8.1 General Element Related

Insert Elements (Process, Place, or Graphical Elements): To insert a process, place or graphical element in the material flow 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.

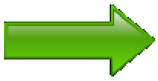
Adapt Element Size To Master: Several elements (processes, places) can be adapted to match the size of one selected master element: Choose one element that has the size to which the others should be matched, if required adjust its size to your needs. From the context menu of this element choose 'Set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

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.

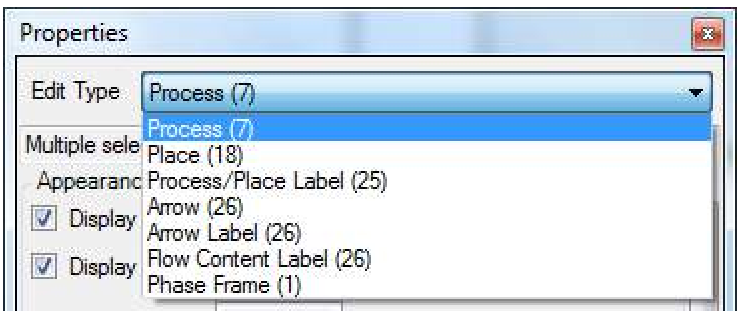


Figure 24: Multi Element Edit in Properties dialog

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.

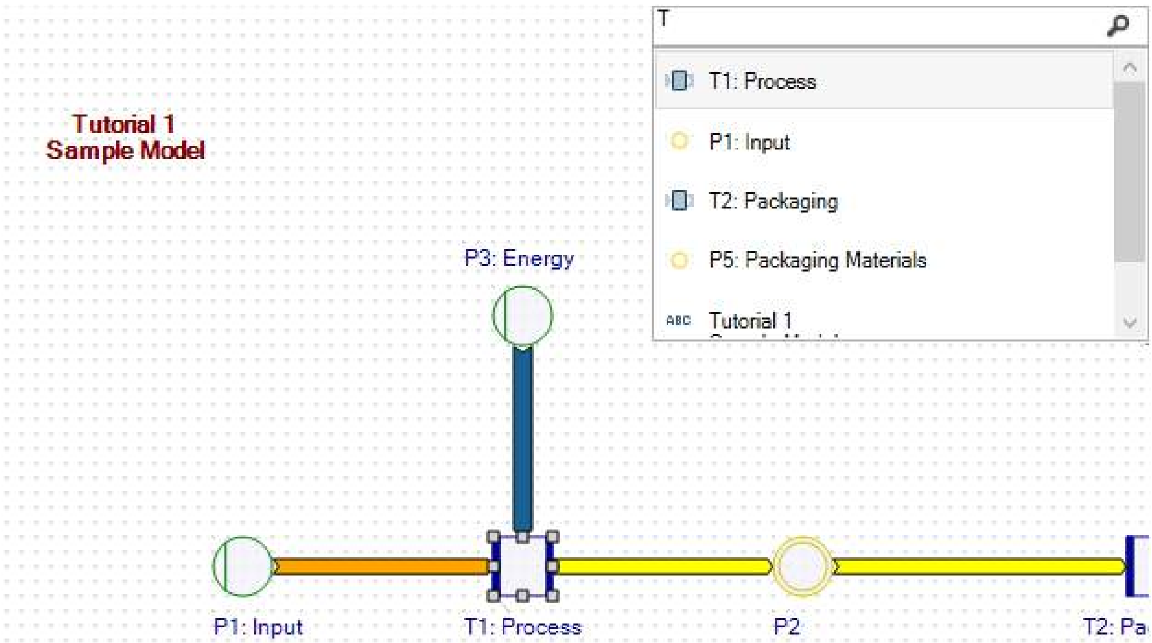


Figure 25: Search Elements in the Modelling Editor

8.2 Process

In this section you can find hints on functions that relate specifically to the graphical handling of processes in a material flow 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 chapter 9.

In the ISO standard on Material Flow Cost Accounting (MFCA) a "process" is referred to as "quantity centre". Since "process" is the common term to refer to locations of transformation of inputs to outputs, we stick to the term "process" rather than "quantity centre". The user is advised to read the two terms synonymously.

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 QC1, QC2, QC3). This ID is used to identify the process (or quantity centre). 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 installation.

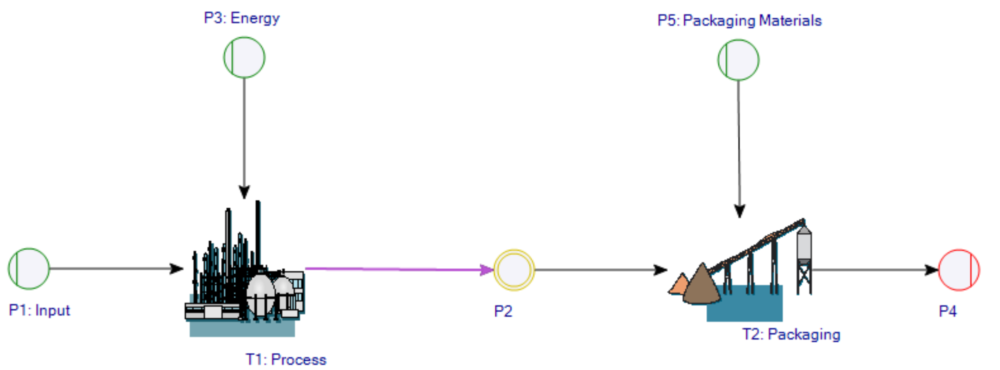
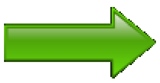


Figure 26: The default process symbols have been replaced with an icon from the clipart gallery

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.

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 the chapter on Sankey diagrams.



For information on the specification (i.e. definition) of processes (a.k.a. quantity centres) please read in chapter 9

8.3 Place

In this section, find hints on functions that relate specifically to the graphical handling of places (input place, output place, connection) in an material flow 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", "Connection" or "Storage".

An input place is used at the system boundary. The input place can be considered a source into the material flow system. The demand of material from outside the system is always satisfied and the quantity shown after calculation is negative to signal how much was demanded from outside the system (e.g. from a supplier, energy consumption, or extraction of raw materials).

An output place is also located at the system boundary. The output place can be considered a sink from the material flow system, where flows are delivered to the system surrounding (e.g. products to the market or emissions into the air)

Connection places are by default found within the material flow model between two processes. Flows leaving a process are booked onto the connection place. The subsequent process(es) check the quantity of flow available on the connection place and withdraw it fully. At the end of a calculation there should be no flow left on a connection place, since all materials are handed fully onto the next process. Should a stock remain on a connection place, then the material flow model is not balanced and a warning will be issued.

Storage places, in contrast to connection places, can gather material. A flow outputted from a process and send to a storage place will not automatically be forwarded to the next connected process. The subsequent process demands from the storage place the amount of material required and the storage place only delivers this flow, if the required quantity is available as a stock. As such, storage places decouple network sections and act as "buffer" between these sections. A begin stock can be entered in a storage place.

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 material flow 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).

8.4 Arrow

In this section you can find information related 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 place 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 un-attach 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 or reference 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 on calculation about specifying a flow in an arrow.

8.5 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 by right-clicking with 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.

8.6 Module Gallery

Umberto 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:\Documents and Settings\Umberto Efficiency+\Gallery. The directory path can be set by clicking on the button 'Open Root Location for Modules'.

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) 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 material flow 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 Efficiency+. 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, depending on your Umberto version.

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

9 Specifying Processes

Processes, sometimes also referred to as 'transitions', 'activities' (in LCA), and 'quantity centres' (in MFCA) are represented in the models by squares. They are the most important element in the material flow 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, that all processes are specified.

9.1 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.

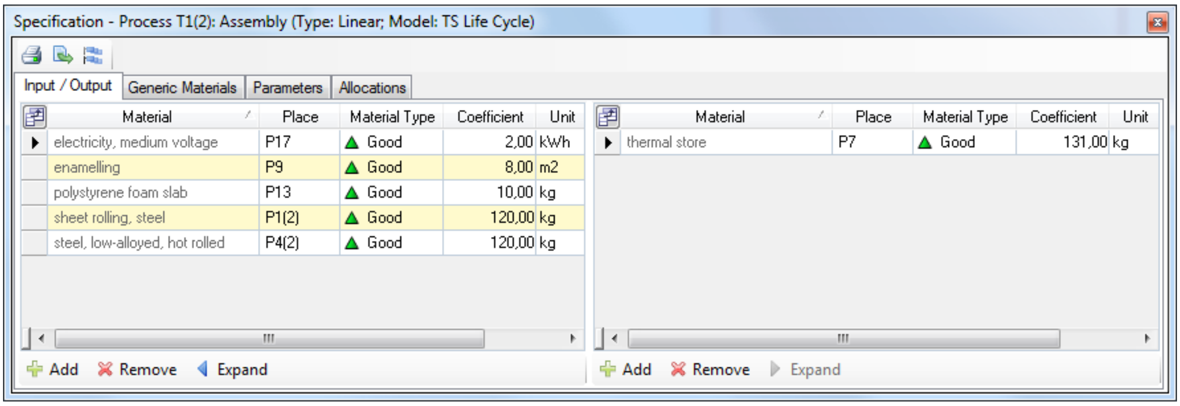


Figure 27: Specification Editor window for a process, 'Input/Output' tab

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 (if installed).

Alternatively click on the button 'Add' for the input or the output side and select one or several material entries 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. This is by default a text string search for material entries that contains the search string.

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.

Another option for adding flow entries on the input or output side of a process is dragging one or multiple 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.

Use multi-selection of several input or output items and the command 'Assign Place' from the context menu, to assign the same place to multiple entries.

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 %".

Flows with a coefficient value "0.00" (nil flows) are permitted. This can be used to model branches of a production system that are temporarily idle or not supplied with flows. Zero as a coefficient can be the result of a function evaluation, fed via an Live Link or manually entered by the user explicitly.

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

Note that if a market price has been defined for the entry in the material properties (see section 7.1) then this price is shown in the 'Price' column. The quantity multiplied with the price is displayed in the 'Value' column.

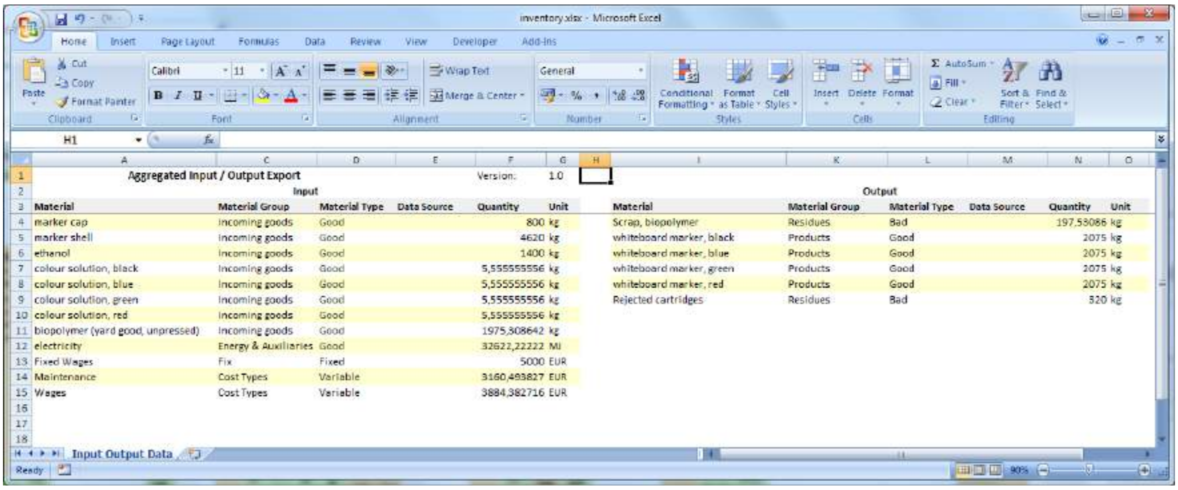
Removing Flow Entries: To remove a flow entry from a process specification mark the entry on the input or output side, and click on the associated 'Remove' button.

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:



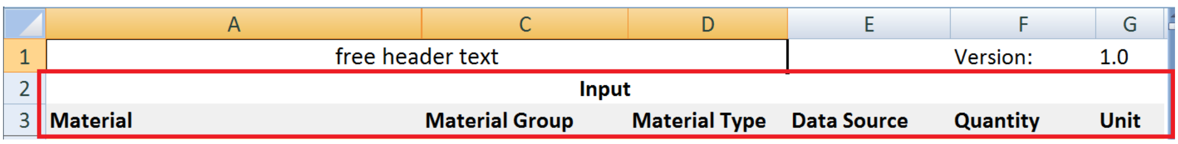
	A	C	D	E	F	G
1	Aggregated Input / Output Export				Version:	1.0
2		Input				
3	Material	Material Group	Material Type	Data Source	Quantity	Unit
4	marker cap	Incoming goods	Good		800	kg
5	marker shell	Incoming goods	Good		4620	kg
6	ethanol	Incoming goods	Good		1400	kg
7	colour solution, black	Incoming goods	Good		5,555555556	kg
8	colour solution, blue	Incoming goods	Good		5,555555556	kg
9	colour solution, green	Incoming goods	Good		5,555555556	kg
10	colour solution, red	Incoming goods	Good		5,555555556	kg
11	biopolymer (yard good, unpressed)	Incoming goods	Good		1975,308642	kg
12	electricity	Energy & Auxiliaries	Good		32622,22222	MJ
13	Fixed Wages	Fix	Fixed		5000	EUR
14	Maintenance	Cost Types	Variable		3160,493827	EUR
15	Wages	Cost Types	Variable		3884,382716	EUR

	I	K	L	M	N	O
2		Output				
3	Material	Material Group	Material Type	Data Source	Quantity	Unit
4	Scrap, biopolymer	Residues	Bad		197,53086	kg
5	whiteboard marker, black	Products	Good		2075	kg
6	whiteboard marker, blue	Products	Good		2075	kg
7	whiteboard marker, green	Products	Good		2075	kg
8	whiteboard marker, red	Products	Good		2075	kg
9	Rejected cartridges	Residues	Bad		320	kg

Figure 28: 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.

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 29: 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 30: 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 or a cost 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 tis column hidden.
Column C	Material Group	Name of a material group or a cost group. Should have exactly the same spelling as the group in the project.
Column D	Material Type	"Good", "Bad" or "Neutral" for materials "Fixed" or "Variable" for cost entries
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 For cost items use one of the predefined currencies. See annex D "Currency".

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 or a cost 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 tis column hidden.
Column K	Material Group	Name of a material group or a cost 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 cannot be imported.
For cost items on the input side the "Material Type" column is used for defining whether the cost type entry is "Fixed" or "Variable".

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".
For cost items use one of the predefined currencies. See annex D "Currency".

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 6.1) 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 Efficiency+).

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.

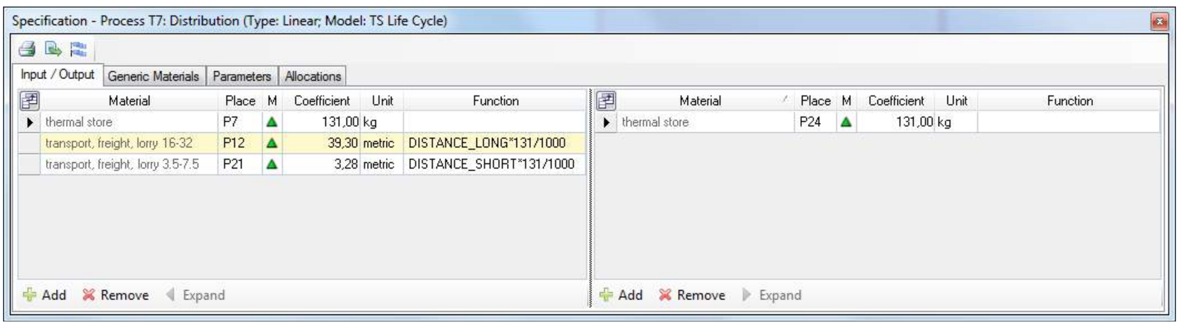


Figure 31: Specification Editor window for a process, 'Input/Output' tab, use of a function with parameters DISTANCE_LONG and DISTANCE_SHORT to determine coefficient values

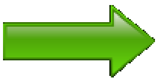
You can use names of parameters, mathematical operators, and a set of pre-defined functions within the term entered in the "Function" field.

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 9.4.2

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 in the coefficient column of the specific line of the table on the input or output side. 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. 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.

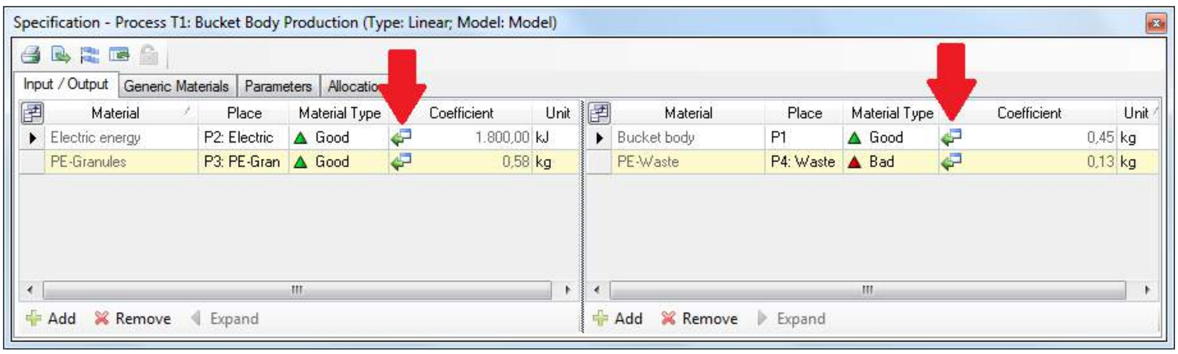


Figure 32: Live Link references of four coefficient values in a process specification indicated by an icon

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.

An overview of Live Links set from the model to data sources in Excel spreadsheets can be found in the 'Edit Live Links' dialog that can be opened via the Tools menu. See section 13.3 for a description of the 'Edit Live Links' dialog.

9.2 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 7.1). 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.

Hint: The column 'Material Type' is hidden by default in Umberto Efficiency+. If you make it visible using the 'Column Field Chooser', the variable process cost entries show a symbol of a golden coin.

