GreenDelta
sustainability consulting + software

Introduction to openLCA

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September 24th-25th , 2014
Zurich, Switzerland

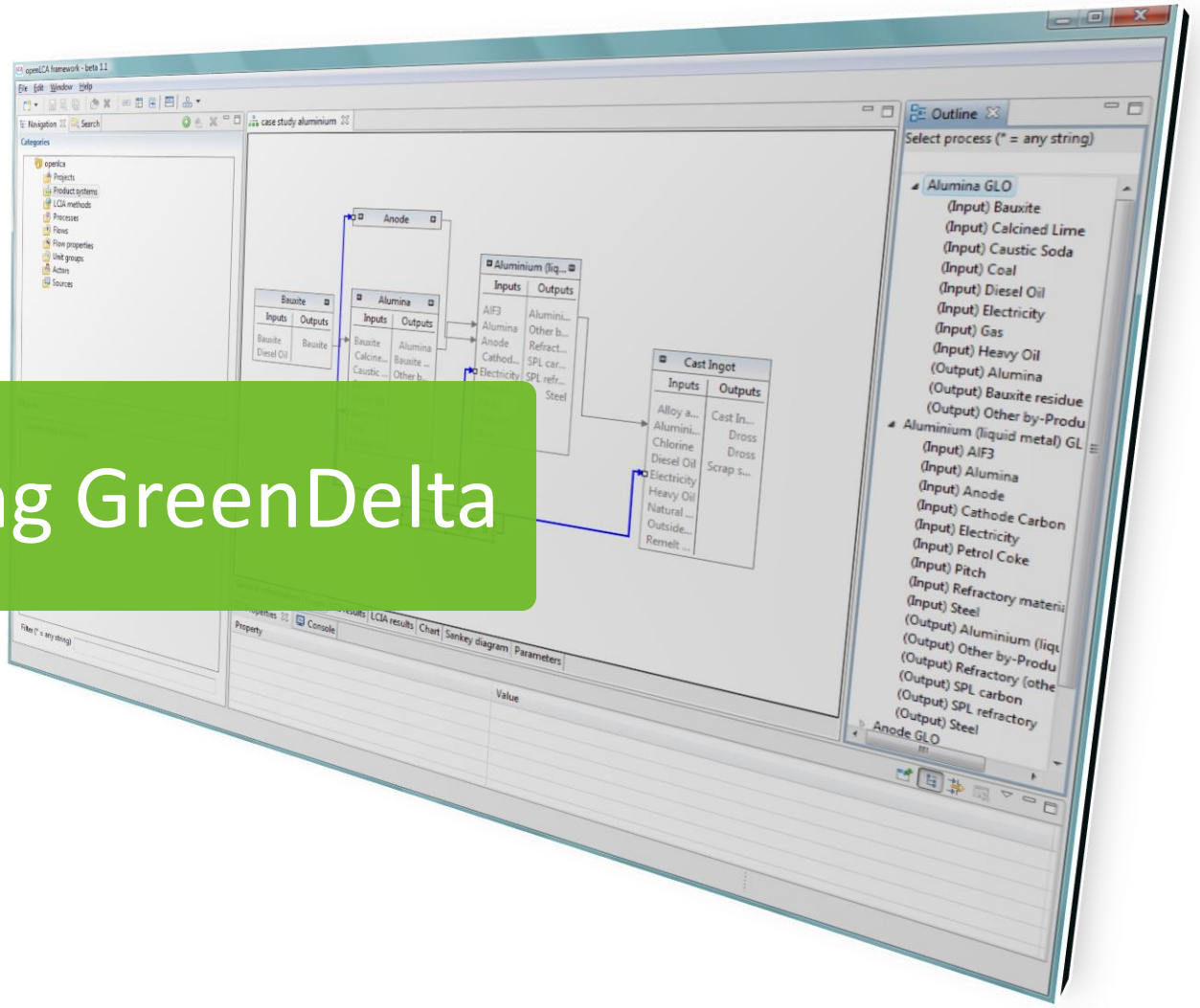
Day 1

- Introduction to GreenDelta
- Introduction to openLCA
- Functions and features (overview)
- Installation
- First look at the software
- LCA data import
- Tips and tricks for dealing with openLCA
- Modelling
- Results analysis and interpretation
- Data export
- Sensitivity analysis

Day 2

- Allocation and system expansion
- Uncertainty analysis
- Life Cycle Costing
- Additional (new) features
- Experimental features
- Regionalised LCIA
- Ecoinvent 3

Introducing GreenDelta



GreenDelta

GreenDelta background

- Founded by Dr. Andreas Ciroth in 2004
- 10 employees (engineers, biologists, business administrators)
- Office in Berlin
- Business world-wide: sustainability research, life cycle assessments, databases, software for life cycle assessments and sustainability

GreenDelta team

- Our mixed team helps us to provide users with a range of perspectives and solutions

Andreas Ciroth
Founder & Managing Director

Michael Srocka
openLCA Technical Lead

Cristina Rodríguez
Environmental Consultant

Sarah Winter
Client Relations, LCA Modeling

Sebastian Greve
Software Developer

Martin Pluta
Web and Software Developer

Kathleen Kiehl
Client Relations, LCA Specialist

GreenDelta for openLCA

- Software expansion/adaptation
- Case studies
- Guided case studies
- Data acquisition
- Database compilation

GreenDelta for openLCA (II)

- Crititcal review (ISO 14040)
- LCA, LCC, SLCA
- Data management and hosting
- openCLA Training
- Service und Support

Customers


BASF
The Chemical Company


SIEMENS


Steelcase


SIG


Knoll


PE INTERNATIONAL

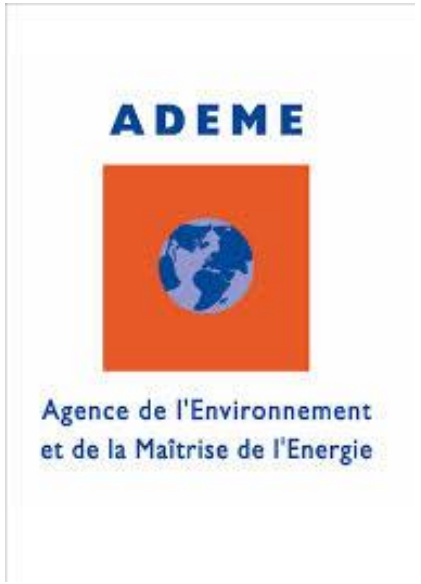

PRé


ecoinvent
Centre

Customers


JRC
EUROPEAN COMMISSION


UNEP


ADEME
Agence de l'Environnement
et de la Maîtrise de l'Energie


Federal Institute for
Research on Building,
Urban Affairs and
Spatial Development
within the Federal Office for
Building and Regional Planning


FCh
FUNDACIÓN CHILE


SYKE
Finnish Environment Institute


UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY


USDA

Customers

ifeu
Institut für Energie- und Umweltforschung Heidelberg GmbH

DTU
Technical University of Denmark

VE RI TAS

SINTEF

CHALMERS

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

KIT
Karlsruher Institut für Technologie

Introducing openLCA

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A free & professional approach to Life Cycle Assessment

- Completely open source
- Mac OS, Windows, and Linux
- Written in Java
- A truly international system with an established community of contributors and about 300 downloads per week

> 1,000 users

- Scalability and performance of leading software
- Customizable
- Intuitive user experience
- Upgrades keep you at the forefront of LCA software technology
- Quick, flexible, modern & expandable

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openLCA: open source

- Mozilla public license 1.1
- Transparent: source code can be viewed and changed by anyone
- open source nature of the software makes it very suitable for use with sensitive data
- you can freely share both the software and any models you create, as long as the database license allows it

openLCA application

- LCA, LCC, SLCA
- Carbon & water footprints
- Environmental Product Declaration (EPD)
- US EPA‘s Design for the Environment label
- Integrated Product Policy (IPP)

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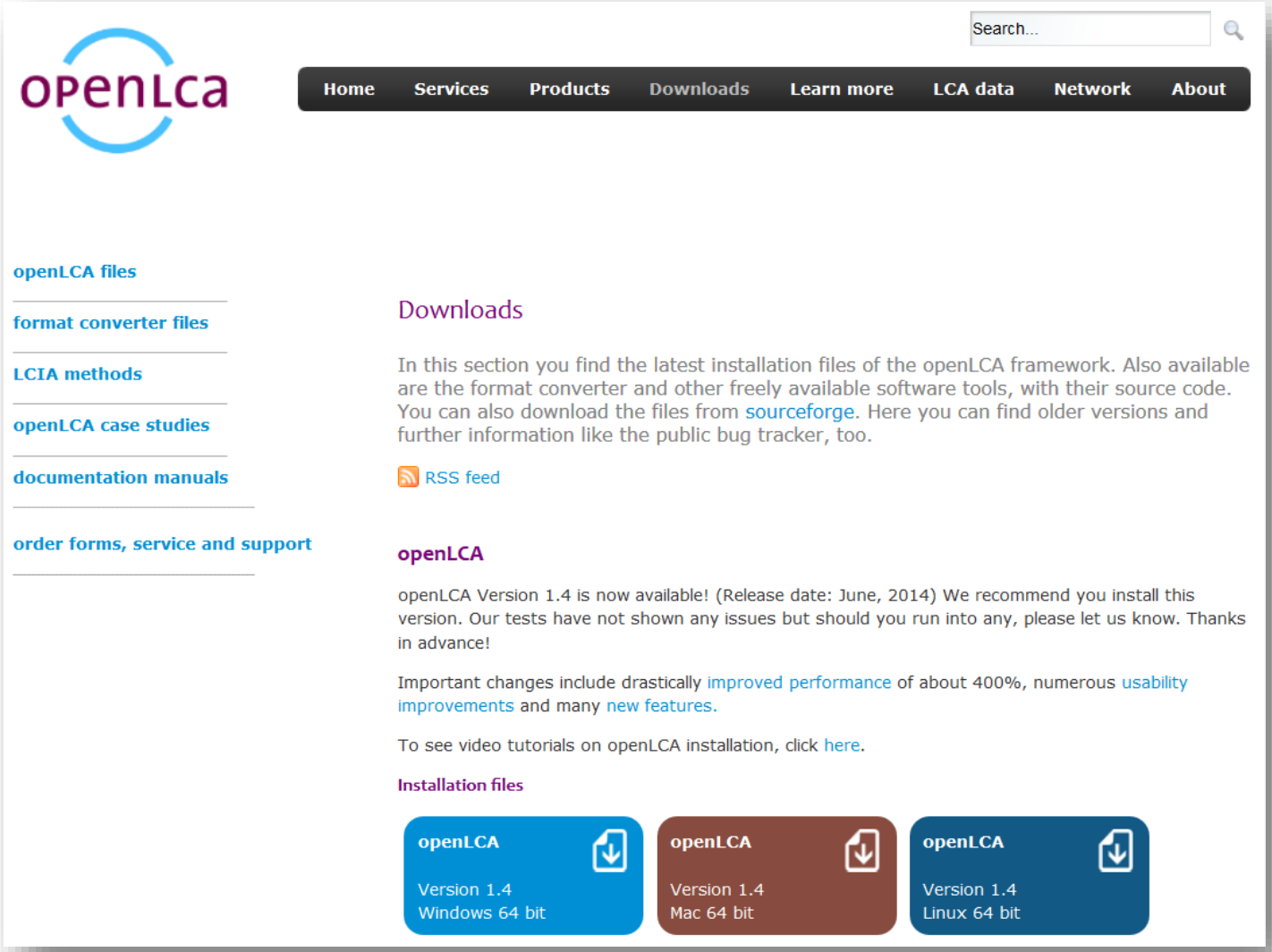
openLCA.org