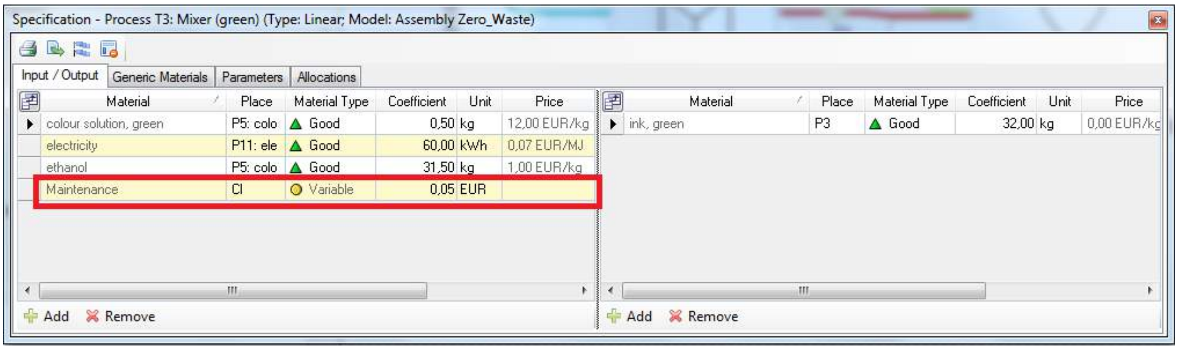


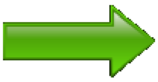
Figure 33: Specification of a process, 'Input/Output' tab with a variable process cost entry

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 9.4.2

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.

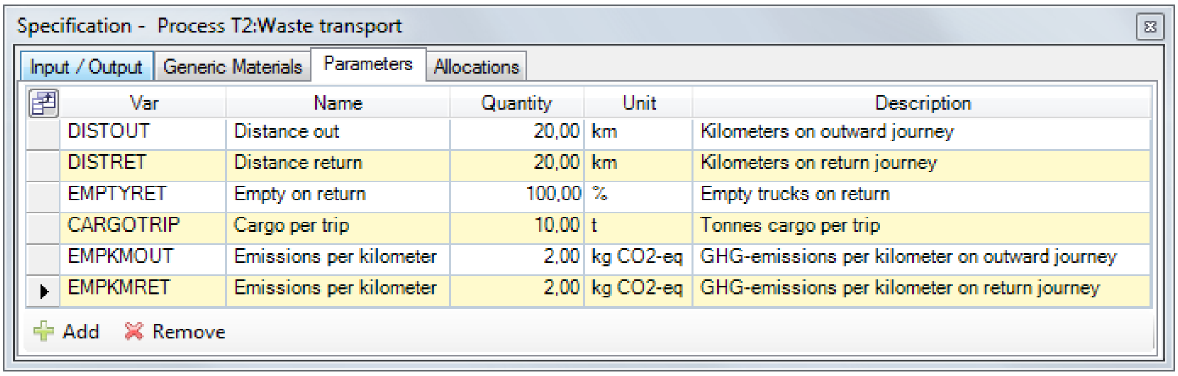
Live Links to Cost Entries: In the same way as described above for flow coefficient values, values for cost entries on the input and output side of a process specification can also be fed from an external data source via a so-called Live Link.

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.

9.3 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.


Specification - Process T2:Waste transport

Input / Output | Generic Materials | Parameters | Allocations

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

Add Remove

Figure 34: 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 both for input/output flow entries as well as for cost entries (see above) and in the user defined functions for the process specifications (see section 9.4.2).
Apart from process parameters, valid locally in one specific process, there are also net parameters that are available globally (see section 9.6).

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.

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.

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 sections 9.1 and 9.4.2). A list of valid expressions can be found in Annex A.

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 in the 'Quantity' column 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.

An overview of Live Links set from the model to data sources in Excel spreadsheets can be found in the 'Edit Live Links' dialog that can be opened via the Tools menu. See section 13.3 for a description of the 'Edit Live Links' dialog.

9.4 Allocation in Multi Product Processes

9.4.1 Allocation in Multi Product Processes

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. Allocation settings in the multi-product process are taken into account when running the calculation of the material flow model (to be more precise: when running the second of the two subsequently executed calculations, see 10.1 for more information). Allocation is used to determine how the expenses in the process are assigned to the different products for which are delivered by the system.

Examples for processes that are multi-product processes and that require allocation:

- A packaging machine that puts shrink-wrap around pallets of boxes with consumer products is used for different products. The consumption of energy and shrink foil should be adequately allocated to the products (e.g. evenly between the products, or by number of pallets being shrink-wrapped).
- A boiler that produces steam that is distributed to more than one station.
- A waste incineration plant, which produces both district heat and electricity that is sold off to the market. In this case most likely the allocation of expenses (e.g. fuel to fire up, emissions from incineration) is between heat and electricity (both on the output side of the process) and waste being accepted for incineration (red material type on the input side).

Allocation is not required in processes that yield but one product. Hence, if a process specification has only one reference flow 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 relevant at all.

The default setting for allocation is "Physical", if the reference flows are of the same unit type.

There are several possibilities for default allocation on the process level:

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 and energy as input (expenses), waste and emissions as additional expanses on the output side. The process yields two products (Product 1 and Product 2) in different quantities.

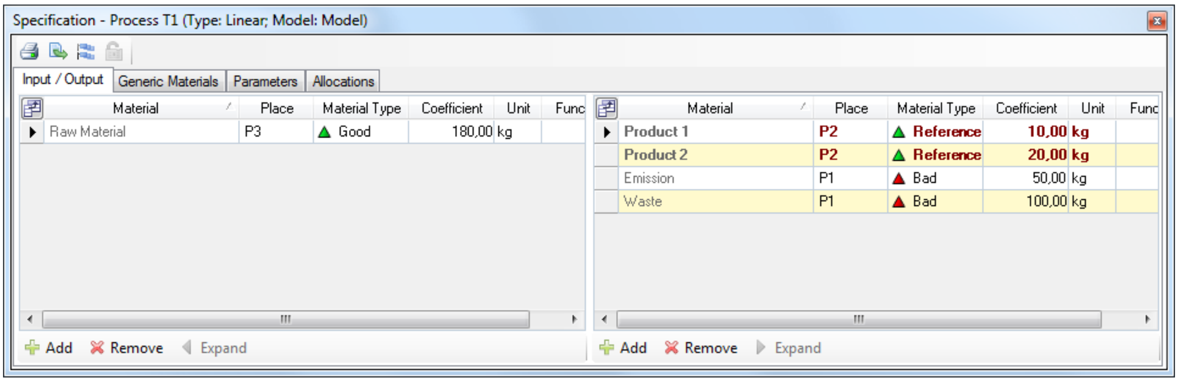


Figure 35: Specification window, 'Input/Output' tab, two reference flows

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.

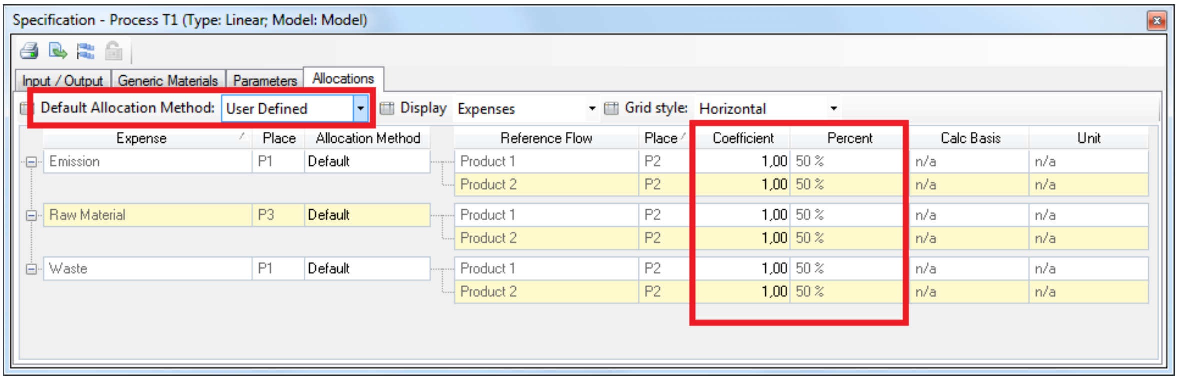


Figure 36: Specification Editor, 'Allocations' tab, 'User Defined' allocation

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 of an expense to the two 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'.

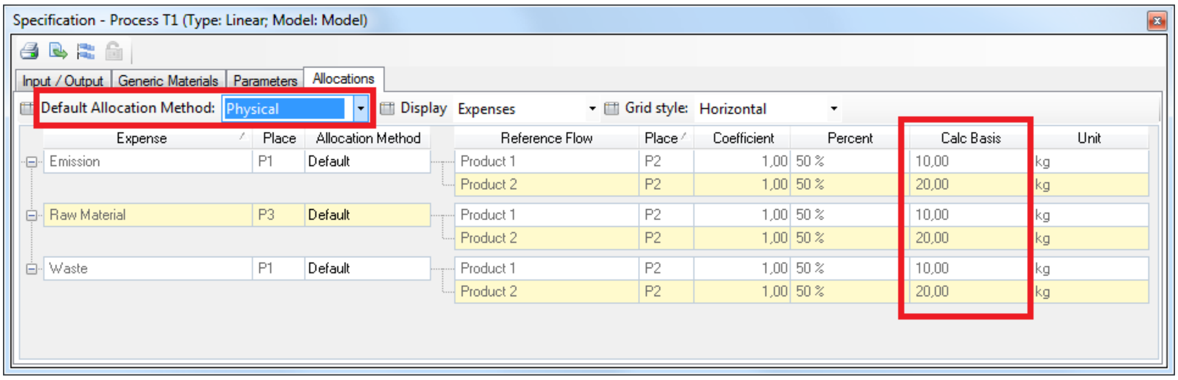


Figure 37: Specification Editor, 'Allocations' tab, 'Physical' allocation

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 10.1):

```
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.

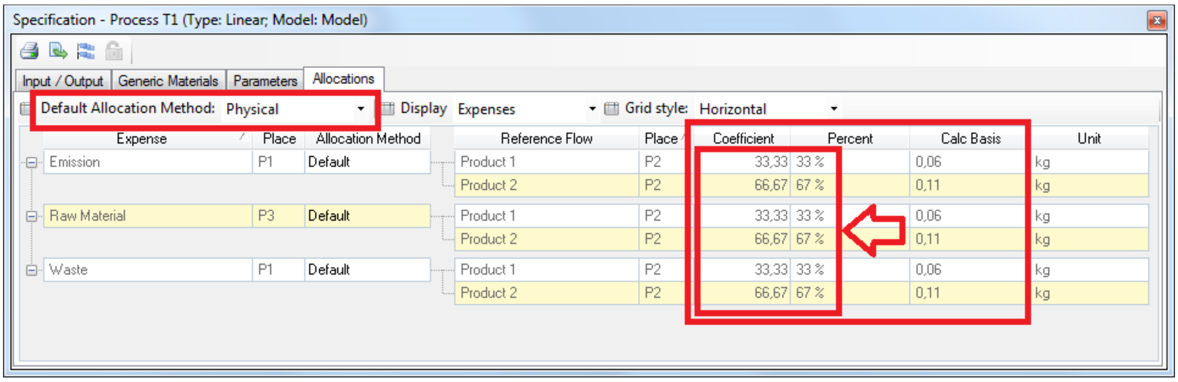


Figure 38: 'Allocations' tab, 'Physical' allocation. After the first calculation the allocation factors were determined and can be viewed in "Calc Basis" and "Coefficient" column

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.

9.4.2 Allocation for MFCA

To consider the special role of material losses in material flow cost accounting, the allocation differs slightly from the allocation described above for conventional cost accounting.

When taking an MFCA perspective, it is important to set the allocation factors on the "MFCA Allocation" tab for each process (quantity centre). Expenses in a process specification (=in each quantity centre) have to be assigned to products and to material losses (i.e. all entries that are located in the "Losses" material group or in one of the four subgroups therein ("Production Waste", "Waste", "Wastewater" and "Miscellaneous") that are outputs of this process.

In the example below there are three entries on the input side that need to be allocated to two product outputs and to one material loss.

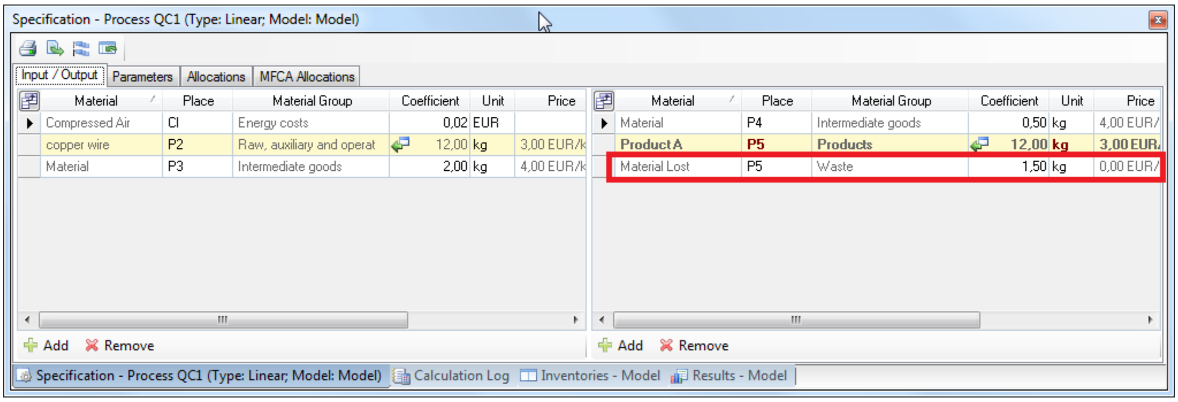


Figure 39: 'Input/Output' tab. A material loss from the "Losses/Waste" material group is defined on the output side.

In the conventional cost accounting approach, the material loss (entry "Material Lost") is considered an expense that is allocated on the tab "Allocations" to the two products.

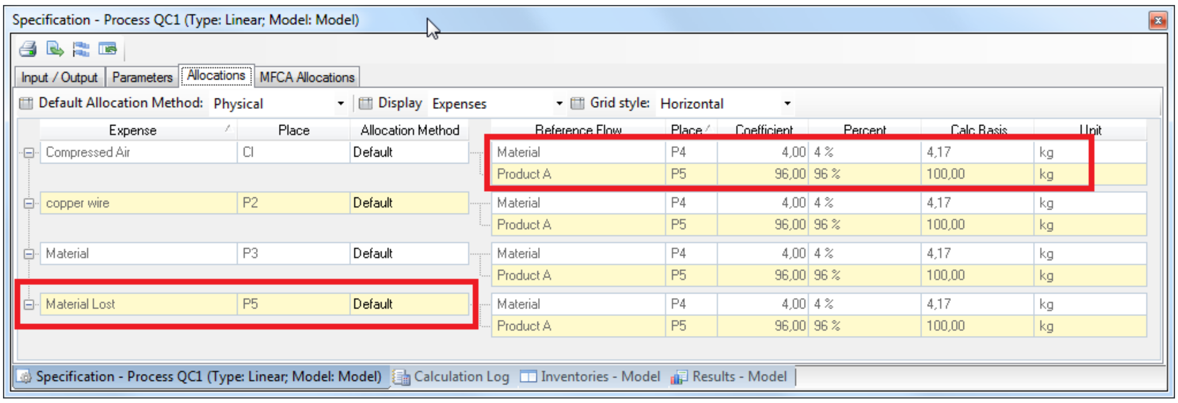


Figure 40: 'Allocations' tab. Expenses are allocated to the two products (goods) that are on the output side of the process. Note that the material loss itself is considered an expense and needs to be allocated to the two products

In contrast, in the material flow costing accounting approach, the material loss (entry "Material Lost") is now treated equally with the products, and allocation of the expenses is made between three items (two product entries, one material loss entry). These allocations are made on the "MFCA Allocations".

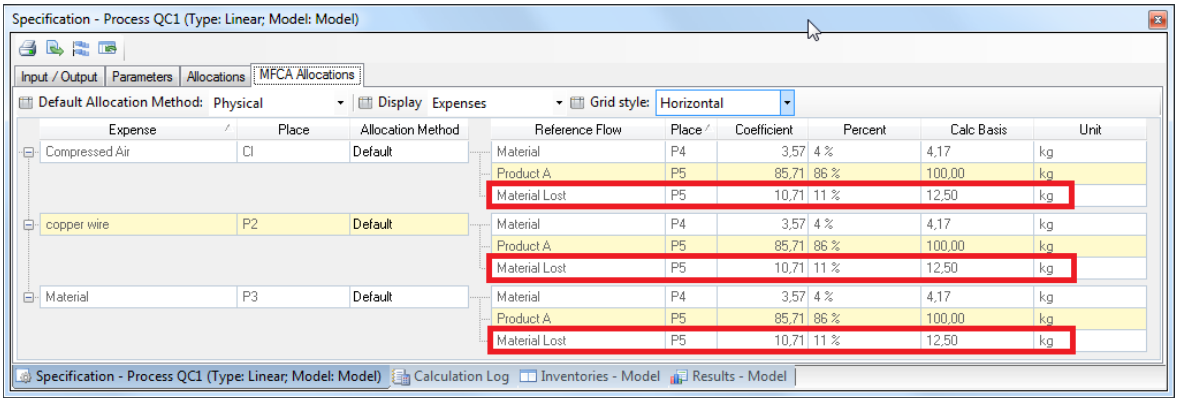


Figure 41: 'MFCA Allocations' tab. Expenses are allocated to the two products (goods) and to the material loss.

By default the allocation method used is "Physical" (i.e. allocation by mass). The user can decide to switch to "User Defined" and enter individual allocation values, as described above.

Again, the dropdown lists 'Display' and 'Grid Style' can be used to adapt the display of the allocation items.

9.5 User Defined Functions

In addition to the common linear specification of processes using coefficient, or parameters values that are being evaluated, Umberto Efficiency+ also offers the possibility to define processes using mathematical functions and operators. For more advanced material flow 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' specification 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.

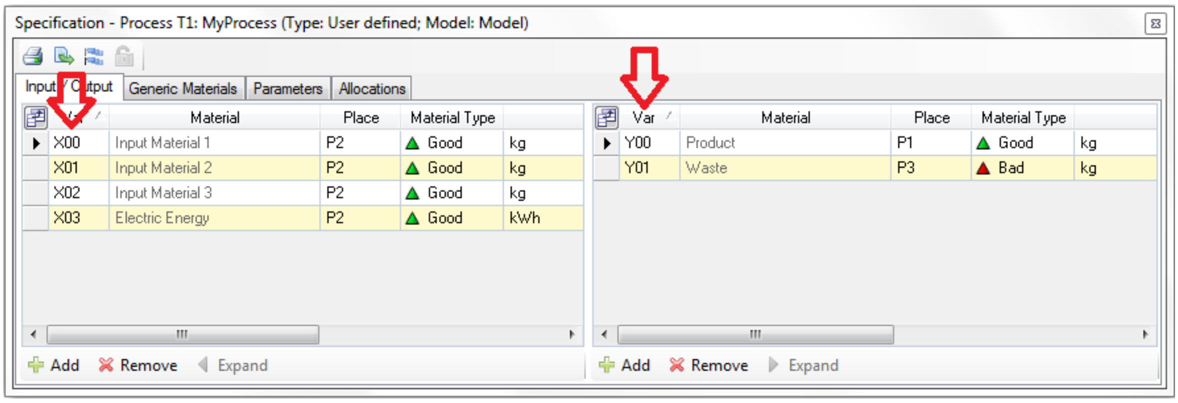


Figure 42: Specification Editor window for a process, 'Input/Output' tab with 'Var' column

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 functions editor can be opened using the button 'Edit User Defined Functions' in the process specification window, or by selecting the respective command from the context menu of the process symbol in the model editor.

In the functions editor one line is used for one assignment starting with the variable name, followed by an equals sign, and an expression or term on the 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)
;machine costs using machine hours at 100.000 kg per hour
MACHINEHOURS = Y00/100000
A00 = MACHINEHOURS*2500
```

In the above example "Y00", "X00" and "X01" are variable names for flows in the process. "THRESHOLD" is a parameter name that is tested in a conditional statement and "MACHINEHOURS" is a locally defined variable name for an intermediate calculation. "A00" is a variable identifier for a cost type (in this case the costs depend on the machine hours that in turn depend on the throughput "Y00" at the process kg. The line starting with a semicolon (";") is a comment line.

"C00" is a variable name for a process parameter (see section 9.3) and "N02" is a variable name for a net parameter (see section 9.6). 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.

Such a list of assignments to variables must not be confused with a dataflow or procedural programming language or a script. 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.

To be able to calculate the process independently 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).

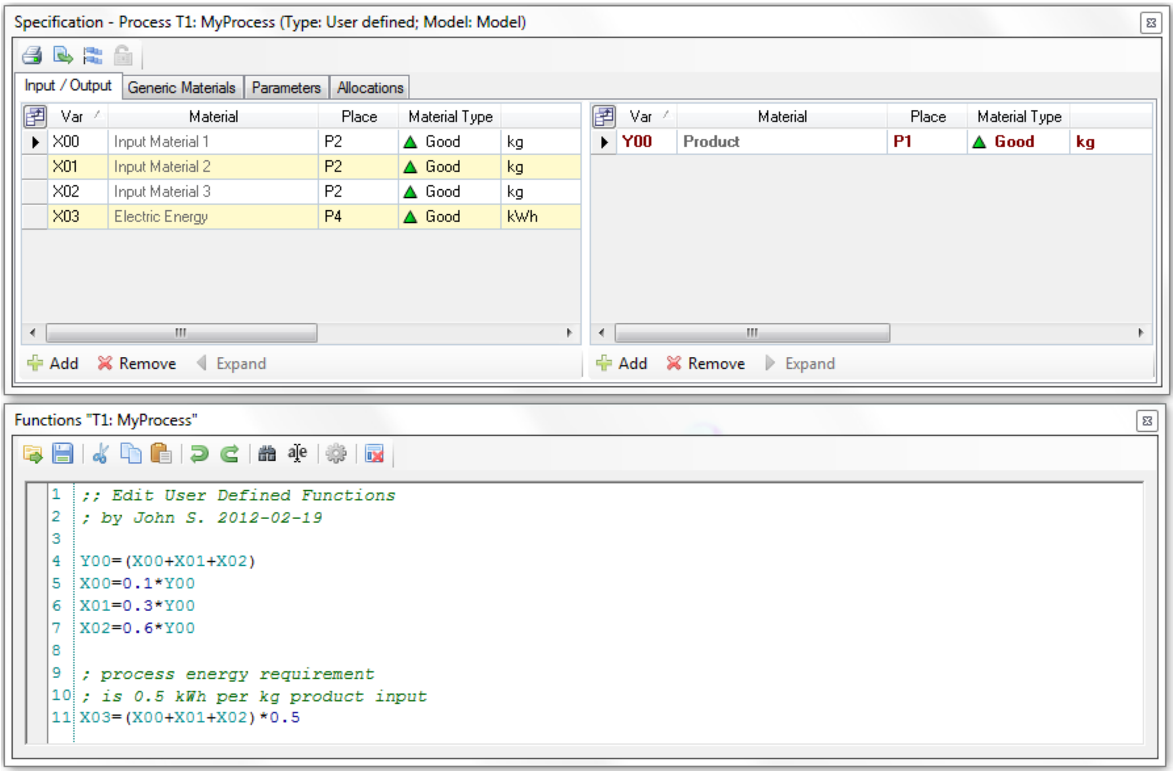


Figure 43: "Functions" Editor for specification of a process in the 'User Defined Functions' mode.

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

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.

Use of scripting (Iron Python) for advanced specification of processes is described in chapter 15.

9.6 Subnets (Hierarchical Models)

Subnets are a possibility to build hierarchical 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 still available in the inventory.

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.

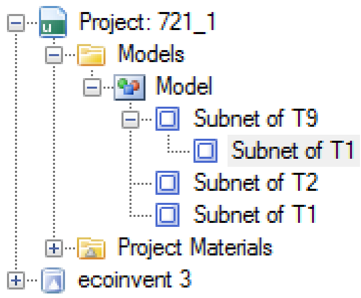


Figure 44: Subnet structure of a model shown in the Project Explorer

Create Subnet: 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.

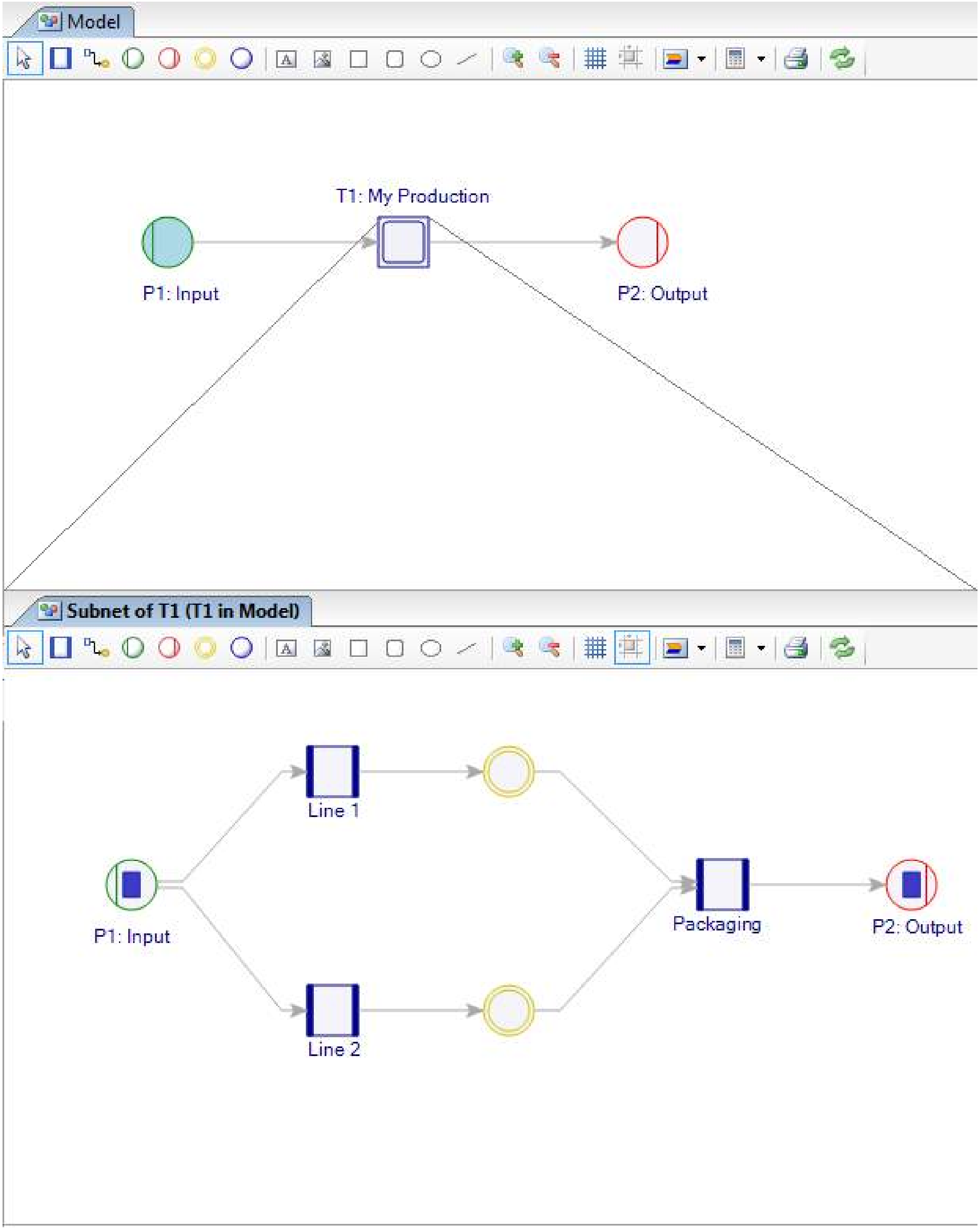


Figure 45: Subnet: The process T1 My Production has been converted to a subnet ("Subnet of T1") that opens in a new editor window. The port places P1 and P2 serve as the connecting link between parent and subnet level. In the subnet there are three processes "Line1", "Line2" and "Packaging",

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 material flow 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 8.3 to connect the input and output places to the existing port places with the colored marker in the center.

Unconnected input and output places 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 8.4).

Open Subnet: The subnet typically lies hidden "behind" a subnet process symbol. It can be opened by double-clicking the subnet process symbol. Alternatively, use the 'Open Subnet' command from the context menu of the process in the model editor, or use the 'Open' command from the context menu of the subnet entry in the Project Explorer.

Close Subnet: A subnet can be closed by simply closing the tab in the model editor area. This can be done using the 'Close button' at the top right. Alternatively, use the 'Close' command from the context menu of the subnet symbol in the Project Explorer.

Delete Subnet: 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.

Store and Reuse 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).

9.7 Net Parameters

The value of a net parameter can be used in the 'User Defined Functions' (see section 9.5) 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.

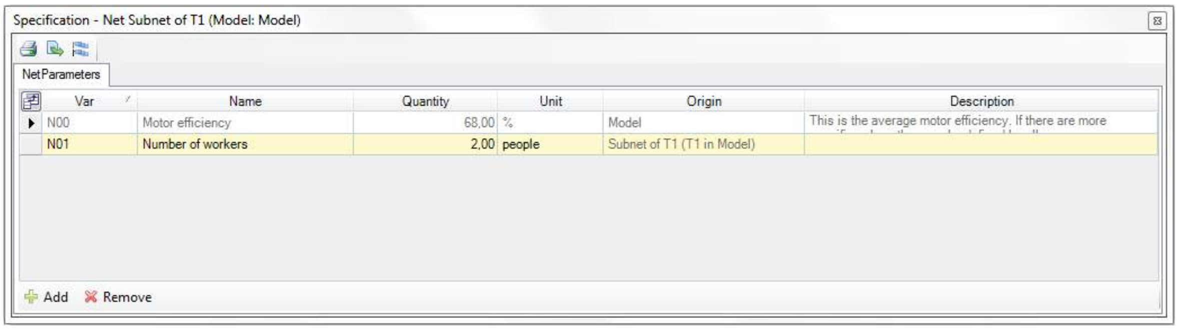


Figure 46: Specification Editor window, 'Net Parameters' tab

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.

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.

An overview of Live Links set from the model to data sources in Excel spreadsheets can be found in the 'Edit Live Links' dialog that can be opened via the Tools menu. See section 13.3 for a description of the 'Edit Live Links' dialog.

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.

9.8 Specification of Flows (Arrows) and Stocks (Places)

Specification of processes is the central task when building a material flow model. This chapter focuses entirely on the different possibilities of specifying processes. Once the processes in a material flow model have been specified, it is in most cases sufficient to specify one single flow ("manual flow") and then let the calculation algorithm determine all other flows in the system. This is described below in section 10.1.

Nevertheless, in some modelling situations, it might be required or desired to specify flows (in arrows) or stocks (in places) in addition to the process specifications. This might be necessary for models with decoupled model sections, or models with loops.

Arrow Specification: In order to specify a flow in an arrow, click on the flow in the model to mark it. In the 'Specification' window below the editor click on the button 'Add' to call the 'Search Material' dialog and select a material entry. Alternatively drag&drop an entry from the materials hierarchy in the 'Project Explorer' directly onto the 'Flows' grid in the 'Specification' window.

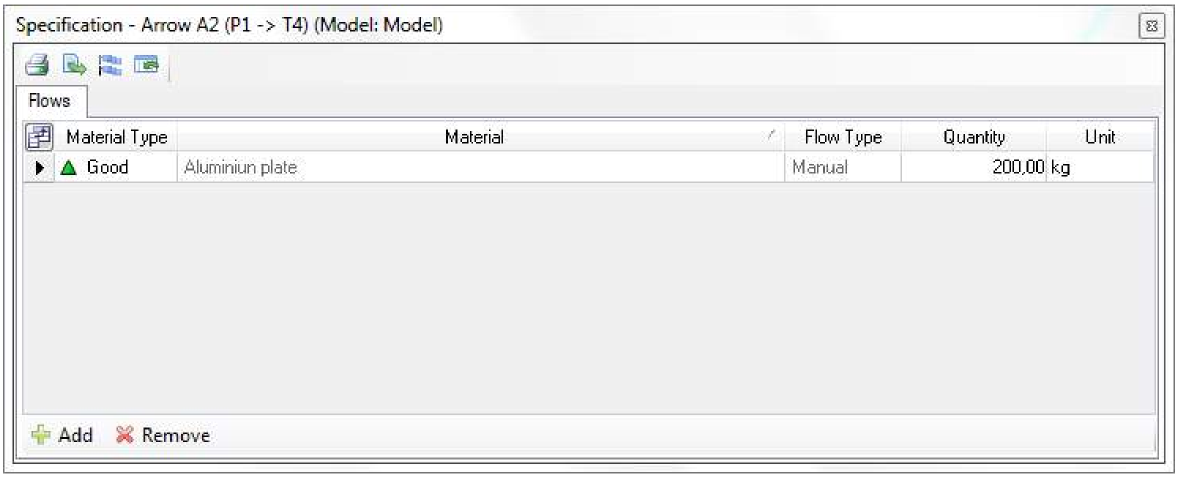


Figure 47: Specification Editor window, 'Flows' tab (an arrow is selected in the model)

Then enter a quantity for the flow in the 'Quantity' column. The flow is indicated as 'Manual' to distinguish it from the calculated flows. The arrow is colored in purple to indicate a manual flow specification.

Several manual flows can be specified in a model. However, if more than one manual flow is defined, the values of the flow must match with the calculated flows, or there is a likelihood of a flow conflict. Mind that "overspecification" with manual flows might lead to a situation where the model cannot be calculated successfully any more.

A manual flow coefficient can also be specified via a Live Link, as has been described for process flow coefficients in section 9.1 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.

Read more about handling Live Link references from Excel spreadsheet into the material flow model in chapter 13.

Place Specification: In order to specify a stock in a place, click on the place in the model to mark it. In the 'Specification' window below the editor click on the button 'Add' to call the 'Search Material' dialog and select a material entry. Alternatively drag&drop an entry from the materials hierarchy in the 'Project Explorer' directly onto the 'Stocks' grid in the 'Specification' window.

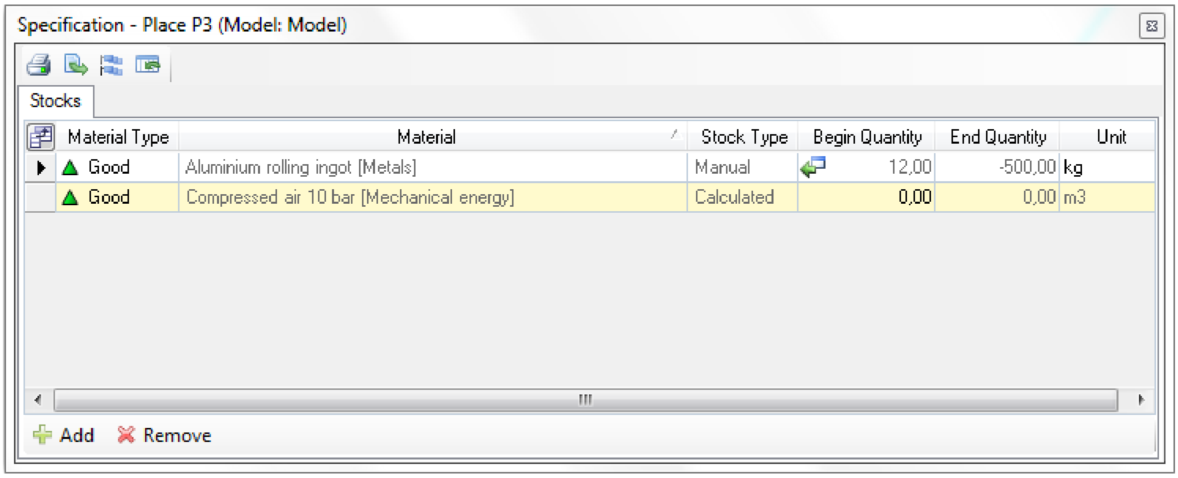


Figure 48: Specification Editor window, 'Stocks' tab (a place is selected in the model). The 'Begin Quantity' value is supplied via Live Link.

Then enter a quantity for the stock in the 'Begin Quantity' column. The stock is indicated as 'Manual' to distinguish it from entries that show calculated stocks ('End Quantity'). The 'End Quantity' value cannot be specified manually.

The begin quantity is the stock before the calculation; the end quantity is the stock at the end of the calculation. If the accounting period is one year, then the begin and end quantities describe the inventories at the begin and the end of the accounting period.

Typically input and output places (i.e. places at the system boundary of the model) do not have defined stocks. Input places feature a negative coefficient at the end of the calculation, indicating the amount of material that has been supplied into the system by an external supplier. Output places after calculation show the "End Quantity" of the material that has been delivered to the outside, the surrounding of the model (e.g. a product shipped to the market, an emission that has been released).

Working with manual stocks in places is mostly done in connection places that can be used as buffers between model sections. Begin quantities specified manually in a connection place can serve as a trigger for the calculation of some model sections that would otherwise not be able to calculate. In the optimal case the connection place should sport the same end quantity after calculation. If not, a difference in the 'Begin Quantity' and 'End

Quantity' indicated flows that are not equilibrated, using the connection place as a buffer.

A manual stock coefficient (begin quantity) can be specified by a function (formula), as has been described for process flow coefficients in section 9.1. The function can be using process parameters or net parameters and all valid expressions described in Annex A.