- Downloads (software, LCIA methods, ...)
- Vidoes, manuals, case studies
- Services (service contracts, training, critical reviews, hosting & data management solutions...)
- Forum

openLCA.org/downloads



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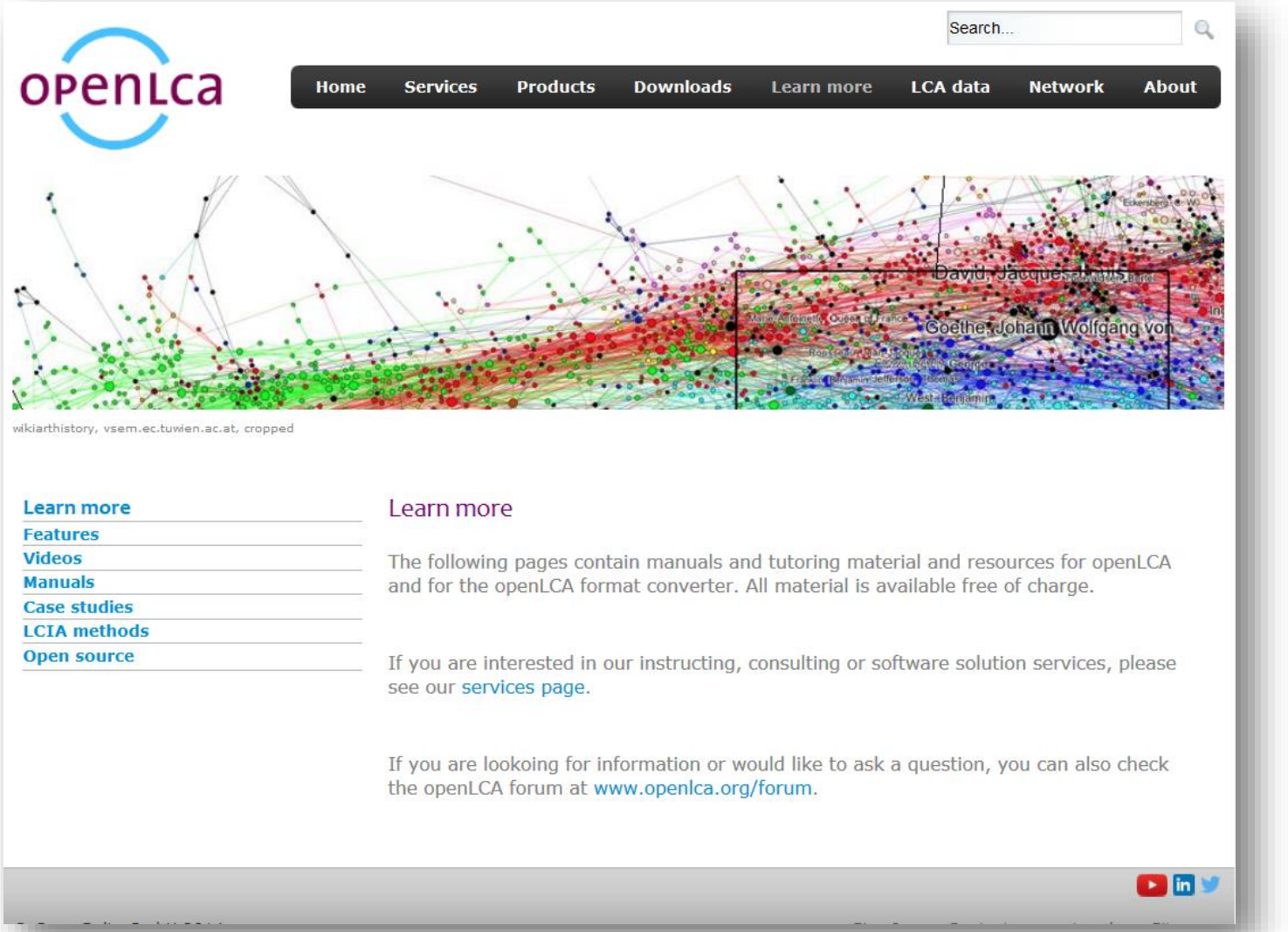
openLCA.org/learnmore



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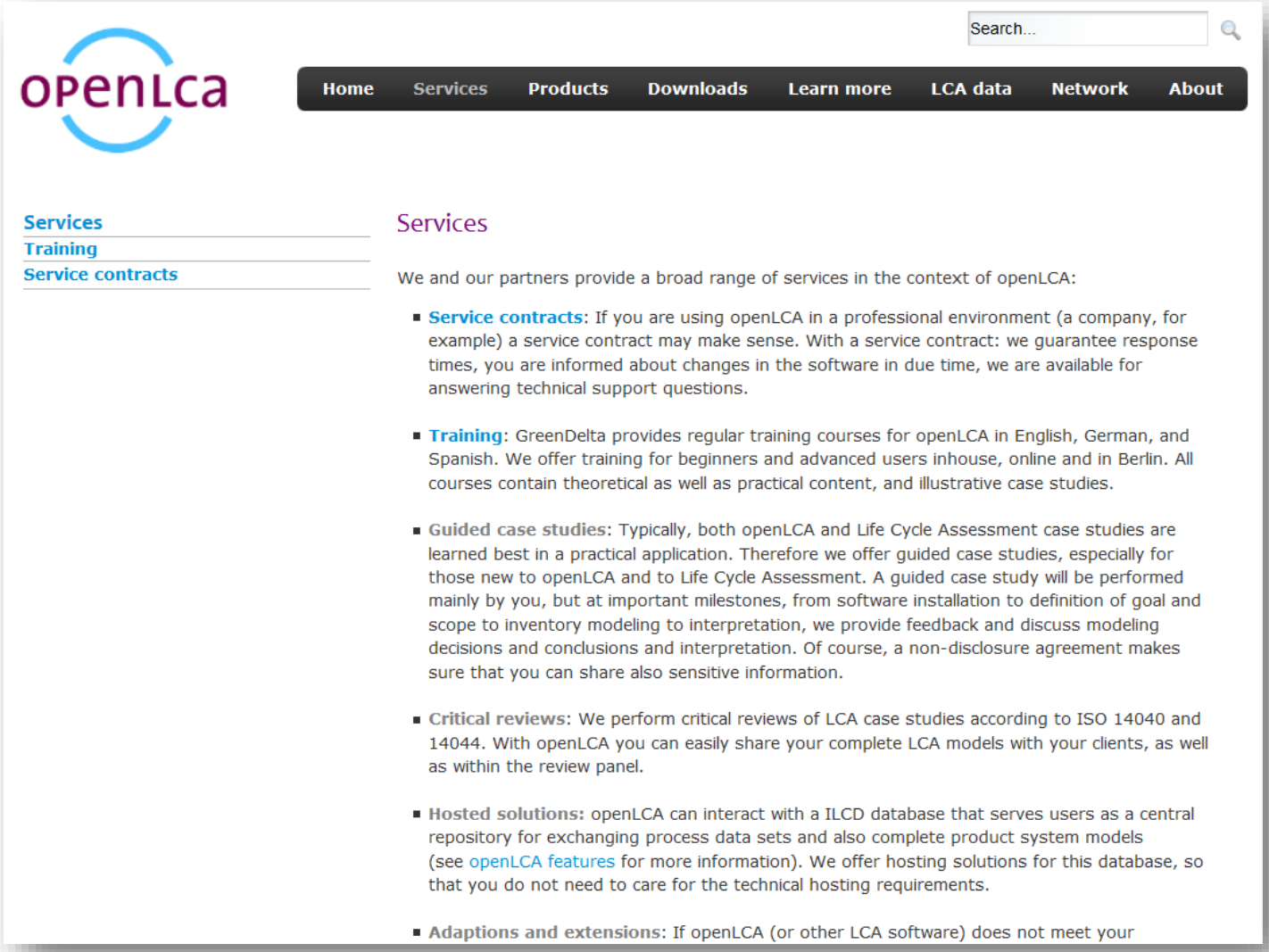
openLCA.org/services



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openLCA.org/forum

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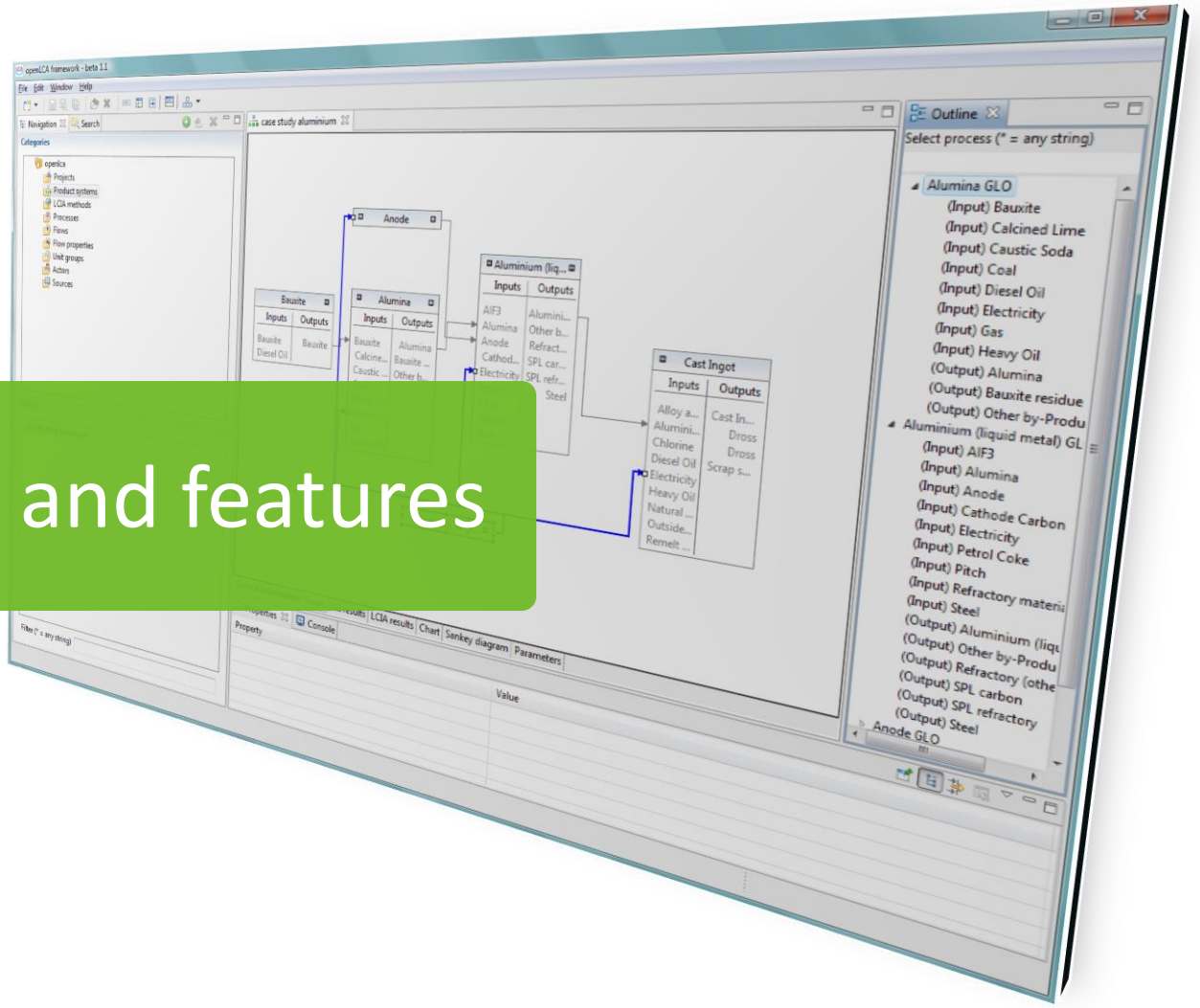
Functions and features