A manual stock coefficient can also be specified via a Live Link, as has been described for process flow coefficients in section 9.1 too. By establishing a reference to a cell in an Excel sheet, the manual stock value can be fed into the model from an external source.

Read more about handling Live Link references from Excel spreadsheet into the material flow model in chapter 13.

10 Calculating the Material Flow Model

10.1 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. 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.

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 be specified by a function (formula), as has been described for process flow coefficients in section 9.1. The function can be using process parameters or net parameters and all valid expressions described in Annex E.

A manual flow coefficient can also be specified via a Live Link, as has been described for process flow coefficients in section 9.1 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 material flow 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 costs 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 costs. 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 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 Costs' (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 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 the calculation, the calculation log will be prompted on a tab the Specification Editor area. The calculation 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 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 Cost Calculation: To separately start the second calculation for determining the flows per product (in a multi-product system) and the costs per product, choose the command 'Calculate Product Flows and Costs' from the calculation menu. The product flows calculation is based on the allocation factors made for multi-product processes.

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 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 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.

10.2 Identification of Products (Reference Flows)

The material flow model is calculated using the manual flow (trigger flow or starting flow). All calculated values hence relate to the quantity of the manual flow. Typically this is the annual production volume. However, other manual flows can be specified. One could for example set a certain maximal output of an emission (emission cap) and run the calculation of the system, to understand how much could be produced in order not to exceed the threshold.

Or, one can specify a given input quantity to find out the flows in the production system.

The product for which the 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 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 types 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 6.2) 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-products that have a value (and are not disposed of) are also "Goods".
- **Bad (red):** "Bads" 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 expenses 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 49: 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 50: 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 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 results can be calculated for them.

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.

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.

10.3 Multi Product Systems and Allocation

The models built with Umberto 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 10.2 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, 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 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.

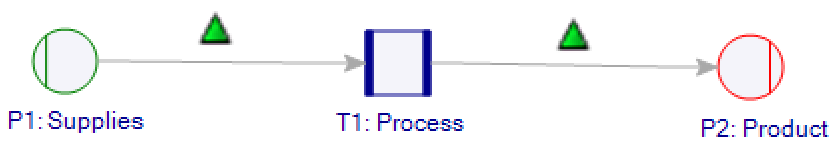


Figure 51: Process with one product output (green), and one or more goods inputs (green).

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.

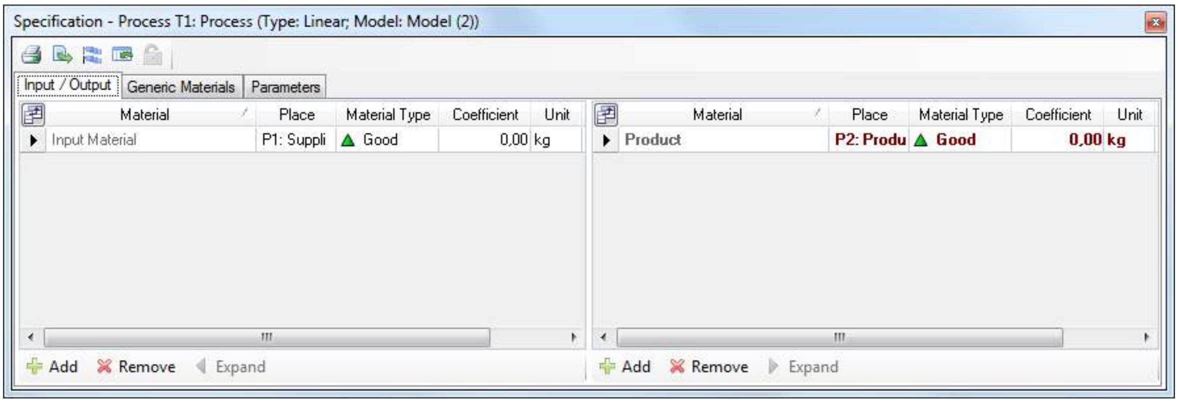


Figure 52: Process specification, 'Input/Output' tab... no allocation required

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.

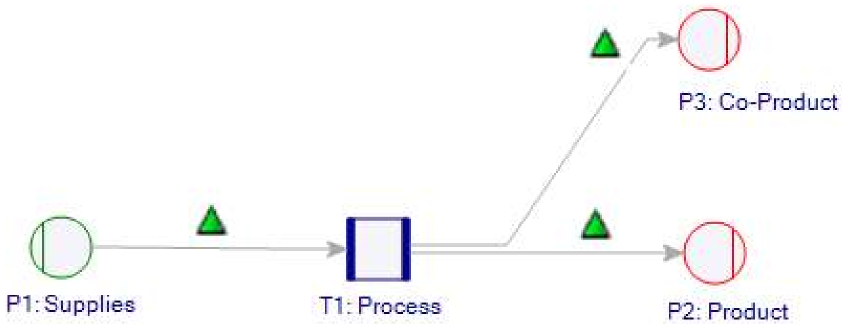


Figure 53: Typical process with one product output (green), a co-product output (green), and one or more inputs (green).

The 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.

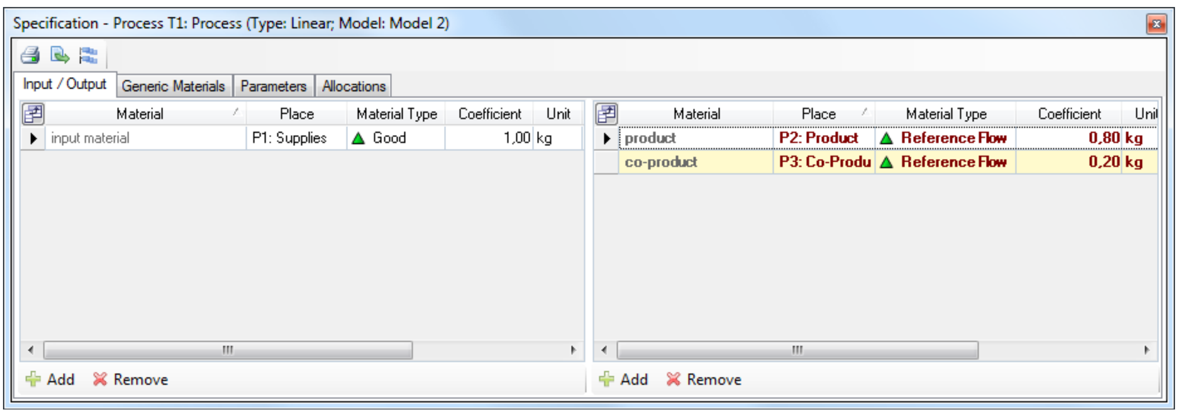


Figure 54: Process specification, 'Input/Output' tab

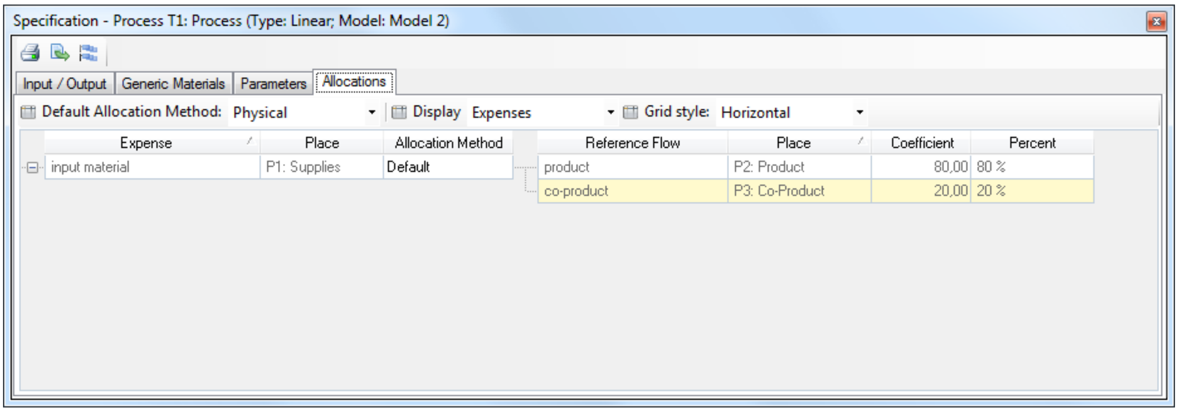


Figure 55: ... and 'Allocations' tab for the above process. In this example the allocation is set to 'Physical'.

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.

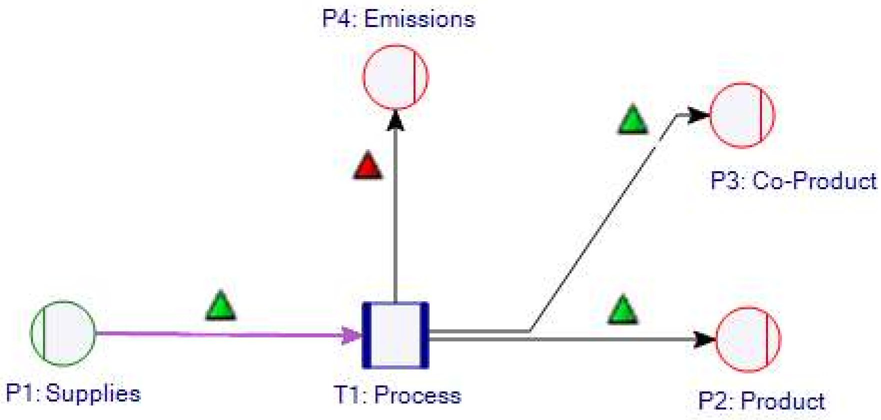


Figure 56: Process with product (green), co-product (green), and one or more inputs (green). Emissions and waste (red) are considered an expense and must be allocated.

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.

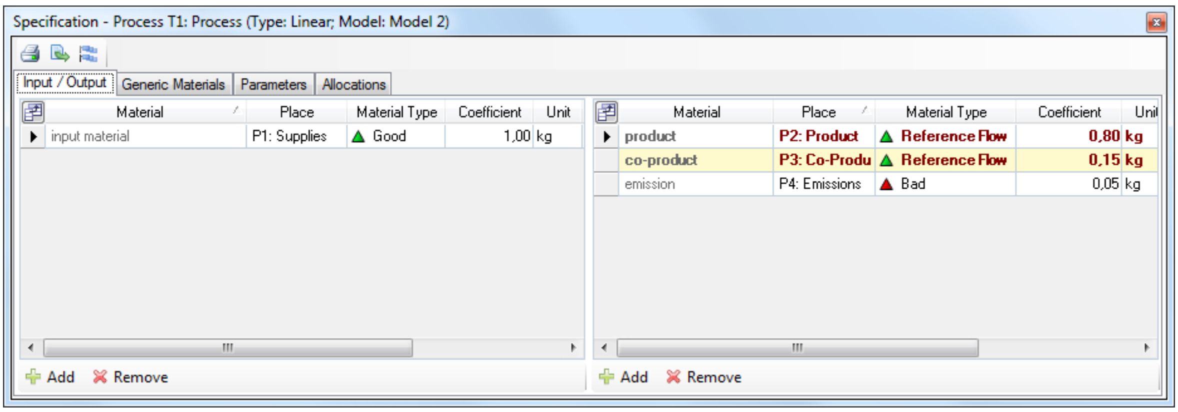


Figure 57: Process specification, 'Input/Output' tab ...

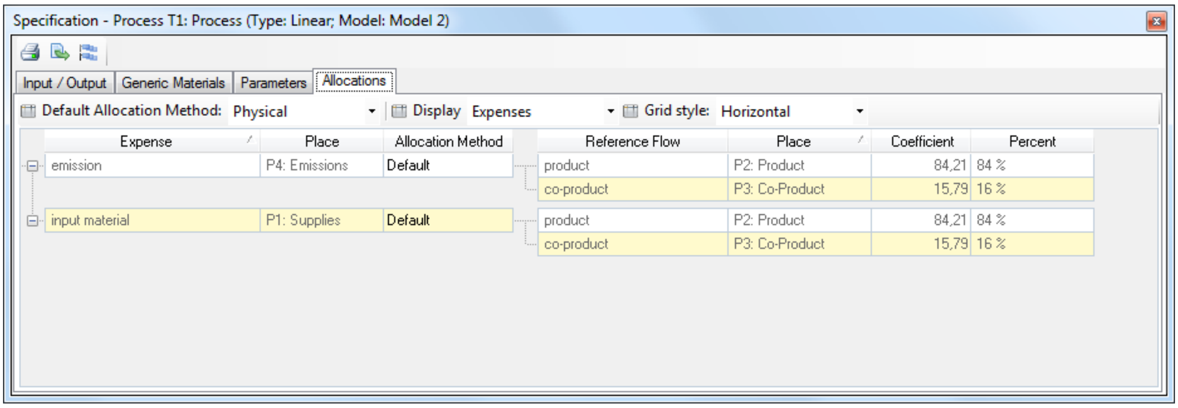


Figure 58: ... and 'Allocations' tab for the above process. In this example the allocation is set to 'Physical'. Both input material and emission are considered an expense and have to be allocated.

11 Inventory Results and Analysis

11.1 Input/Output Flows 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.

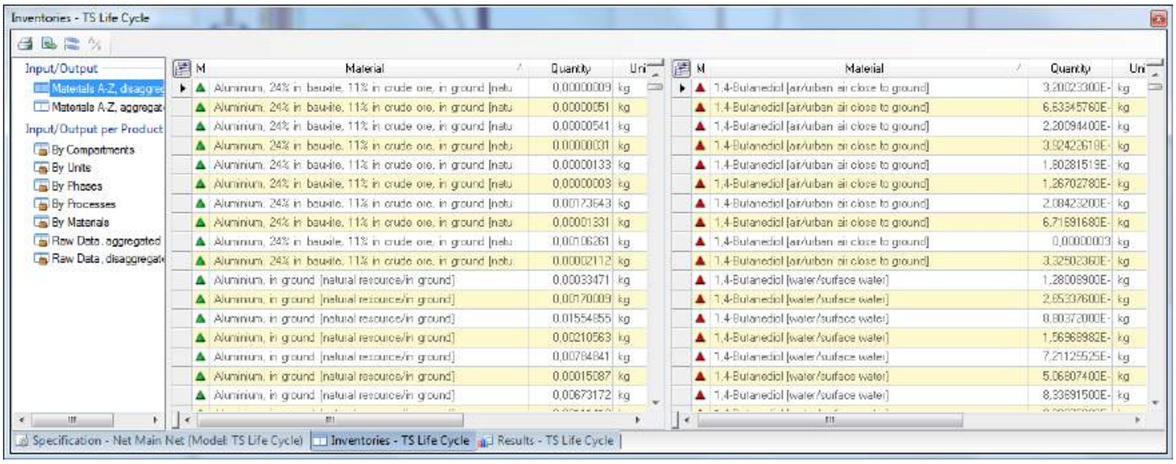


Figure 59: Default view of inventory with Input/Output Flows, materials A to Z, disaggregated

Summary Views of Inventory Results: Two summary views are available to choose from on the left side under the headline "Input/Output":

- view 'Materials A-Z, disaggregated'
- view 'Materials A-Z, aggregated'

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 multiple similar material entries without showing the individual processes. The hint 'Multiple Processes' is displayed in the 'Process' column instead.

Detail Views of Inventory Results: Further pre-defined detail views and grouping of the inventory data are available and can be selected in the list on the left under the headline "Input/Output" per Product":

- by Unit
- by Process
- by Material
- view 'Materials A-Z, aggregated'

For multi-product models (systems that yield more than one product or that 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 from the dropdown list 'Selected Product'.

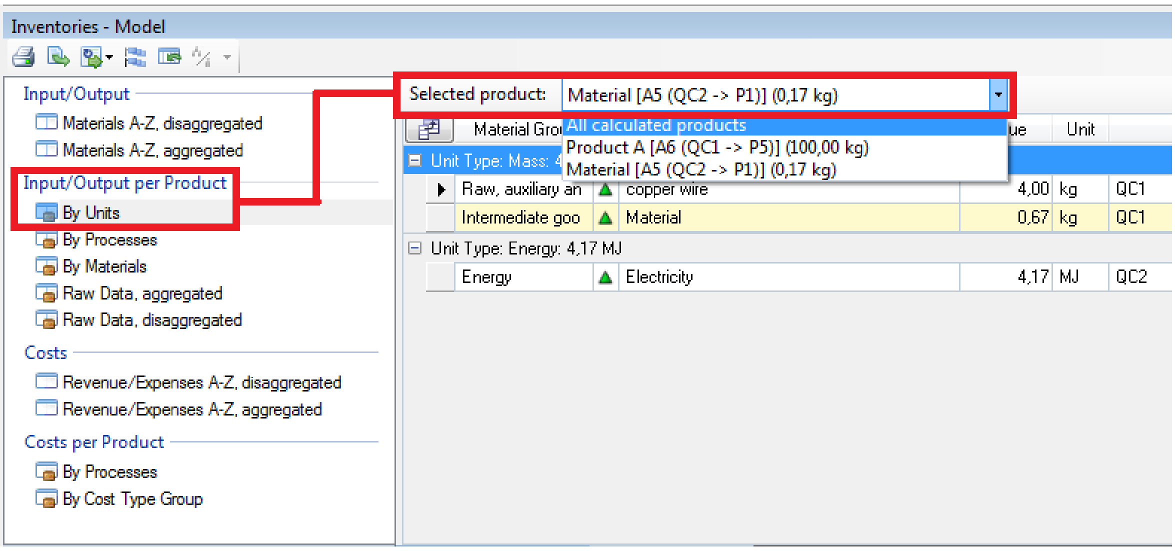


Figure 60: To see an inventory for a specific product (instead of for all products), choose the product from the dropdown list "Selected Product" above the table

The following inventory views are available:

- **Inventory By Units**: A grouped list of inputs and outputs of the model by unit type. Aggregated view with only one entry per 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 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.
- **Inventory By Processes**: A grouped list of inputs and outputs of the model by process. This is similar to the above view "By Phases". Aggregated view with only one entry per 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. 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 flow from the system environment or that release this flow.
- **Raw Data, aggregated**: A plain view of all inventory data. This is an aggregated view with only one entry per 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 inventory 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.

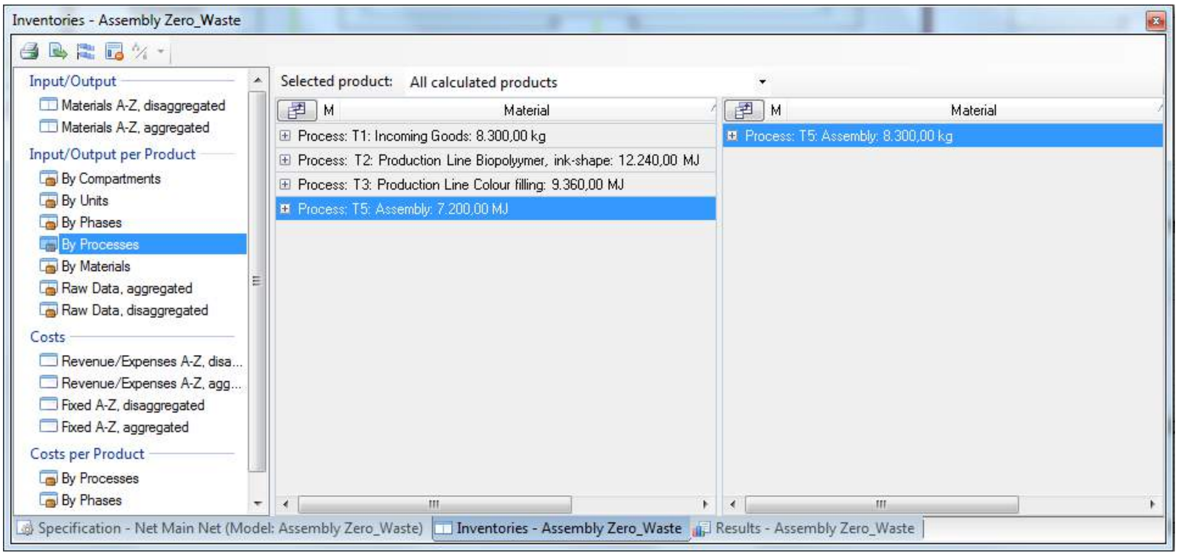


Figure 61: Inventory of input/output flows grouped by process, all groups shown collapsed

See the section on grid handling above to learn how to further sort and group the list of input/output flows.
Remember that if you prefer another grid layout in the inventory, you can adapt it. The setting will be maintained until the 'Reset Grid Layout' button is clicked. See section 4.2 for more details.

Note that in all grouped views flows of the unit type 'Mass' (basic unit 'kg') are by default shown at the top. These are considered the most important flows and of primary interest. 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 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 0 and 12.2)

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"

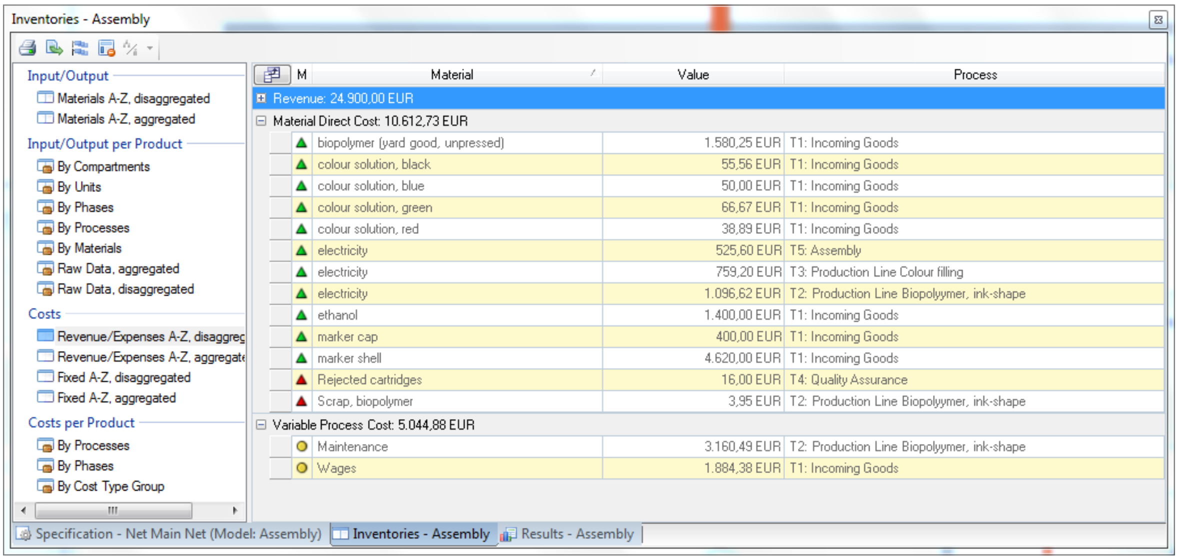


Figure 62: Default view of costs inventory with Input/Output Flows, materials A to Z, disaggregated

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.

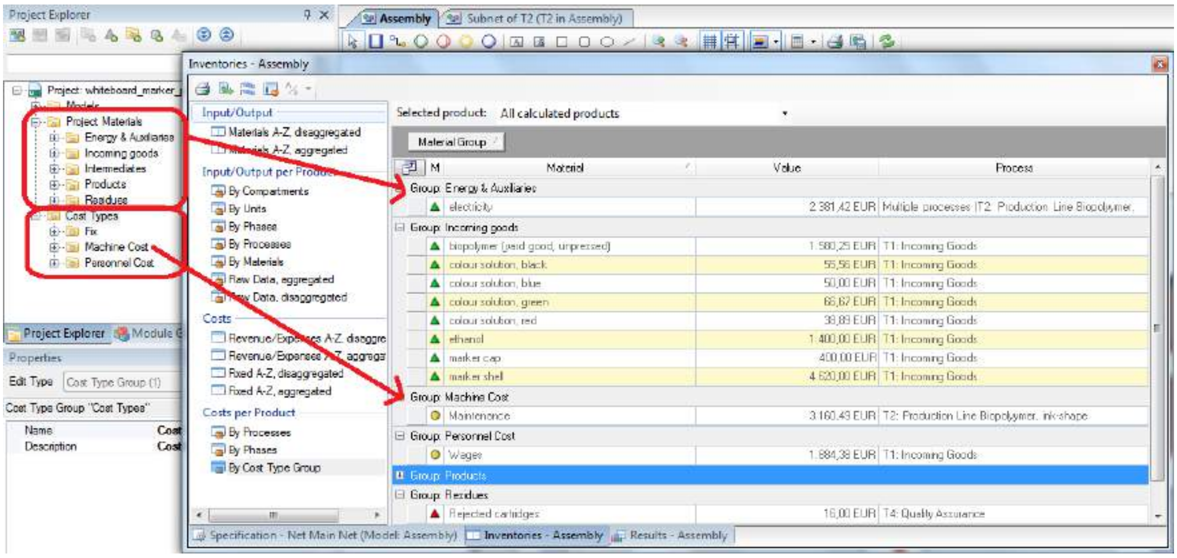


Figure 63: In the Costs per Product / By Cost Type Group view costs are structured by material groups and cost type groups defined in the Project Explorer

Additional views for costs can be created using the grouping and sorting features for grids (see section 4.2)

Find out how to export inventory cost data as raw data to Excel for creating diagrams based upon the data in section 12.3.3.

11.3 Flows Sankey Diagrams

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

Numerous options exist, to adapt the Sankey diagram.

Sankey diagrams can only be created after the calculation of the model (see chapter 10.1). The flow quantities determined for each material in the arrows are the basis for displaying Sankey arrows.
The color for each flow is defined in the properties of a material. See chapter 6 on materials.

To switch to the Sankey diagram mode, click on the button 'Show Sankey Diagram' in the Model Editor toolbar. The diagram can 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.

To select the type of Sankey diagram use the dropdown menu next to the button 'Show Sankey Diagram'.

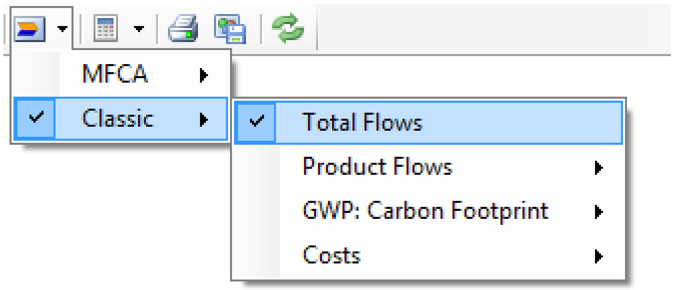


Figure 64: Choosing a type of Sankey diagram from the cascading menu under the 'Show Sankey Diagram' button

The dropdown menu next to the button 'Show Sankey Diagram' only shows all entries after both calculations of the model (Total Flows, Product Flows, GWP and Costs) have been performed. If it doesn't show any entries, please run the calculation first (see section 10.1).

The following four types of Sankey diagrams are available for the classic approach and for the material flow cost accounting approach.

- Total Flows
- Product Flows
- GWP (Carbon Footprint)
- Costs

For the latter three, you can select to display a Sankey diagram for an individual reference flow, or for all reference flows together.

The Sankey Mode Label that can be displayed via Menu 'Draw' > 'Sankey Mode Label' shows which type of Sankey diagram has been selected. This information is especially helpful when you plan to export or print the Sankey diagram

GWP (Carbon Footprint) Sankey diagrams are explained in chapter 14.4

Total Flows: The default Sankey diagram view is 'Total Flows'. It will show a Sankey diagram based on the physical flows. Flows of all unit types that are defined in the project are shown in one diagram. Sankey arrows can be switched on/off per unit type (see next section on scaling of Sankey diagrams)

Product Flows: If there are several reference flows in the material flow model, then a Sankey diagram showing the flows associated to each of these reference flows (products) can be interesting. The sum of "All Reference Flows" should again add up to the "Total Flows".

In the conventional cost accounting perspective, only products or intermediates are identified as reference flows. For creating a Sankey diagram that only shows the allocated product-related flows, choose "Classic" from the 'Show Sankey Diagram' menu, and 'Product Flows' from the cascading menu. Then choose one product in the next cascading menu.

In the material flow cost accounting (MFCA) perspective, on top of actual products and intermediates also material losses are identified as reference flows. For creating a Sankey diagram that shows the allocated flows per product and material loss, choose "MFCA" from the 'Show Sankey Diagram' menu, and 'Product Flows' from the cascading menu. Then choose a product or a material loss in the next cascading menu.

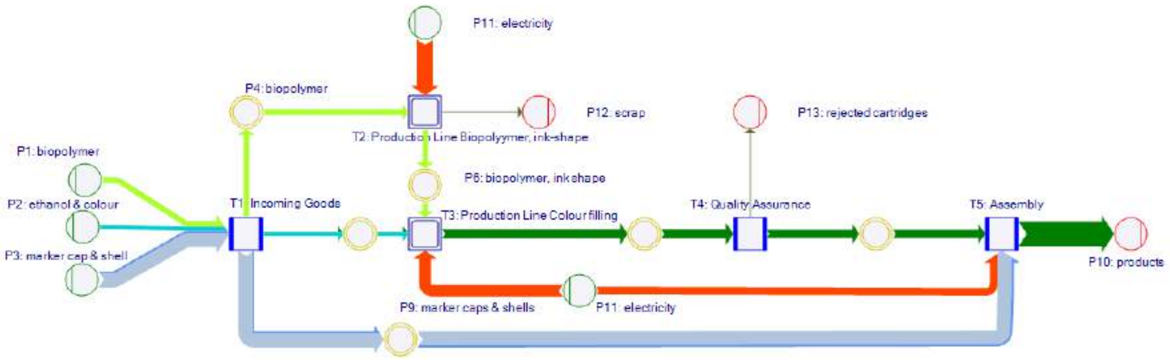


Figure 65: Sankey Diagram showing product-related flows

Hovering the mouse cursor over an arrow in the Sankey diagram shows the flow value in a tooltip.

The flow 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 8.4

Read about exporting and printing Sankey diagrams in chapter 12.3

11.4 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.

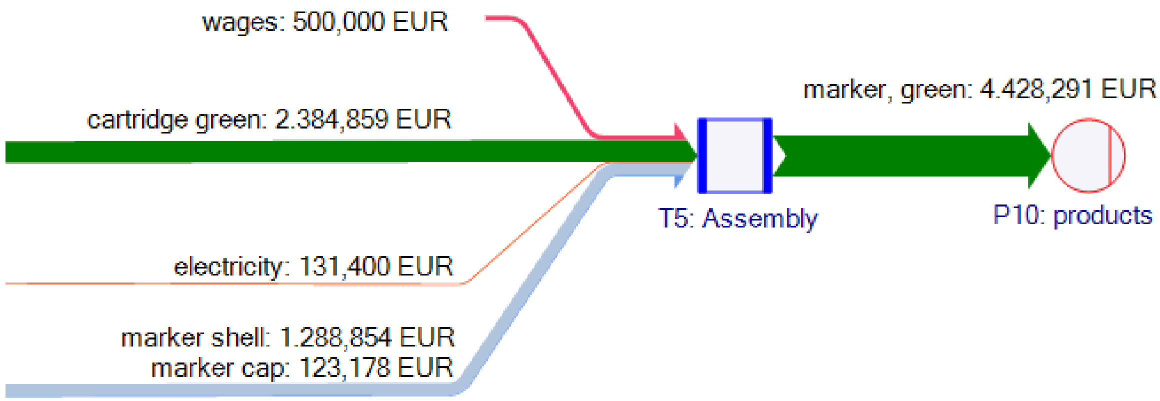


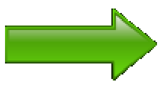
Figure 66: The sum of costs on the input side (material direct costs and variable costs e.g. wages at the process) add up to the output value.

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 9.4)

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 8.4



More about the cost accounting feature in Umberto models can be found in chapter 7

11.5 Sankey Diagram Scaling and Options

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 model. Typically these are mass (kg) and energy (MJ), but when working with other unit types additional basic units are introduced and each one can be scaled individually with its own slider.

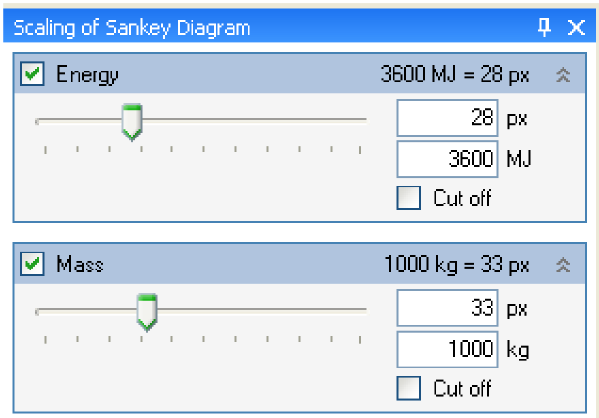


Figure 67: Scaling of Sankey Diagram

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.

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.

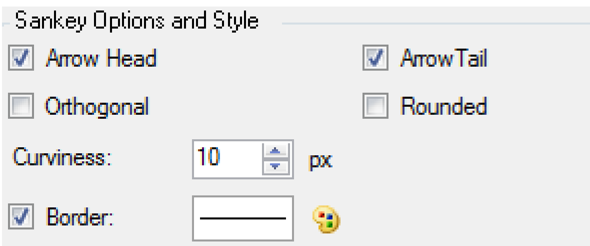


Figure 68: Sankey Options in the Arrow properties dialog

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 8.1 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 is visible when no element is selected. These relate to spikes for the Sankey arrows:

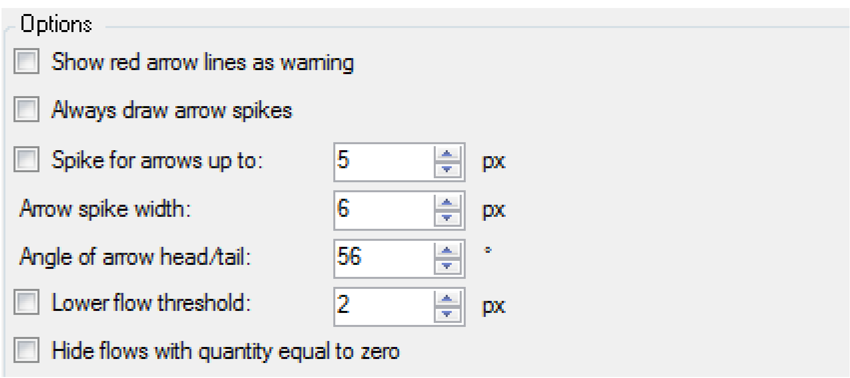


Figure 69: Sankey arrow-related options in Diagram Properties dialog

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.

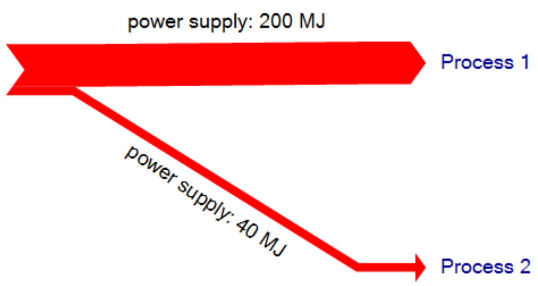


Figure 70: Example for arrow spike for small arrows only

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.

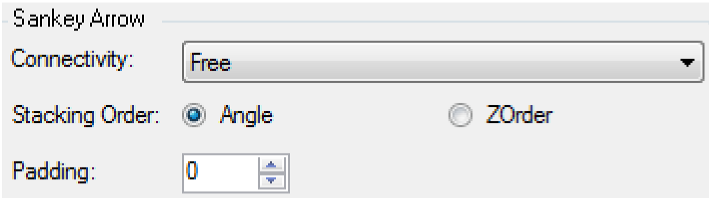


Figure 71: Sankey arrow-related options in Process Properties dialog

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', 'Costs' or 'Carbon Footprint'. These different Sankey diagram types are available for the "Classic" (conventional) cost accounting perspective and for the material flow cost accounting (MFCA) perspective. Switching between the Sankey diagram modes is done using the cascading menu next to the 'Show Sankey Diagram' button or in the View menu (see section 11.3).

The currently set Sankey diagram mode can be shown as text element by choosing the entry 'Sankey Mode Label' from the Draw menu.

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.

Read about exporting and printing Sankey diagrams in chapter 12.3

12 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.

12.1 MFCA Results

In Umberto Efficiency+ the results of the material flow cost accounting calculation is shown directly in the Specification Editor area after a successful calculation.