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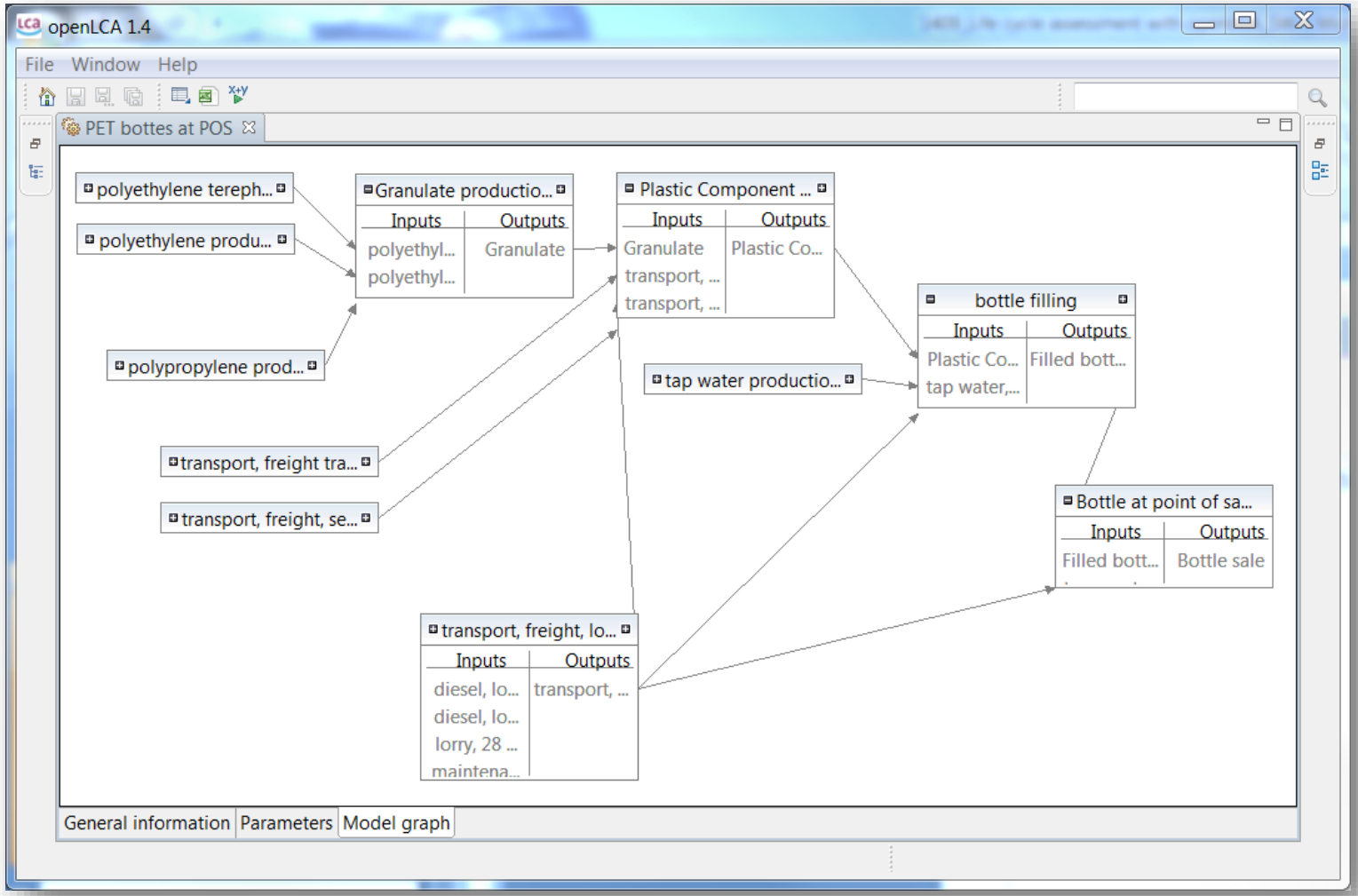
Graphical modelling of product systems

= Process networks

- Process networks can be created automatically and manually
- graphical modeling based on the Eclipse Graphical Editing Framework (GEF)
- Different product systems can be compared (=> project)

Graphic modelling of process networks based on Eclipse GEF



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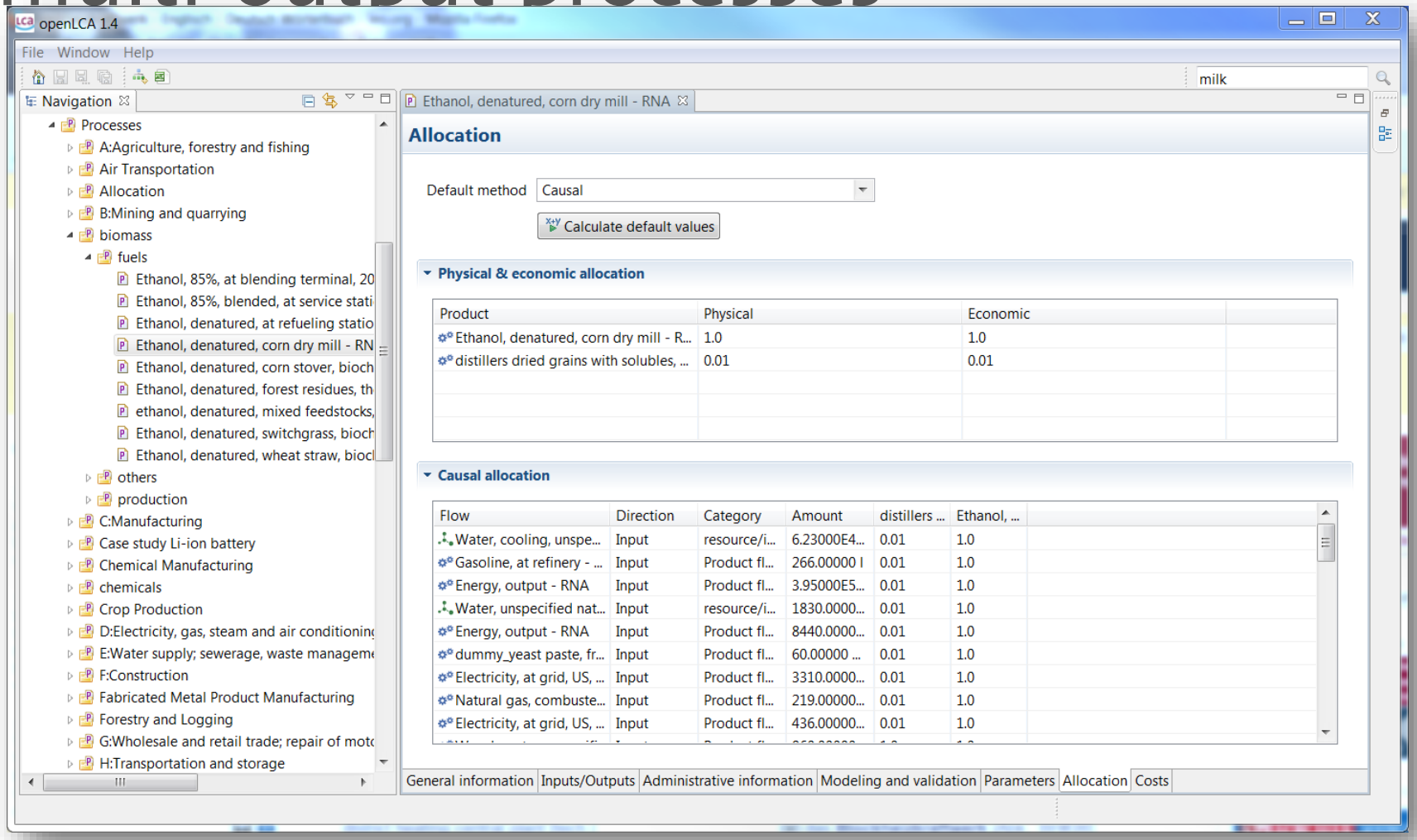
Allocation and system expansion for modelling multi-output processes