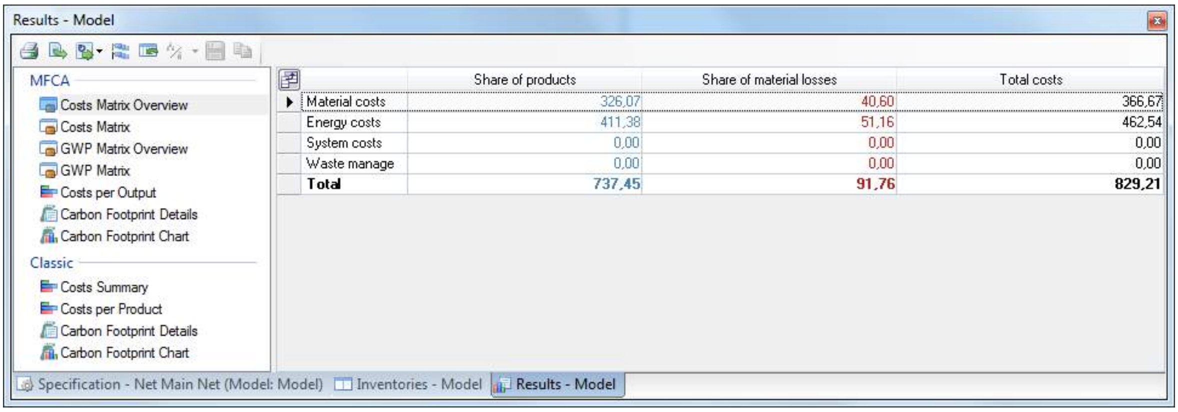


Figure 72: Costs Matrix Overview. This summary of the MFCA calculation is shown directly after a successful calculation of the material flow model

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 7.1 above) and the material direct costs ("Market Price" and "Disposal Costs"). The other costs are collected from the process costs (see section 7.2.2 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 Efficiency+ 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.

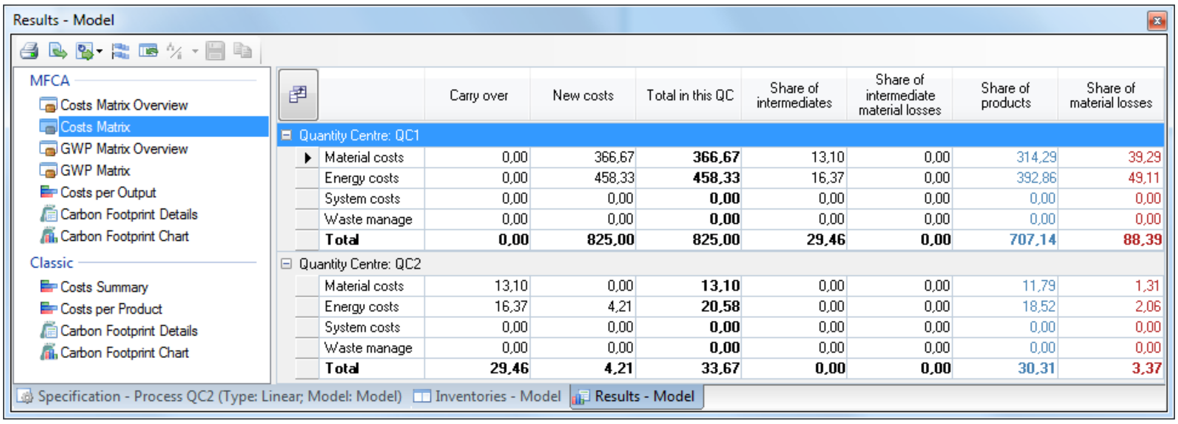
One section or block of the cost matrix table relates to one quantity centre (represented by a process symbol in the model). The block can be hidden by clicking on the minus symbol in front of the quantity centre name in the header.

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.



	Carry over	New costs	Total in this QC	Share of intermediates	Share of intermediate material losses	Share of products	Share of material losses
Quantity Centre: QC1							
Material costs	0,00	366,67	366,67	13,10	0,00	314,29	39,29
Energy costs	0,00	458,33	458,33	16,37	0,00	392,86	49,11
System costs	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Waste manage	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	825,00	825,00	29,46	0,00	707,14	88,39
Quantity Centre: QC2							
Material costs	13,10	0,00	13,10	0,00	0,00	11,79	1,31
Energy costs	16,37	4,21	20,58	0,00	0,00	18,52	2,06
System costs	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Waste manage	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	29,46	4,21	33,67	0,00	0,00	30,31	3,37

Figure 73: 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.

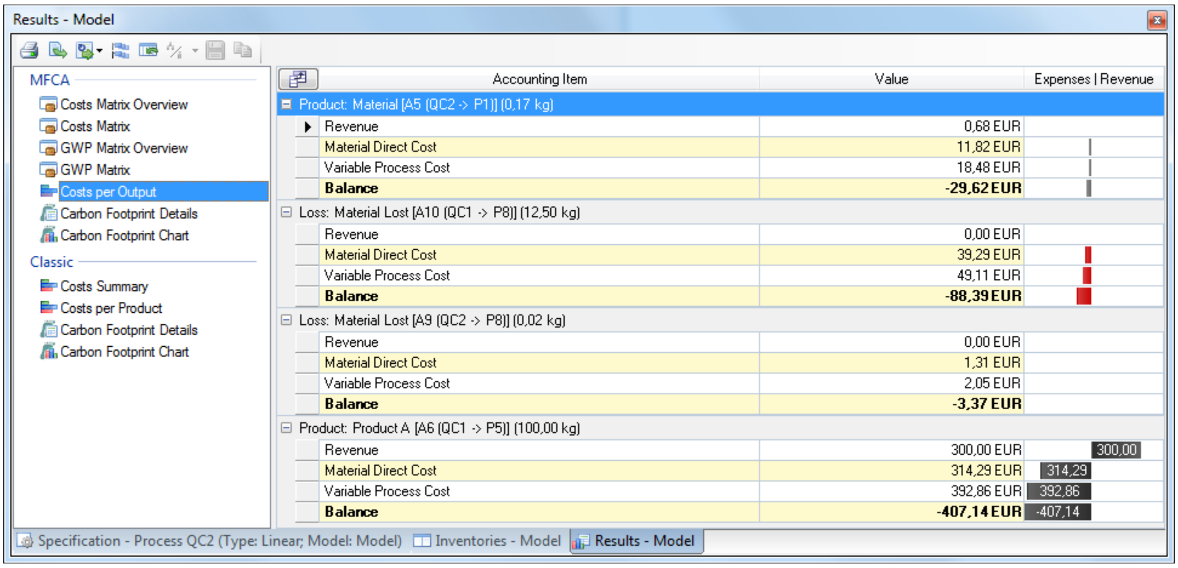


Figure 74: Costs per Output

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 14.3.

12.2 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".

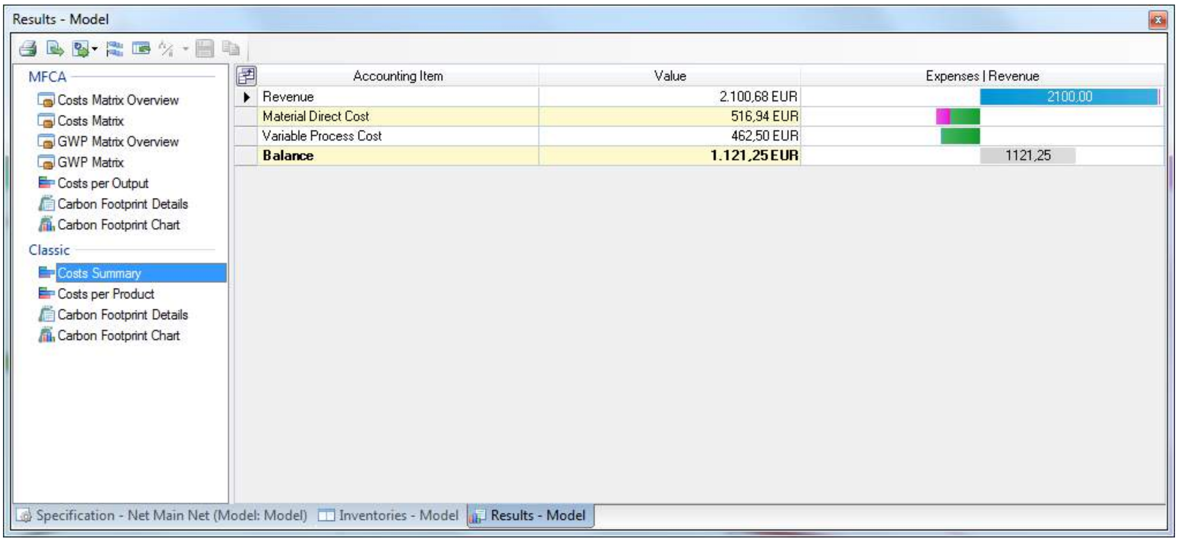


Figure 75: Costs Summary

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).

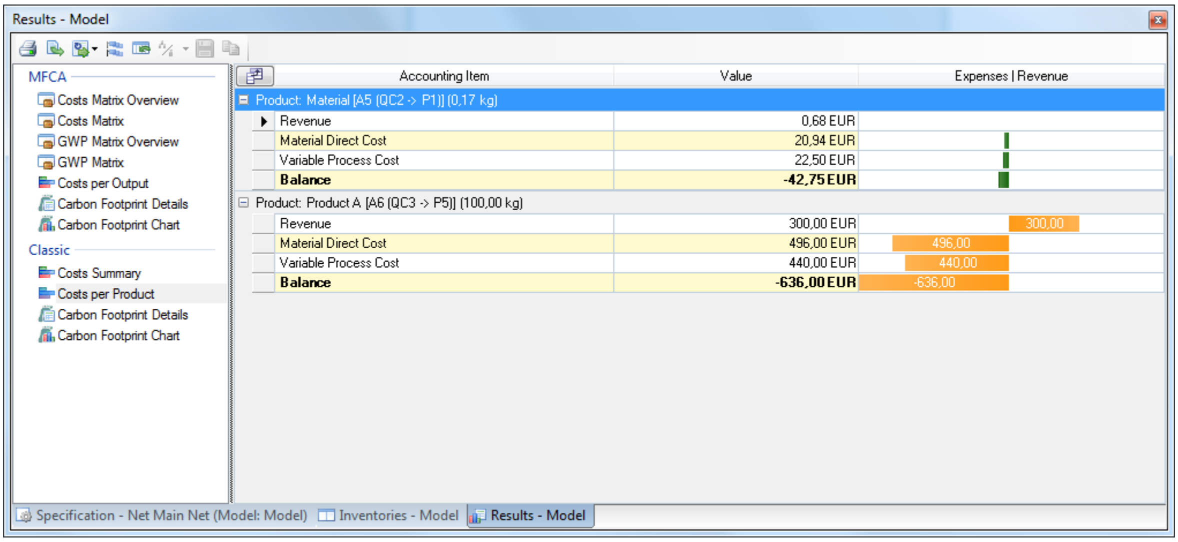


Figure 76: Costs per Product in the conventional cost accounting group on the 'Results' tab

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 12.3.1 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 14.3.

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 10.1) 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.

12.3 Printing and Exporting

12.3.1 Model / Sankey Diagram Printing and Exporting

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.

Copy Cost Sankey Diagram to Clipboard: To copy a cost Sankey diagram of the model use the command 'Select All' from the context menu of the Model Editor area when in the cost Sankey diagram view. Then use the command 'Copy' to copy it to the clipboard. Open the target application and paste the diagram.

Print Cost Sankey Diagram: To print the currently active cost 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.

12.3.2 Inventory Printing and Exporting

All inventories (see chapter 11) shown in the Specification Editor after a successful calculation of a model can be printed and exported. This includes input/output inventories, the grouped inventory views per product, as well as the cost inventories.

Print Inventories: The inventories and tables shown on the tab 'Inventories' can be printed. Choose the view you wish to print then click on the button 'Print Active Inventory Table'. A PDF file will be generated for printout.

Export Inventories: The inventories and tables shown on the tab 'Inventories' can be exported to Microsoft Excel. Choose the view you wish to export then click on the button 'Export Active Inventory Table'.

Material Flow Raw Data Export: All inventory data calculated from the material flow mode 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. Choose file type "CSV (.csv)" in the 'Export File As' dialog.

To export all inventory data as raw data for the classic accounting perspective click 'Export Material Flow Raw Data' from the dropdown menu of the button 'Export Data'. To export all inventory data as raw data for the MFCA perspective click 'Export MFCA Material Flow Raw Data' from the dropdown menu of the button 'Export Data'.

The two raw data exports are very similar: The Excel table created from 'Export Material Flow Raw Data' will only feature inventory entries for the actual products of the system (column "Product" in the output file). The Excel table created via 'Export MFCA Material Flow Raw Data' will additionally feature inventory entries for the material losses of the system.

State a name for the Excel file. The export file will be opened upon completion of the export.

The material flow raw data includes the following columns:

- Project Name
- Model
- Net
- Timestamp (=Version)
- Product
- Phase
- Arrow
- Material
- Material Type (Good, Bad)
- Material Group
- Flow Type (In, Out, Reference Flow, IntIn, IntOut)
- Quantity
- Unit (physical flows, basic unit)

Thy physical quantities of the inventory flows are shown in their basic unit. Entries for internal flows (flows not located at a system boundary, flowing from a process to a connection place, or from a connection place into a process) are marked "IntIn" (internal flow input) and "IntOut" (internal flow output) in the 'Flow Type' column. The internal flow entries in the export file are not shown in the inventory tables, since only flows at the system boundaries are included in inventories.

Note that the use of the timestamp allows doing model comparisons. Calculation results of two or more model calculations 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.

12.3.3 Results Printing and Exporting

Print Results: The result tables with cost data shown on the tab 'Results' can be printed. Choose the view you wish to print then click on the button 'Print Active Result Table'. A PDF file will be generated for printout.

Export Results: The inventories and tables shown on the tab 'Results' can be exported to Microsoft Excel. Choose the view you wish to export then click on the button 'Export Active Result Table'.

Cost Raw Data Export: All cost data calculated from the material flow mode 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.

To export all result cost data as raw data for the classic accounting perspective click 'Export Cost Raw Data' from the dropdown menu of the button 'Export Data'. To export all reslt cost data as raw data for the MFCA perspective click 'Export MFCA Cost Raw Data' from the dropdown menu of the button 'Export Data'.

The two raw data exports are very similar: The Excel table created from 'Export Cost Raw Data' will only feature cost entries for the actual products of the system (column "Product" in the output file). The Excel table created via 'Export MFCA Cost Raw Data' will additionally feature cost entries for the material losses of the system.

State a name for the Excel file. The export file will be opened upon completion of the export.

The material flow raw data includes the following columns:

- Project Name
- Model
- Net
- Timestamp (=Version)
- Product
- Phase
- Process
- Cost Type (In, Out, Revenue, IntIn, IntOut)
- Material Type (Good, Bad, Variable Process Cost)
- Material
- Quantity
- Unit (currency unit)

Note that the use of the timestamp allows doing model comparisons. Calculation results of two or more model calculations 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.

Printing an exporting of carbon footprint data and results is described in chapter 14.5.

13 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 9.1
- Cost entry coefficients, see section 9.2
- Arrow flow specification, see section 9.8
- Place begin quantity specification, see section 9.8
- Process parameters, see section 9.3
- Net parameters, see section 9.6

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 and Excel 2010.

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

13.1 Establishing (Creating) Live Link

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.

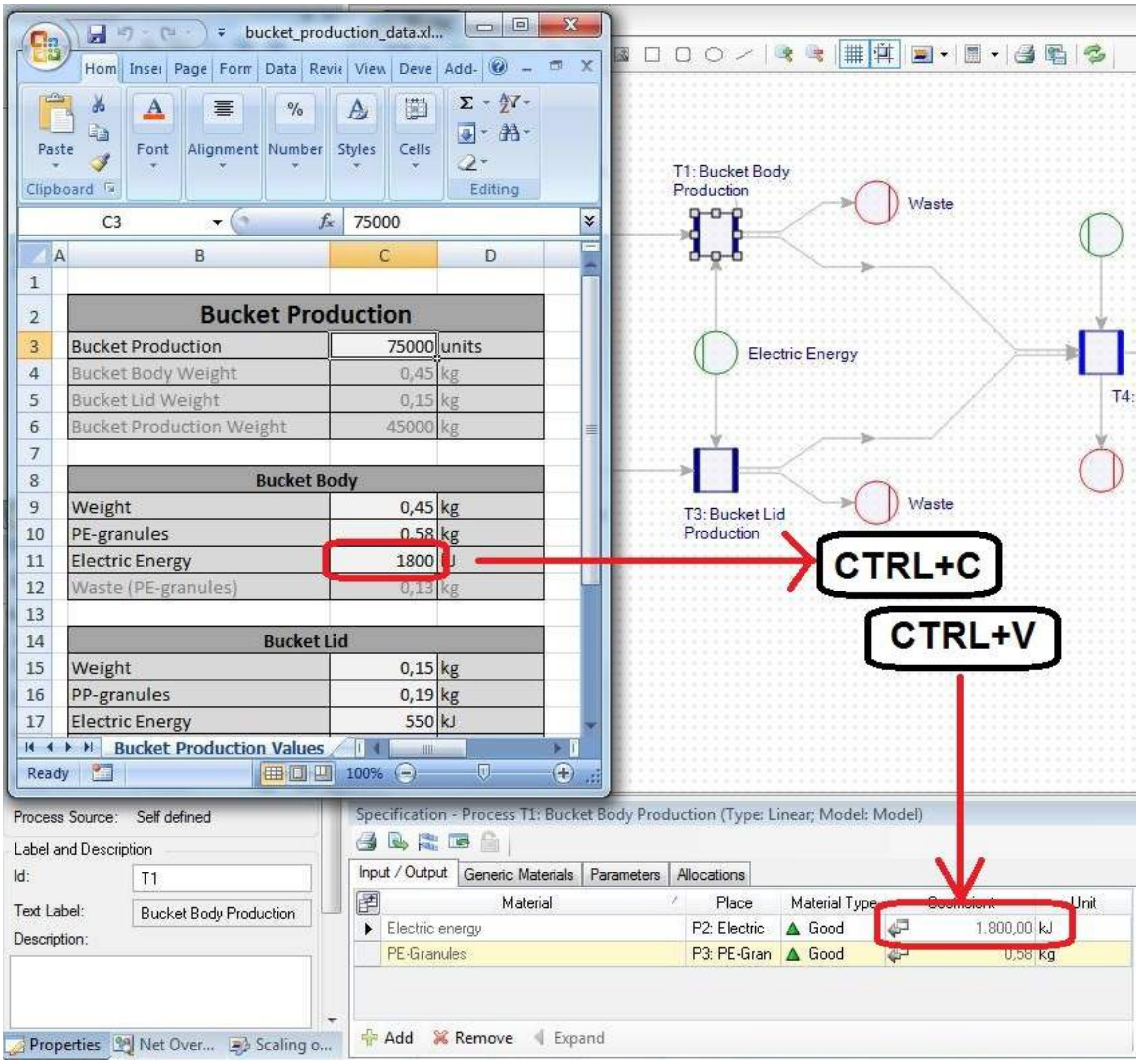


Figure 77: Copy the cell value in Excel. Select the target element in the Umberto model. In the specification area paste it into the 'Coefficient' column.

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 into 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 $").