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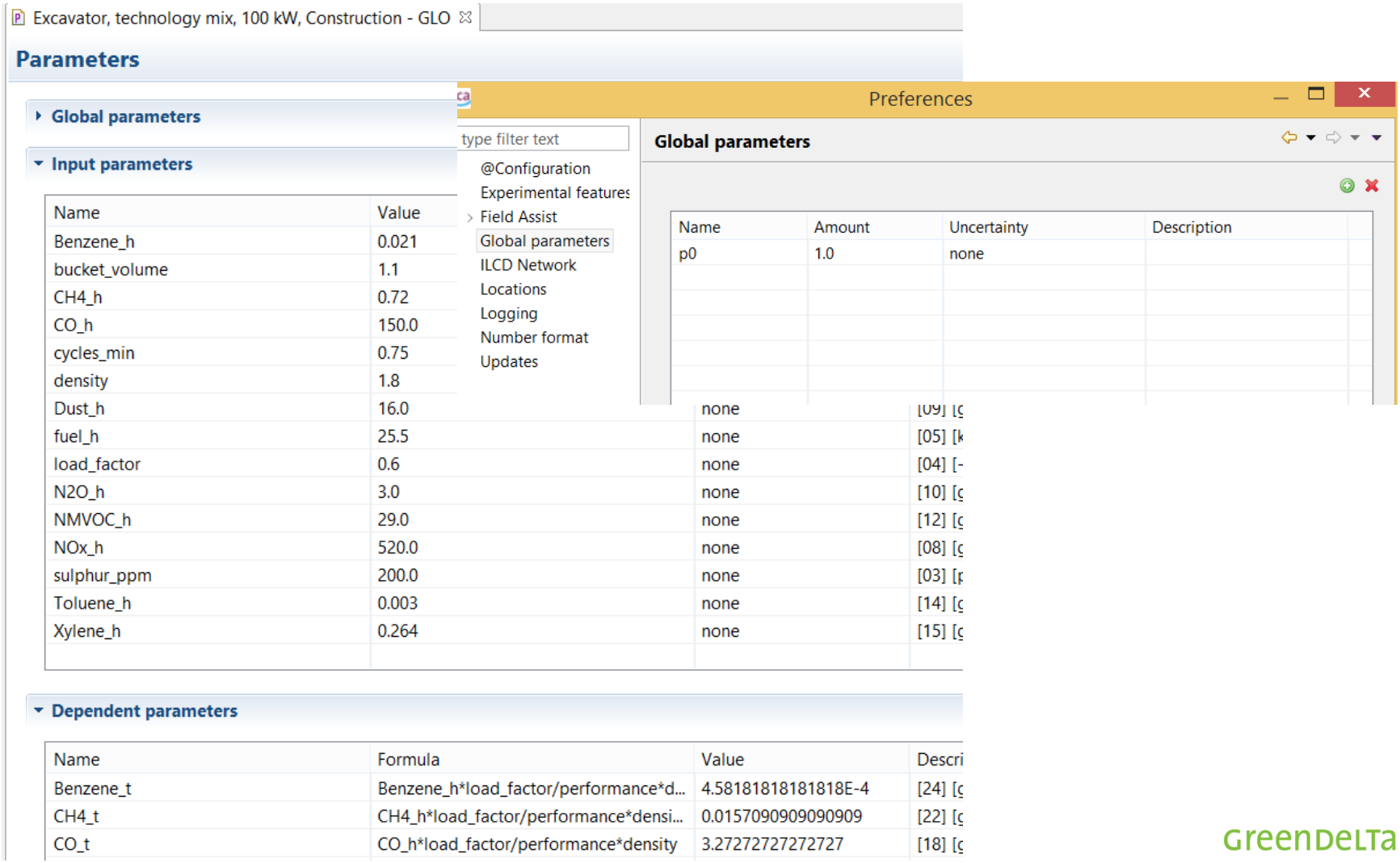
Modeling with parameters

- Parameters can be used instead of concrete values for inputs/outputs
- Define as simple value, formula or complex funtion
- Parameters can overwrite each other
- Available on different levels
  - process
  - product system
  - project
  - impact method
  - database

Local and global parameters



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Calculation of the inventory

- Calculation of life cycle inventory (using the “matrix method”)
- Results are clearly presented in two tables
- Result can be exported to Excel

Calculation methods in openLCA: matrix method

```
> A
                                  Diesel prod. Bauxite mining Alumina prod. Anode prod. Electrolysis Ingot casting
Diesel [kg]                                  1         -1.993          -0.6        -3.2           0          -0.1
Bauxite, at plant [kg]                       0       1000.000       -2685.0         0.0           0           0.0
Alumina [kg]                                 0          0.000        1000.0         0.0       -1925           0.0
Anode [kg]                                   0          0.000           0.0      1000.0        -441           0.0
Aluminium (liquid metal) [kg]                0          0.000           0.0         0.0        1000        -874.0
Ingot [kg]                                   0          0.000           0.0         0.0           0        1000.0
> B
                     Diesel prod. Bauxite mining Alumina prod. Anode prod. Electrolysis Ingot casting
Crude oil [kg]         -1.500000             0          0.00        0.00        0.00          0.00
Bauxite [kg]            0.000000         -1000          0.00        0.00        0.00          0.00
CO2 / CO2 equ. [kg]     0.302000            48        991.00      849.00     9789.00        368.00
NOx [kg]                0.000878             0          1.17        0.29        0.35          0.16
SO2 [kg]                0.001700             0          5.30        1.70       13.40          0.29
> f
                                [,1]
Diesel [kg]                        0
Bauxite, at plant [kg]             0
Alumina [kg]                       0
Anode [kg]                         0
Aluminium (liquid metal) [kg]      0
Ingot [kg]                      1000
> s
                     [,1]
Diesel prod.    11.345994
Bauxite mining   4.517378
Alumina prod.    1.682450
Anode prod.      0.385434
Electrolysis     0.874000
Ingot casting    1.000000
> g
                              [,1]
Crude oil [kg]         -17.018990
Bauxite [kg]         -4517.378250
CO2 / CO2 equ. [kg] 11138.388062
NOx [kg]                2.556104
SO2 [kg]               21.593111
>
```

$$s = \mathrm{A}^{-1} \cdot f$$

$$g = \mathrm{B} \cdot s$$

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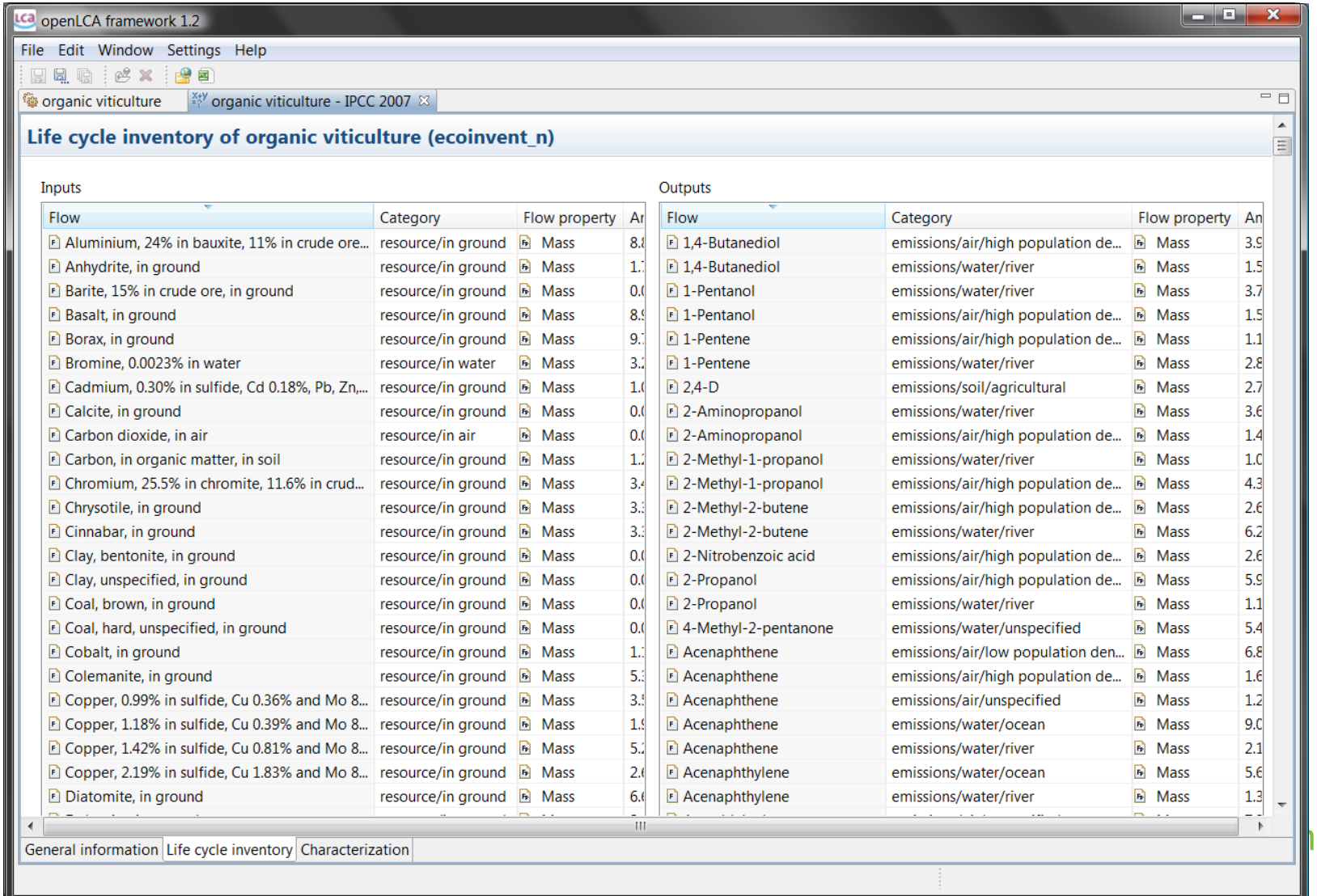
Example: inventory results



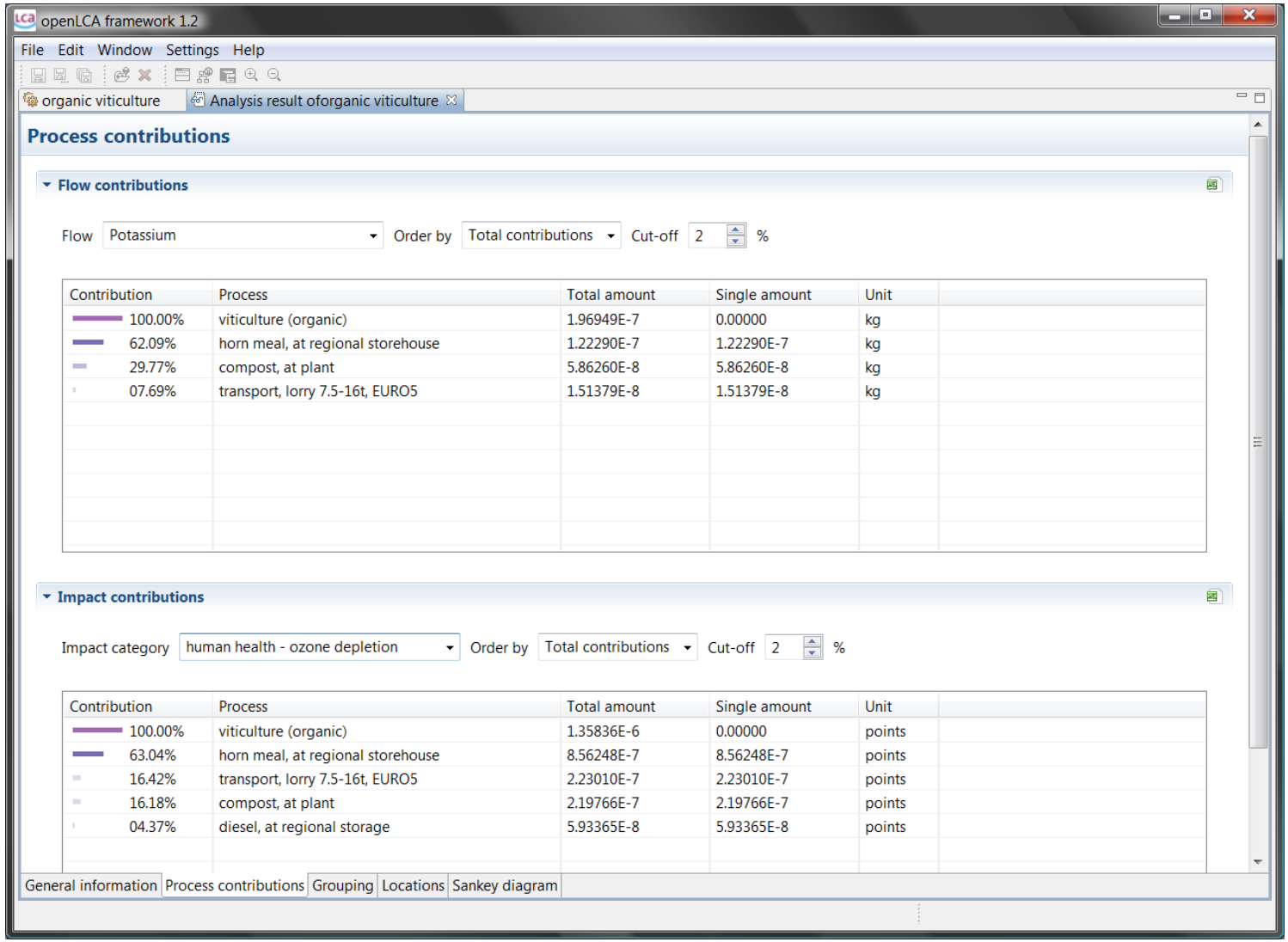
Impact assessment methods

- There are no impact assessment methods included by default in openLCA, but methods are available for free and can be easily imported
- It is possible to modify existing impact assessment methods in openLCA (impact categories and flows can be added / deleted; equivalence factors can be altered)
- It is also possible to create new impact assessment methods

Analysis and interpretation

- In openLCA many functions are available to evaluate the results and to track the origin of environmental effects:
- Various result and influence analyses
- Sankey Diagram
- Representation of the spatial distribution of emissions and resource consumption
- Grouping of processes is possible (e.g. by life cycle phase)
- ...

Contribution analyses



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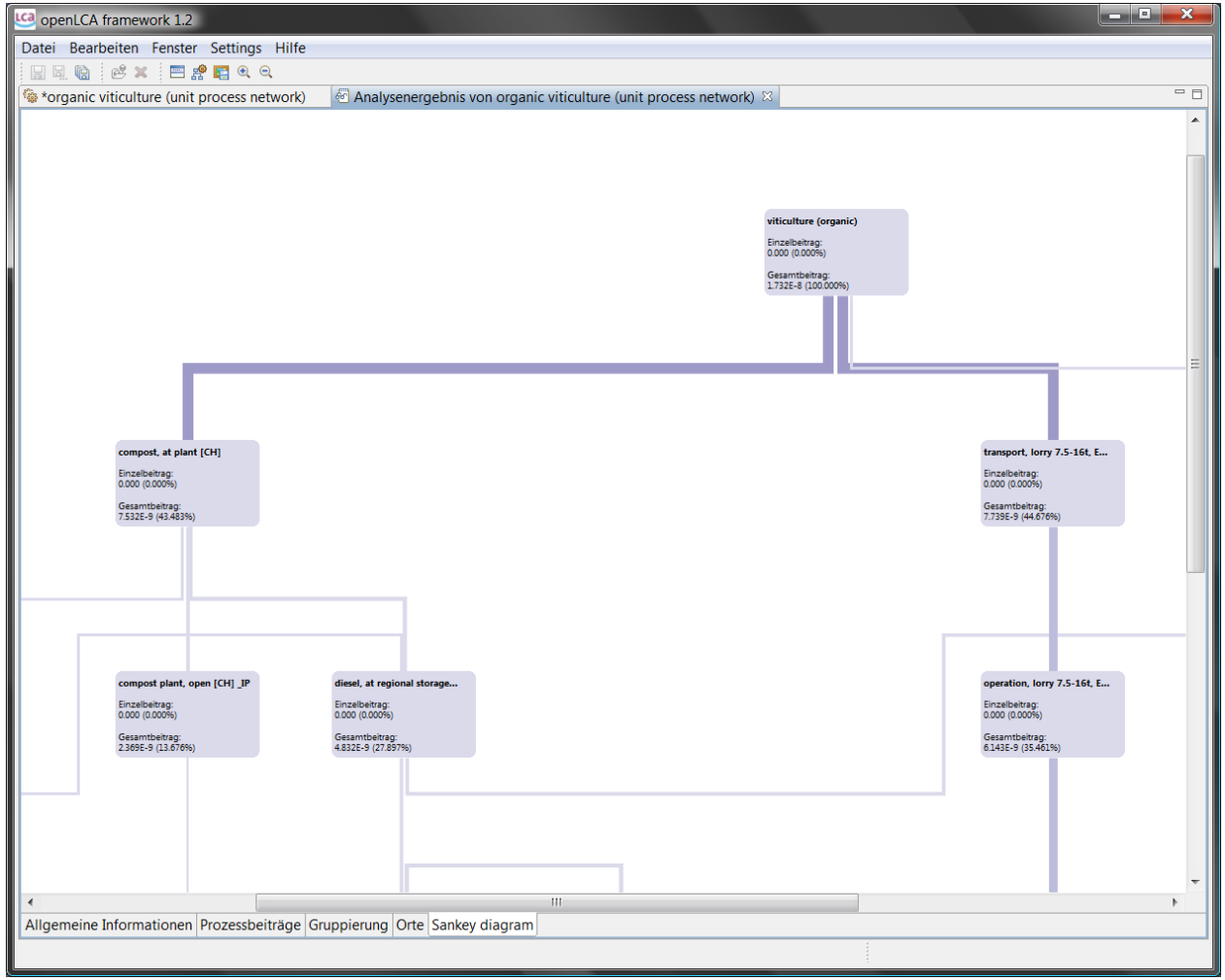
Sankey-Diagram



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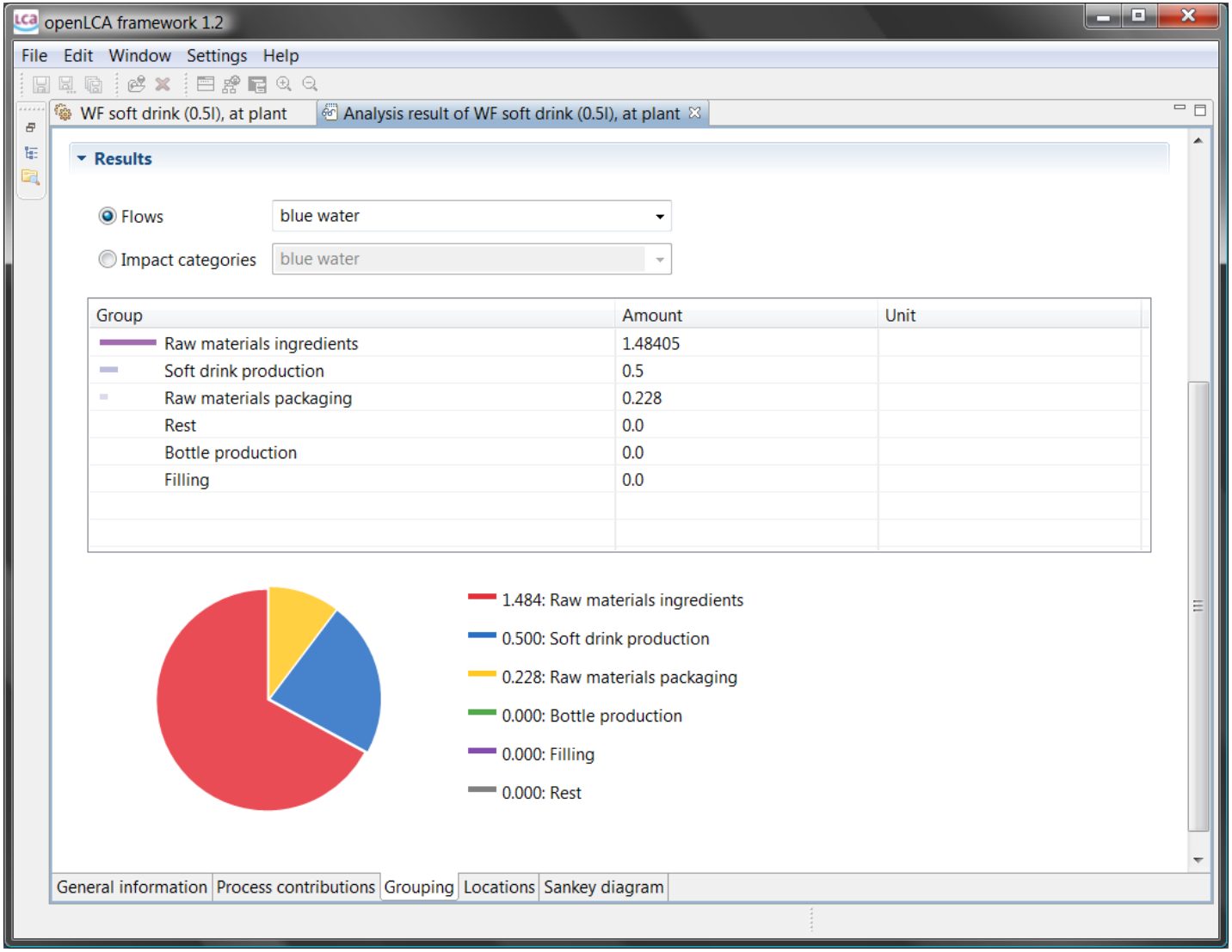
Grouping



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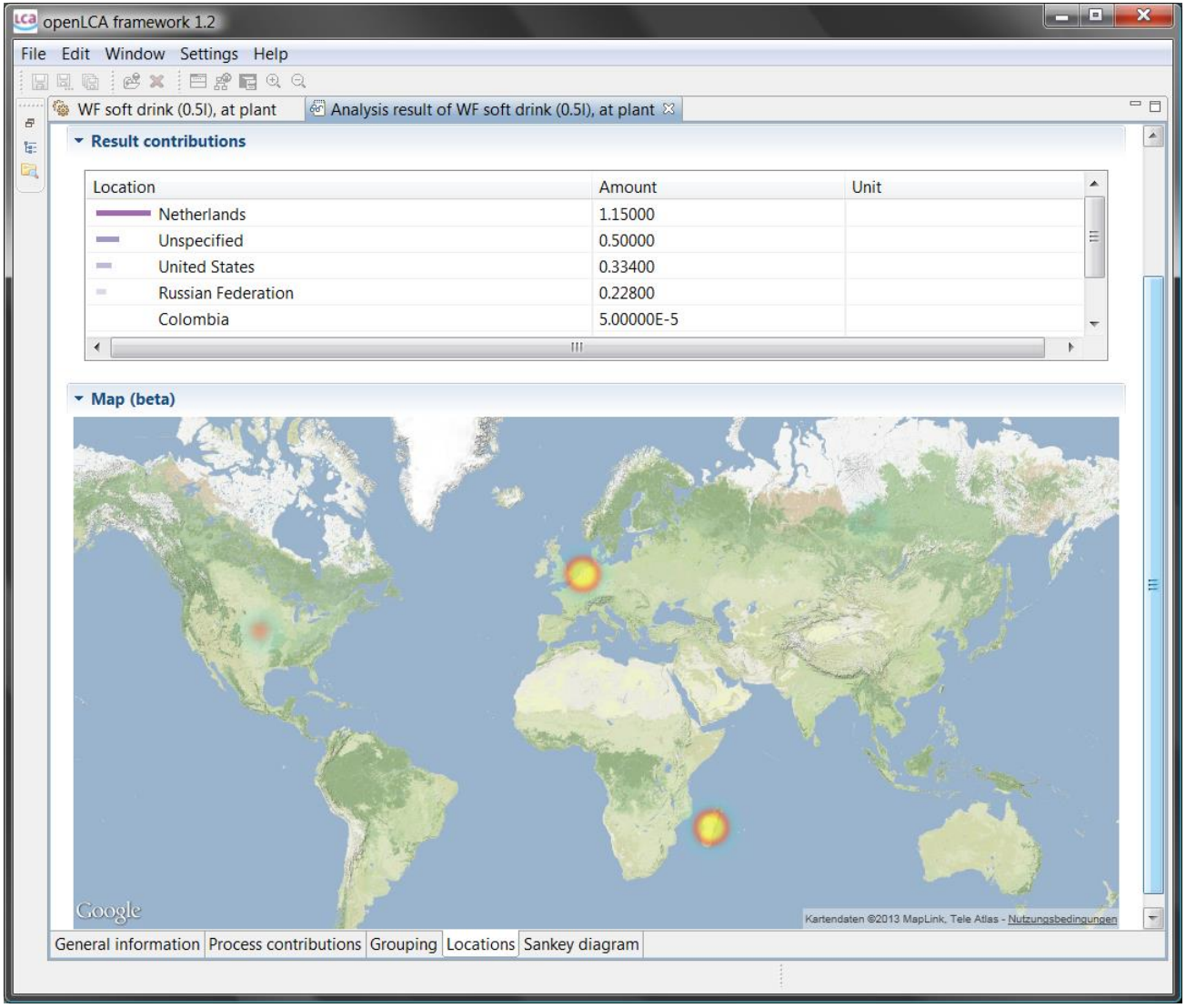
Localisation