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, make sure you name the cell in Excel[3]. Names must start with a letter and must not contain spaces.

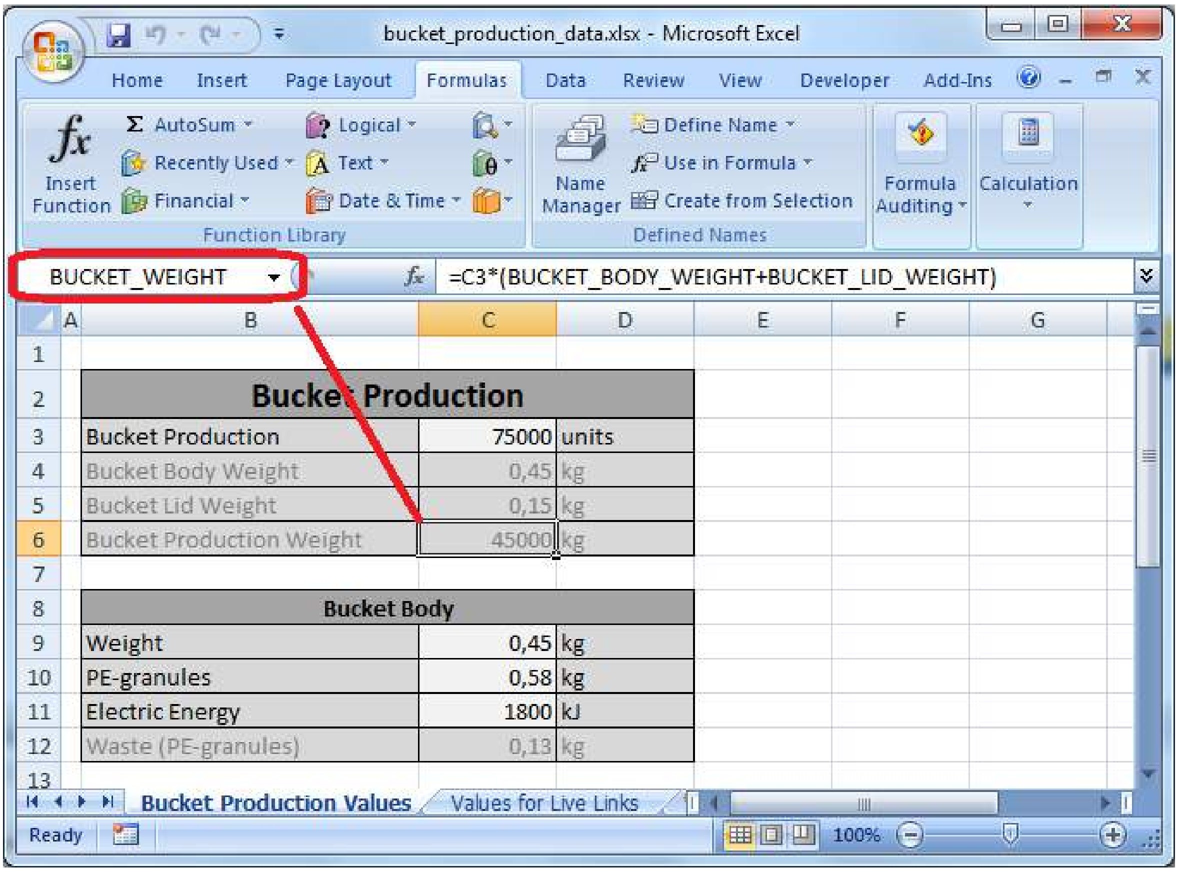


Figure 78: Named cell in Microsoft Excel 2007. For cell C6 the name 'BUCKET_WEIGHT' has been defined.

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 anywhere in the Excel sheet, even when it is moved. When the value in the

[3] 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).

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.

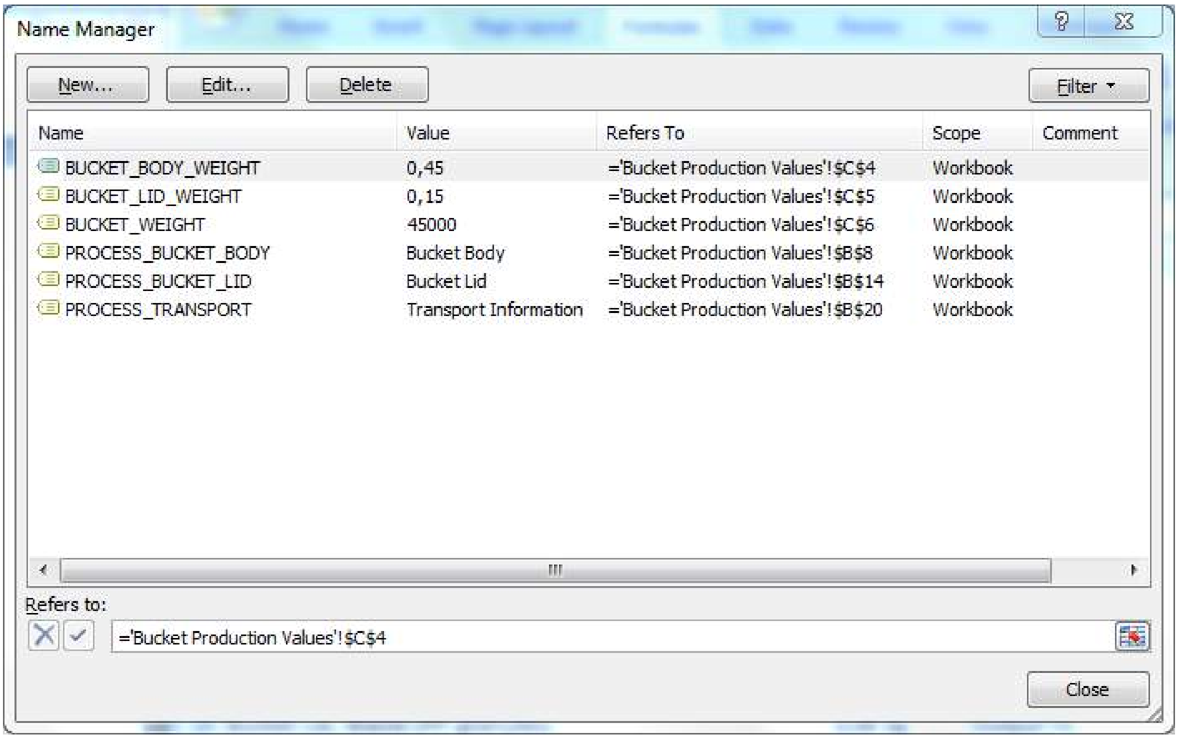


Figure 79: Microsoft Excel 2007 Name Manager also shows the named cells, their current value and the cell it references.

13.2 Update of Live Link Values

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.

13.3 Editing Live Links

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).

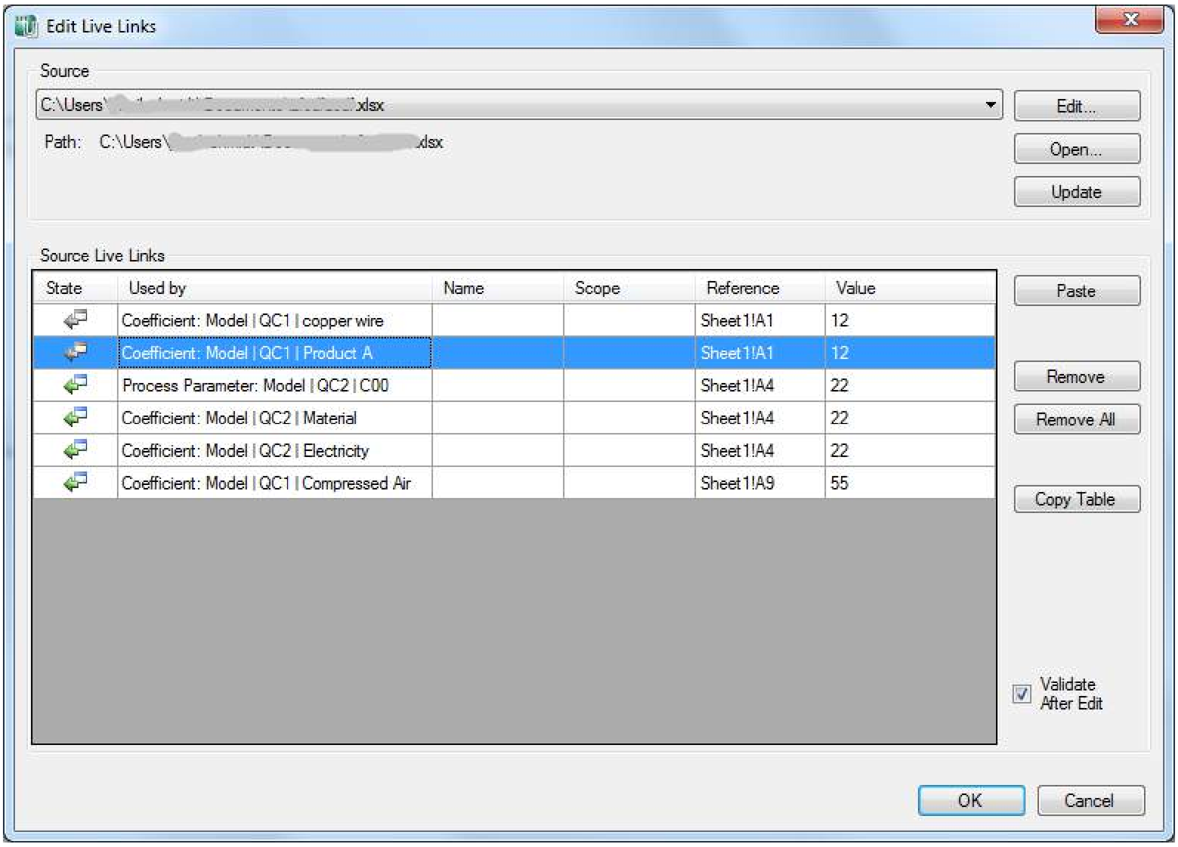


Figure 80: Edit Live Links dialog shows the Excel files and cells to which Live Link references have been created

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: The cell address for a Live Link entry in column 'Reference# (e.g. "Sheet1!A4" can be directly modified to target onto a difference cell, and fetch the value from this other cell instead.

A new value for an existing 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) by selecting a line and clicking on the button 'Paste' or with the context menu command 'Paste Live Link' on the respective line in the table.

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).

Remove Live Links: To remove an existing Live Link from the list, mark the entry in the table and click on the button 'Remove'. All Live Links that exist into the model can be removed by clicking on the button 'Remove All'.

Export List of Live Links: Use the button 'Copy Table' to the right of the list in the 'Edit Live Links' dialog, to copy the content of the list to the clipboard. Paste the list with the six columns to a text editor, a Word document, or another Excel spreadsheet, to produce a compilation of Live Links. Such a report might be useful, e.g. when checking for completeness or correctness of the data from external sources being used in the material flow model.

14 Carbon Footprint

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.

Umberto Efficiency+ includes 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.

The features present for carbon footprinting are from the targeted Umberto NXT CO2 product versions. For more details on actual carbon footprint studies conducted with this version, please contact ifu Hamburg GmbH.

14.1 GWP100a Database

In the current version Umberto Efficiency+ 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[4].

You may have GWP data for material and components you purchase from your suppliers. Read in the next chapter how to 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

[4] 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.

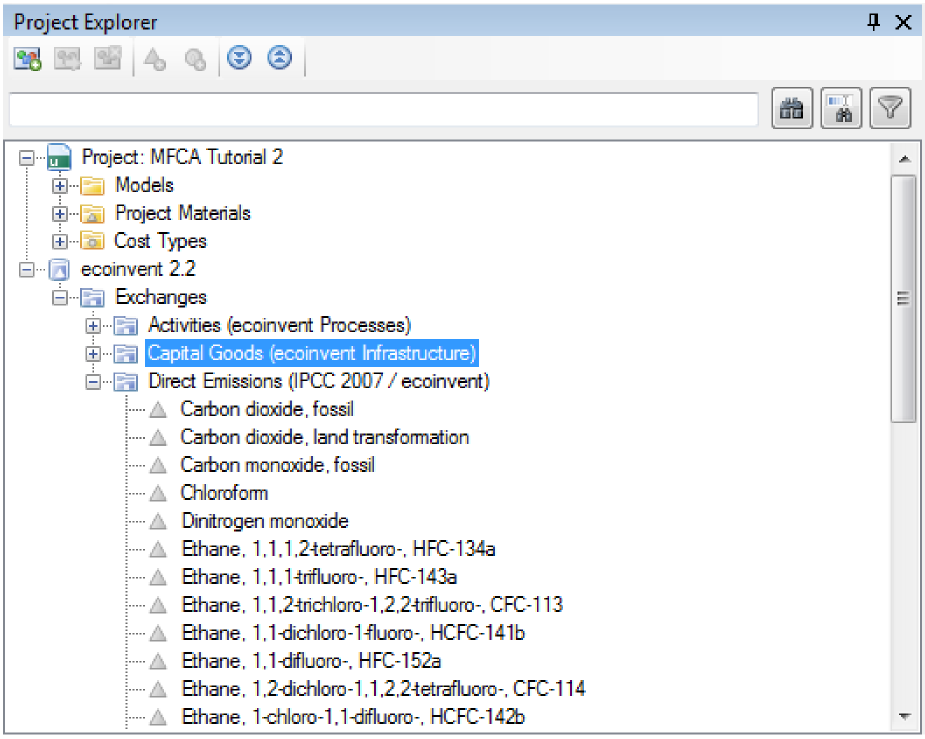
validated datasets for use in Life Cycle Assessments (LCA), approximately 4000 in ecoinvent 2.2 and 9000 in ecoinvent 3 respectively. These datasets are all fully documented[5].

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 Efficiency+ 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[6].



5 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.

6 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 81: 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)'.

14.2 Managing GWP Values

When calculating an inventory of material and energy flows for a production system (see section 10.1), 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.

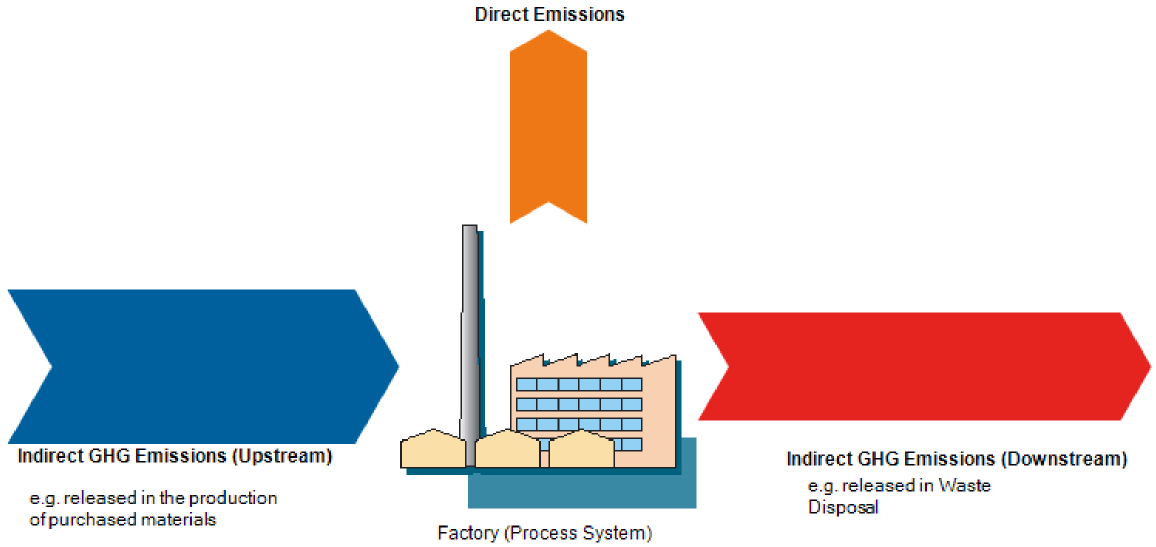


Figure 82: Schematic overview with carbon footprint made up from direct emissions, indirect emissions upstream (goods received) as well as indirect emissions downstream (treatment of waste), all contributing to climate change.

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.

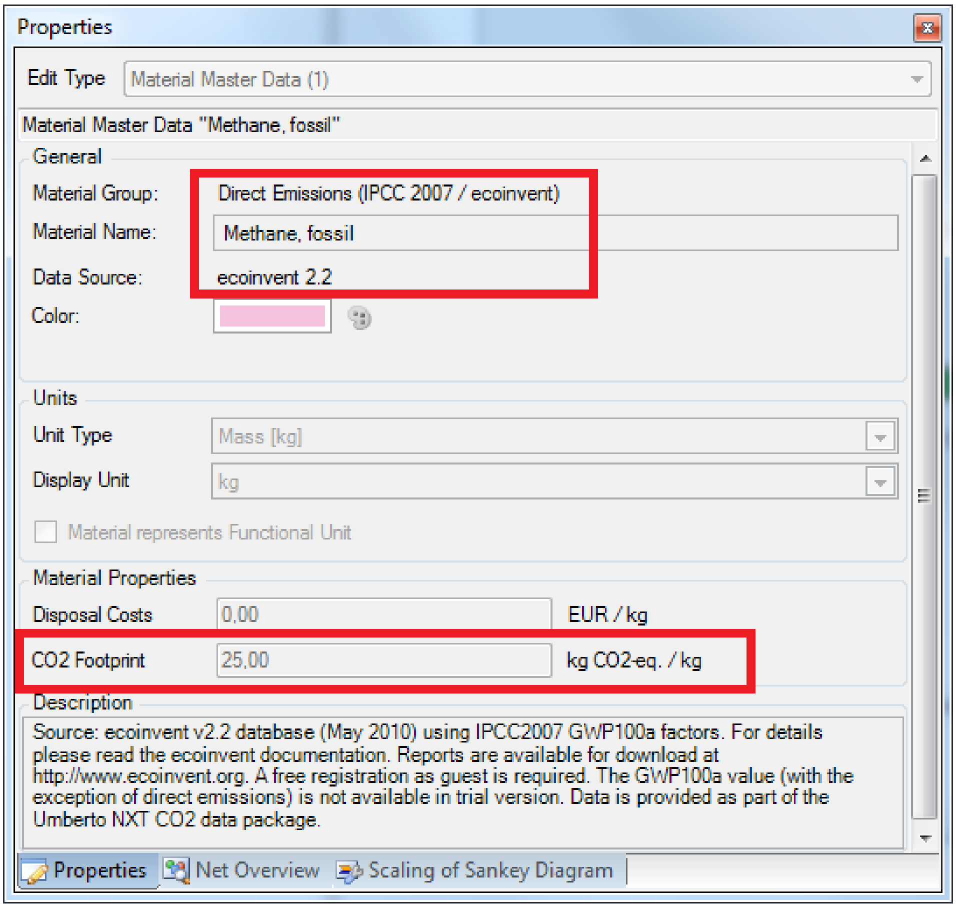


Figure 83: A direct emission entry ("methane") from the ecoinvent 2.2 master data with GWP100a value

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).