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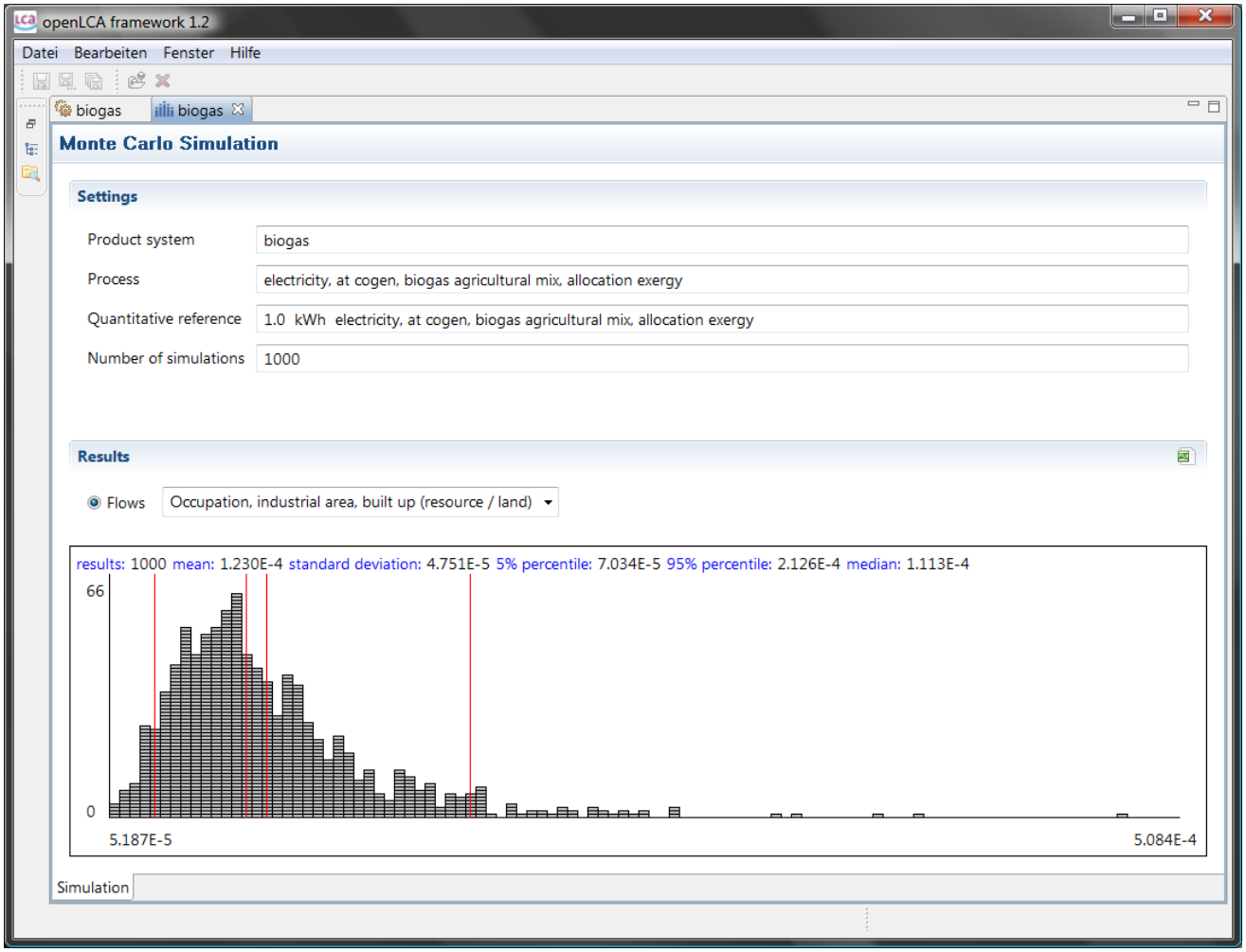
Uncertainty analyses

.. with Monte-Carlo-Simulation or pedigree approach



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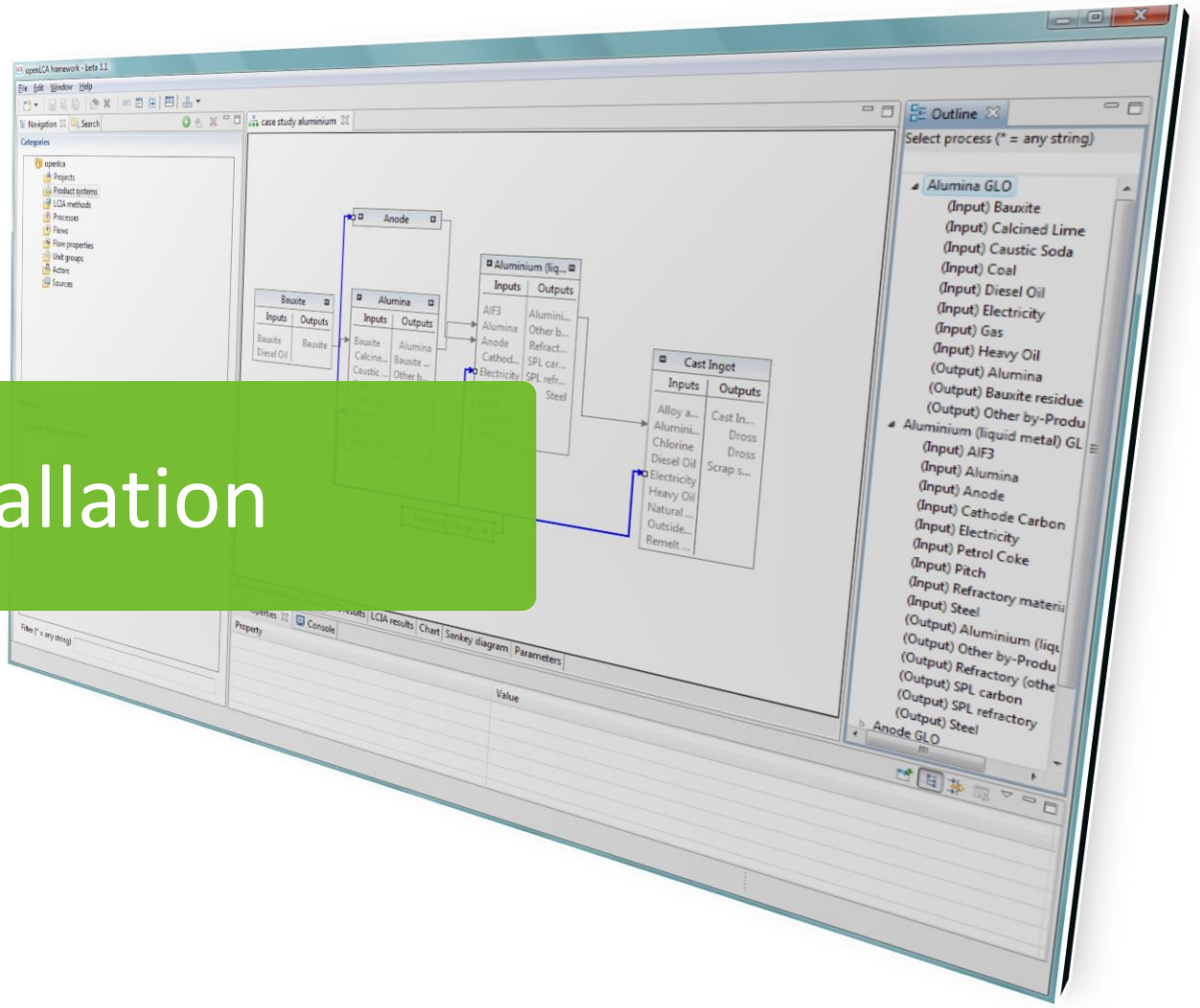
Further characteristics

- Separate calculation of costs possible
- Multiple languages
- Automatic error report
- Integrated static and dynamic help

Installation



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System requirements

Software, required:

- Mac OS: Java Development Kit 8 (http://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html)

Software, optional:

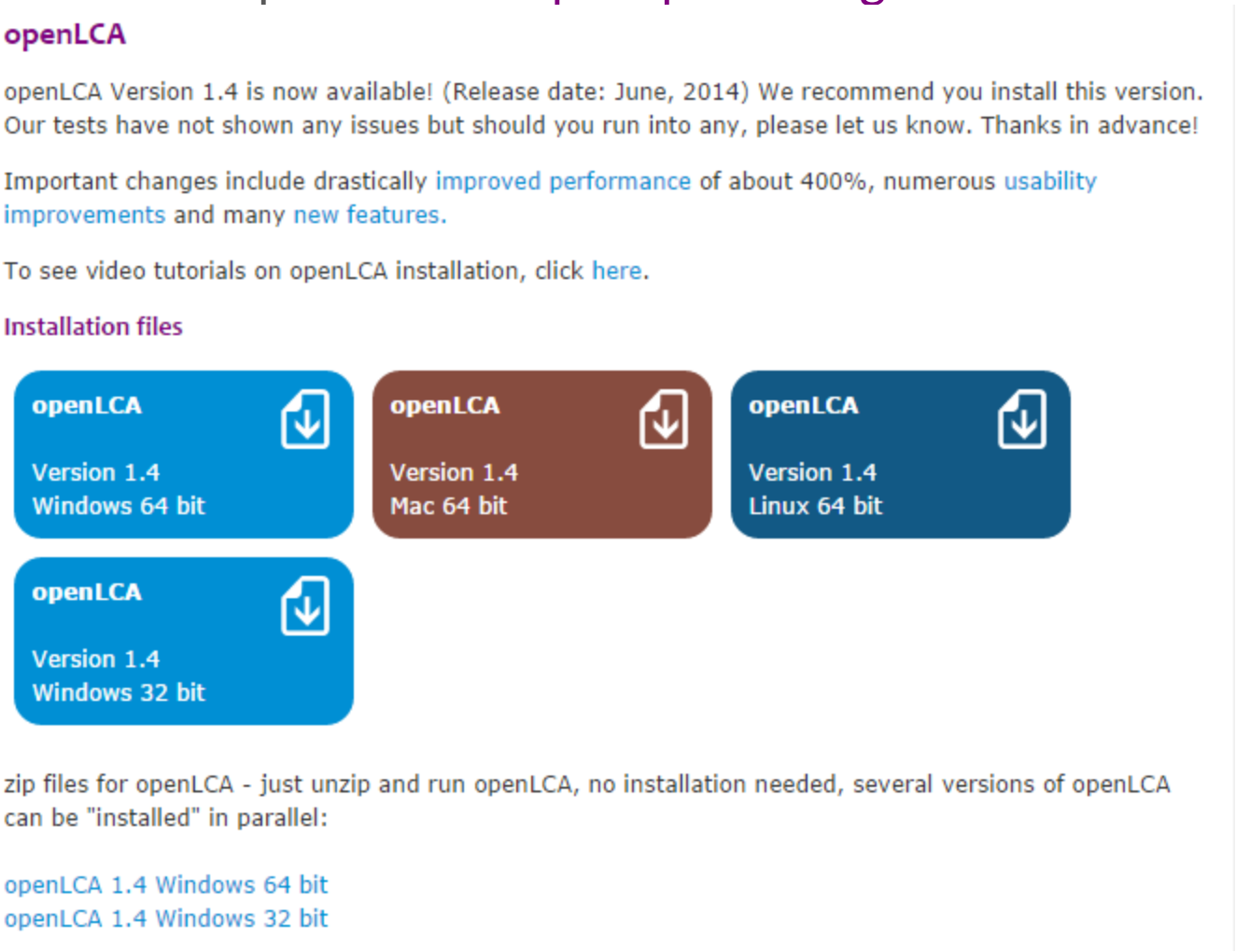
- Windows 64 bit (for modern browser support): Microsoft Visual C++ 2010 Redistributable Package (x64) (http://www.microsoft.com/de-de/download/details.aspx?id=14632)
- Linux (for high performance calculations): libgfortran3

Hardware:

- CPU with 2 GHz or higher
- 1 GB RAM (for analyzing product systems with ~2500 processes, like ecoinvent 2)
- > 3 GB RAM (for analyzing product systems like ecoinvent 3)
- 500 MB free disk space + space for databases (e.g. ecoinvent 3 requires ~250 MB)

Download and installation of openLCA

Download openLCA at http://openlca.org/downloads/



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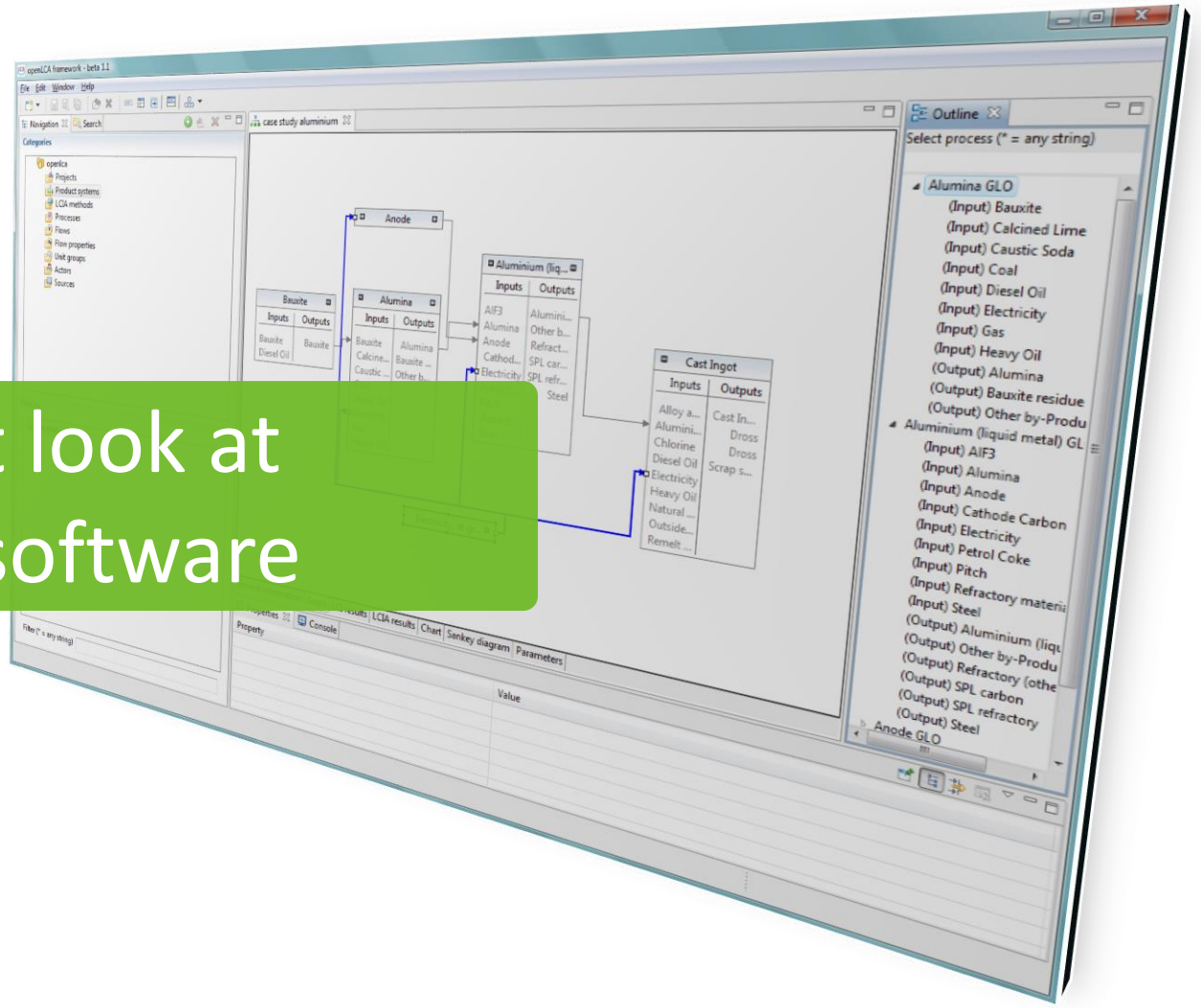
openLCA installer