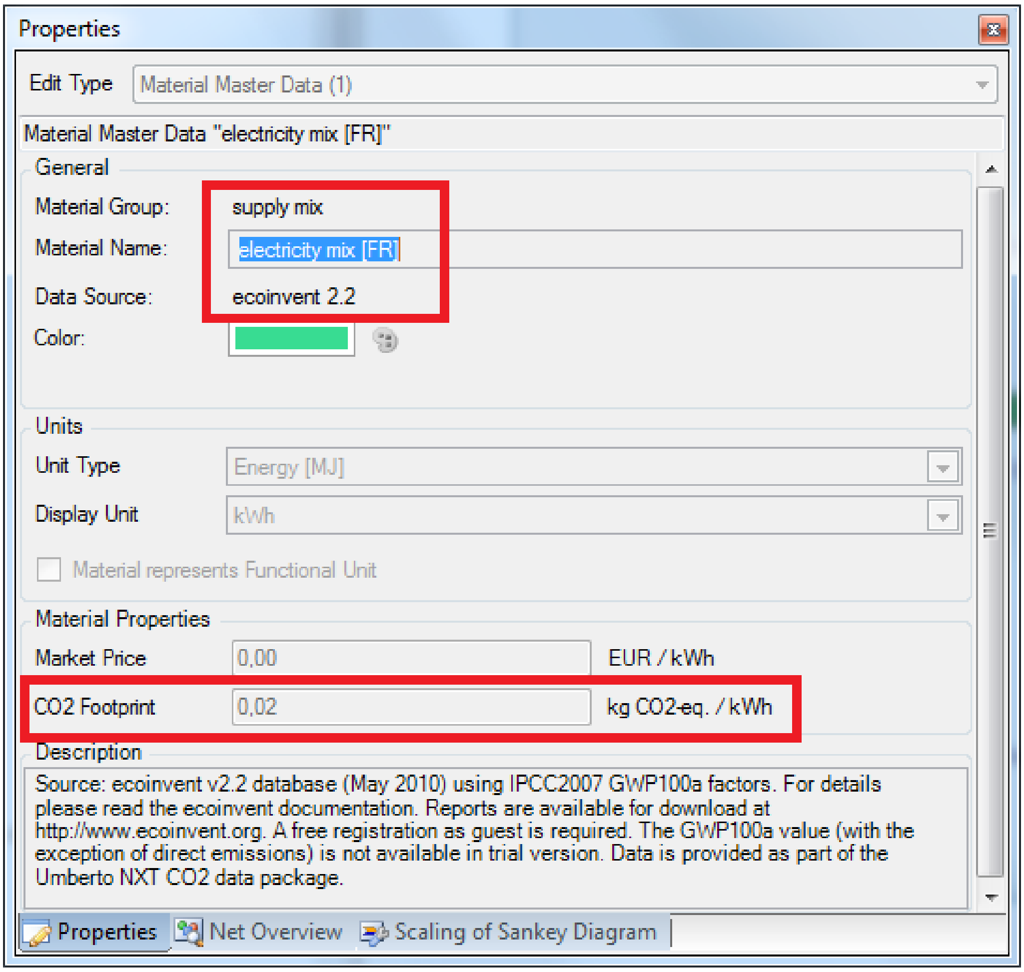


Figure 84: An entry from the ecoinvent database for an intermediate (supply mix "electricity mix [FR]") with its GWP100a value (carbon rucksack) for the production of 1 kWh in France

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.

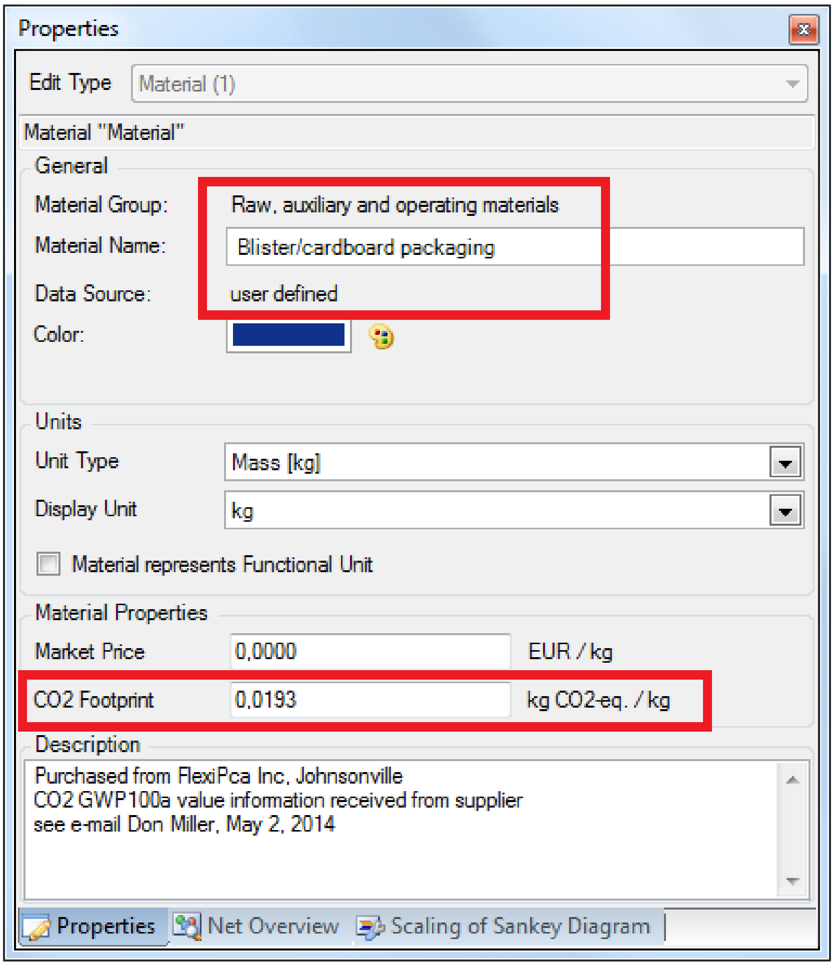


Figure 85: An entry for a self-defined material in the material list with its GWP100a value

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.

14.3 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 7.3.2) 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.

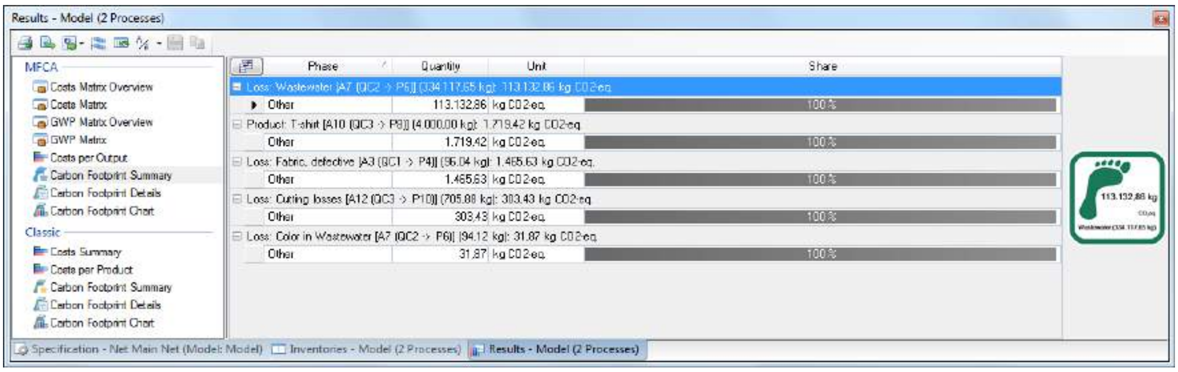


Figure 86: Carbon Footprint Summary, MFCA perspective

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 10.1.

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.

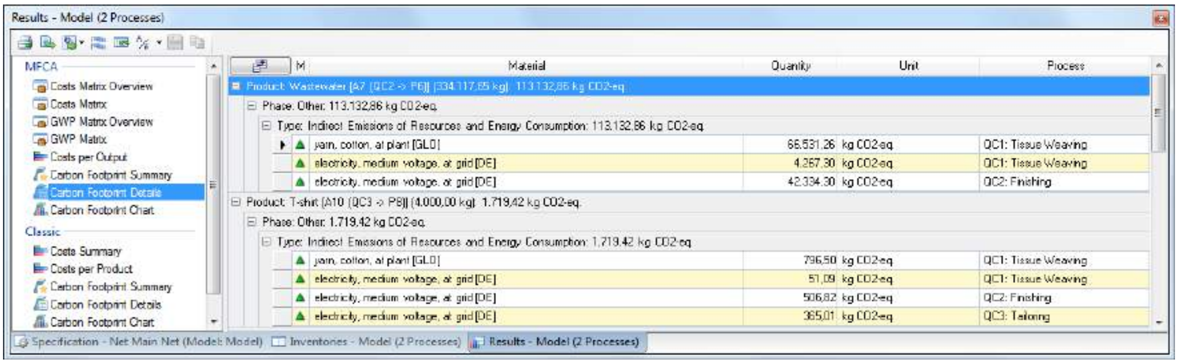


Figure 87: Carbon Footprint Details, MFCA perspective

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 88: 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'.

14.4 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.

Read more about Sankey diagrams and their options in sections 11.3. to 11.5 of this user manual

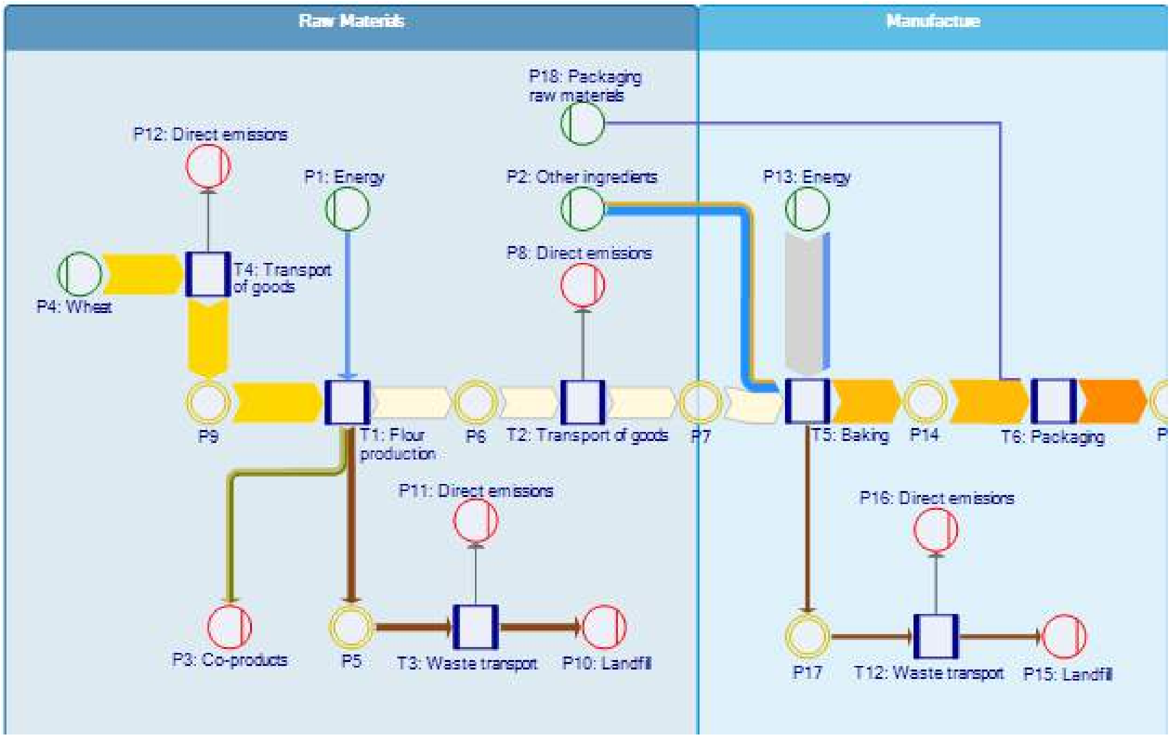


Figure 89: Section of a model showing contributions to the carbon footprint from material supplies and direct emissions

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.

14.5 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 90: 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.

15 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 EfficiencyPlus\"). 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':

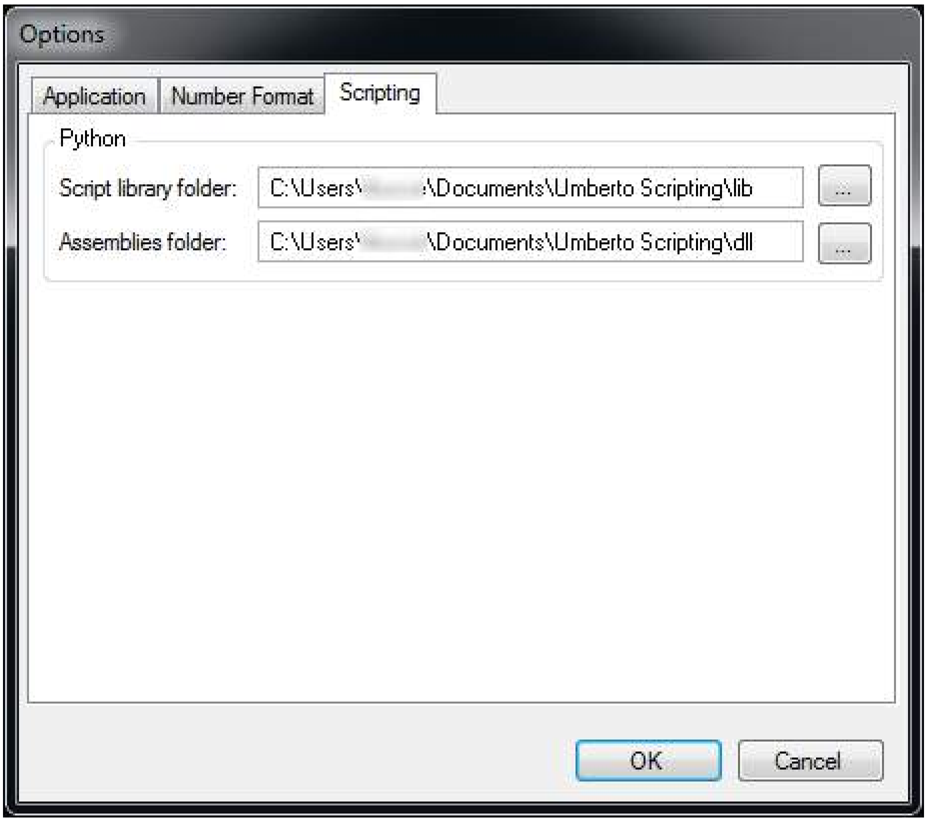


Figure 91: Setting directory path for script library folder and assemblies

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":

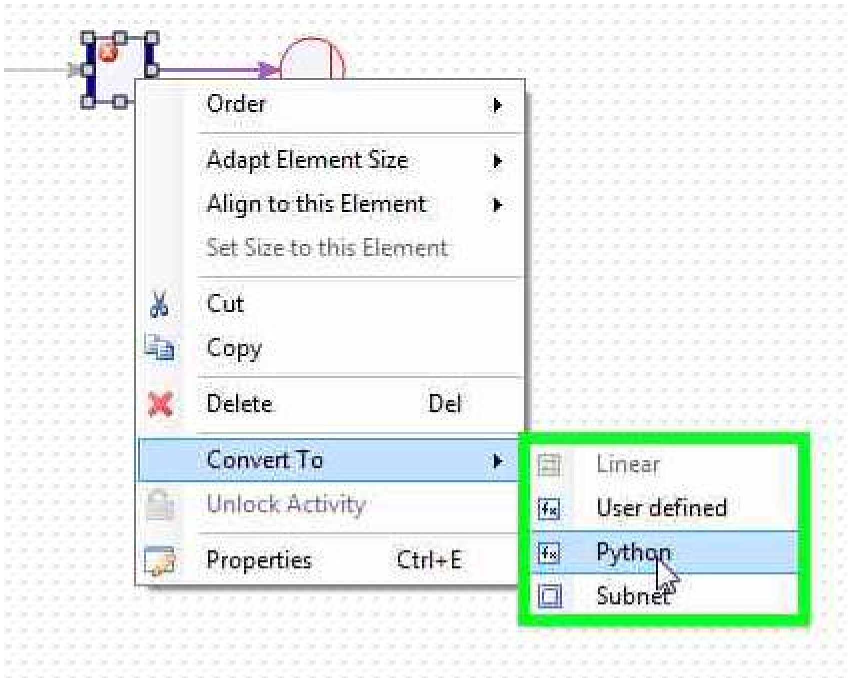


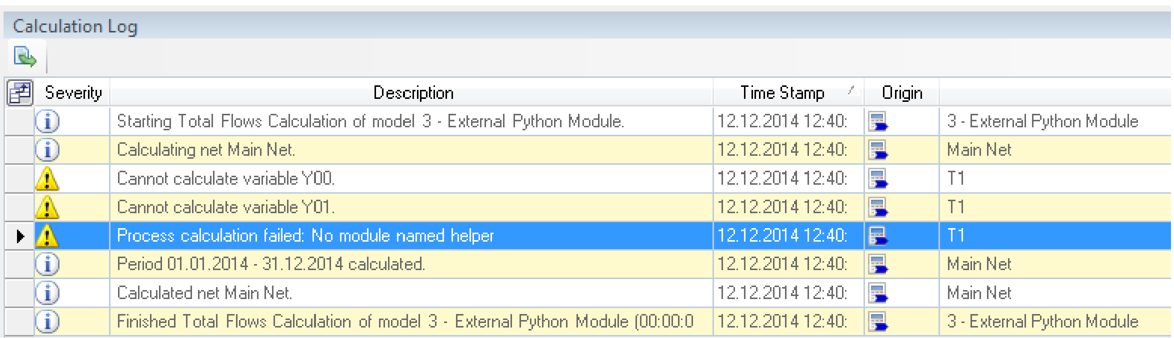
Figure 92: Context menu of the process, setting the specification type to "Python"

The other ("traditional") variants of process specification (linear input/output coefficient, user defined functions, subnet) are described in chapter 9 of the user manuals of Umberto LCA+ or Umberto Efficiency+.

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 93: 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: 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...)

Annex B: Unit Types and Units in Umberto

The following is a list of pre-defined unit types for materials (exchanges), and the units contained within the unit type and their conversion factor.

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 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

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