First look at the software



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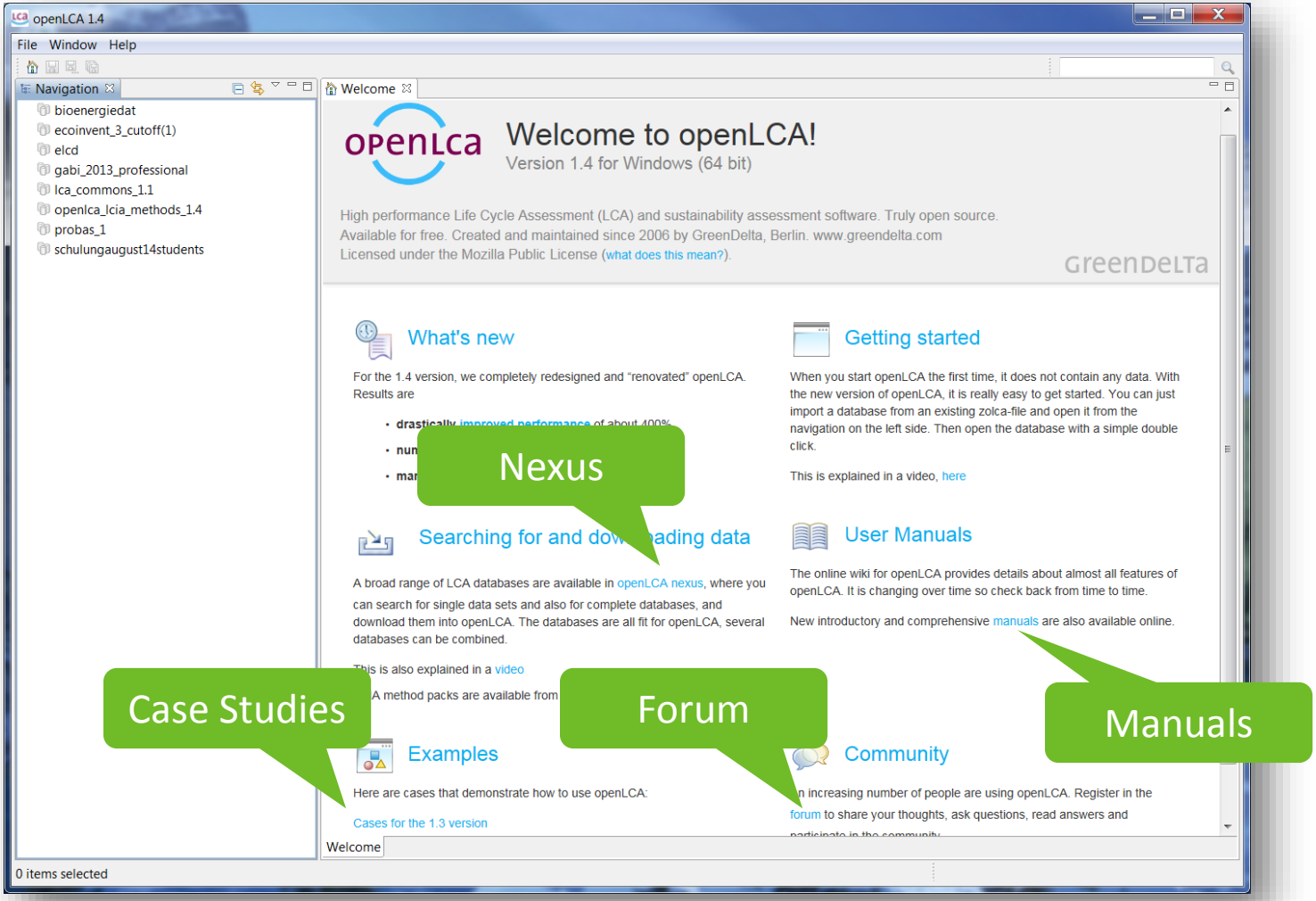
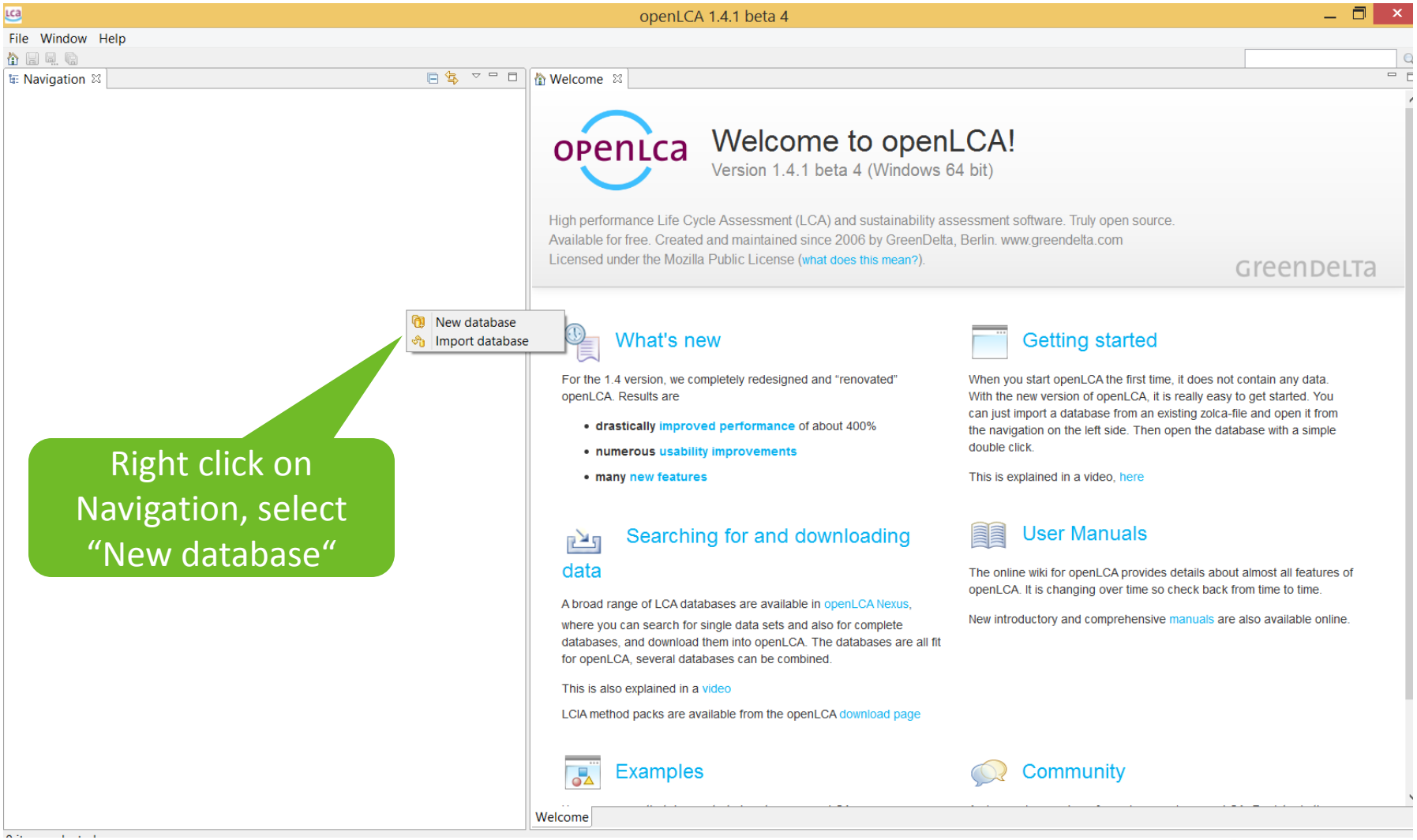
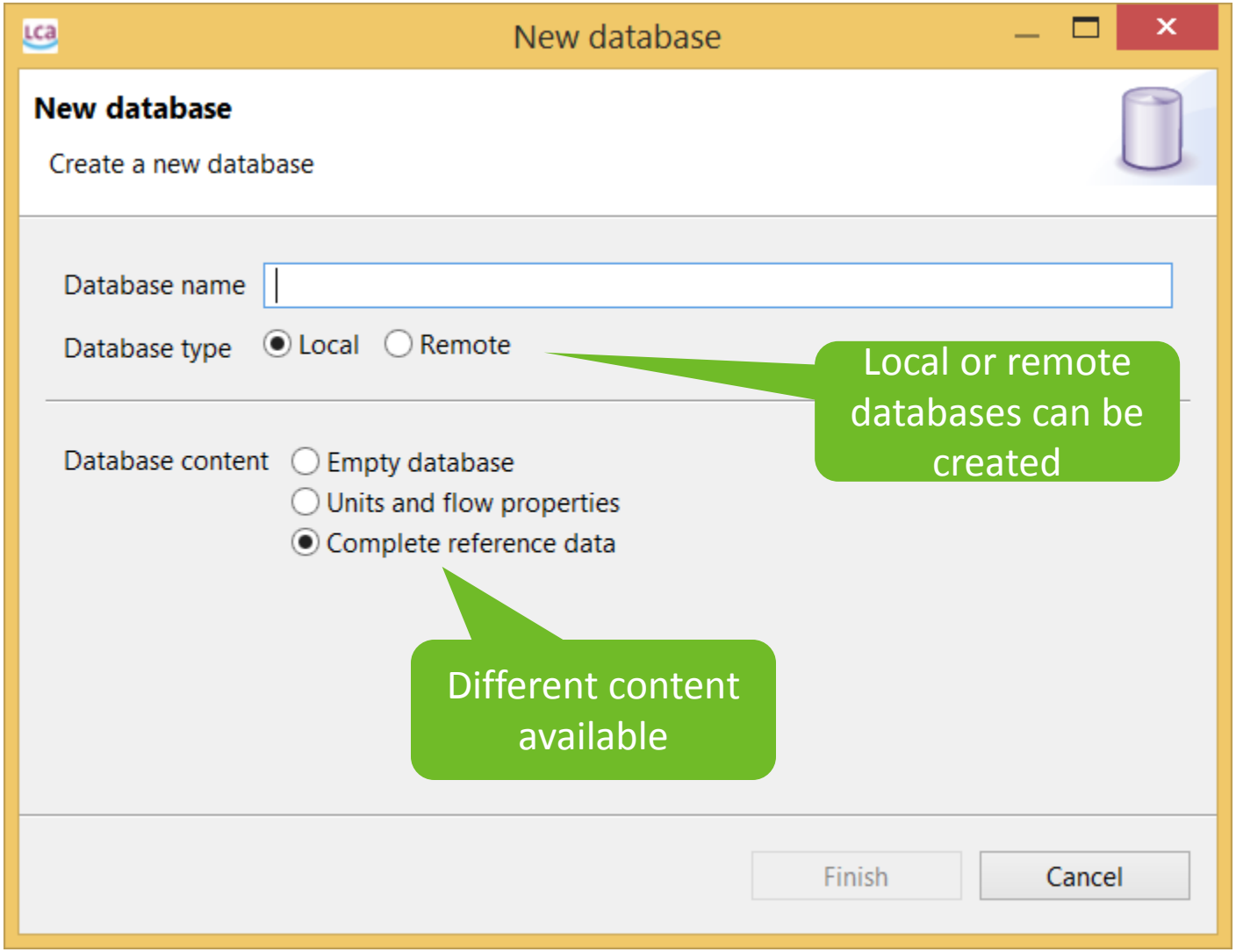
Welcome to openLCA!



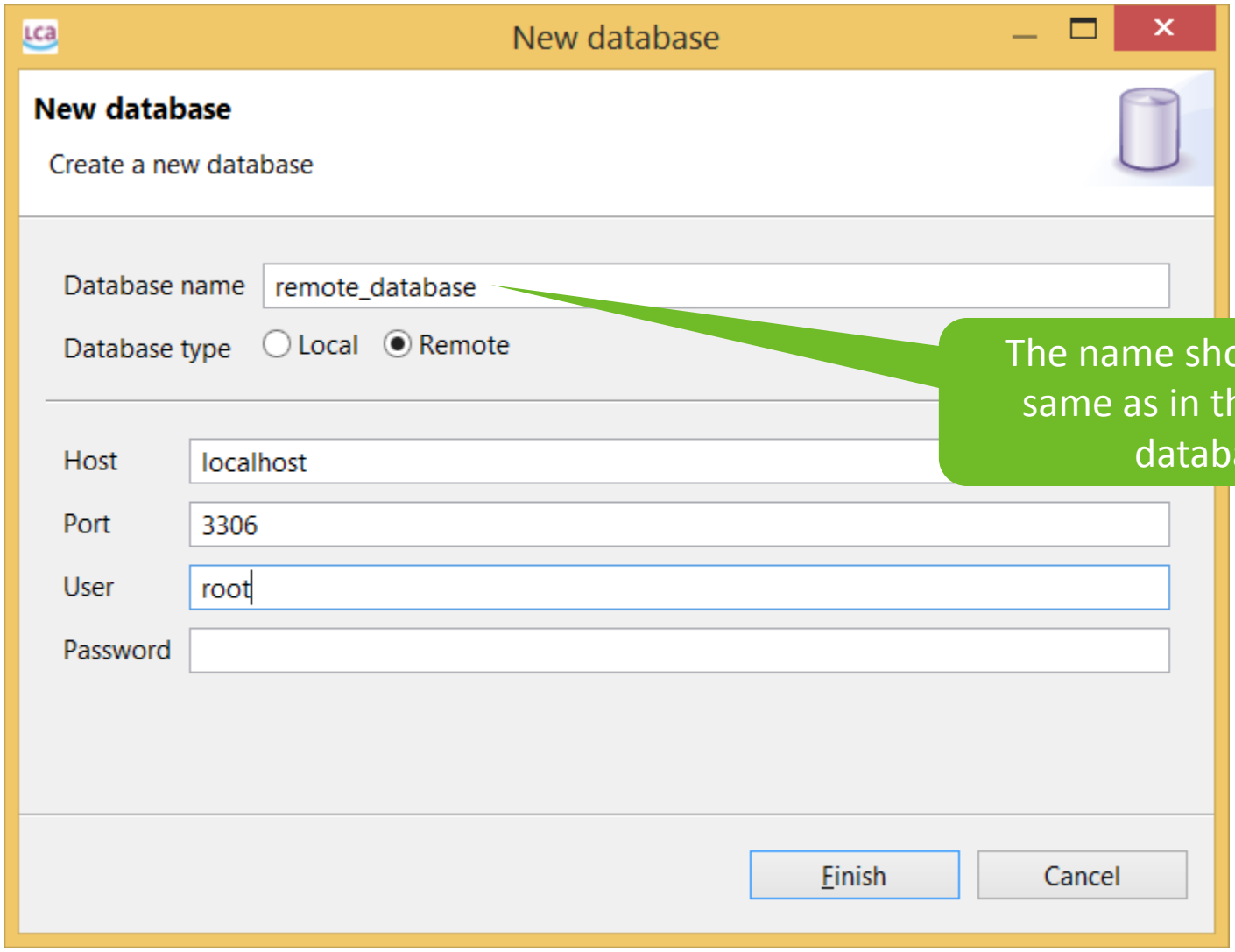
Create a new database



Create a new database (II)



Create a new database (III)

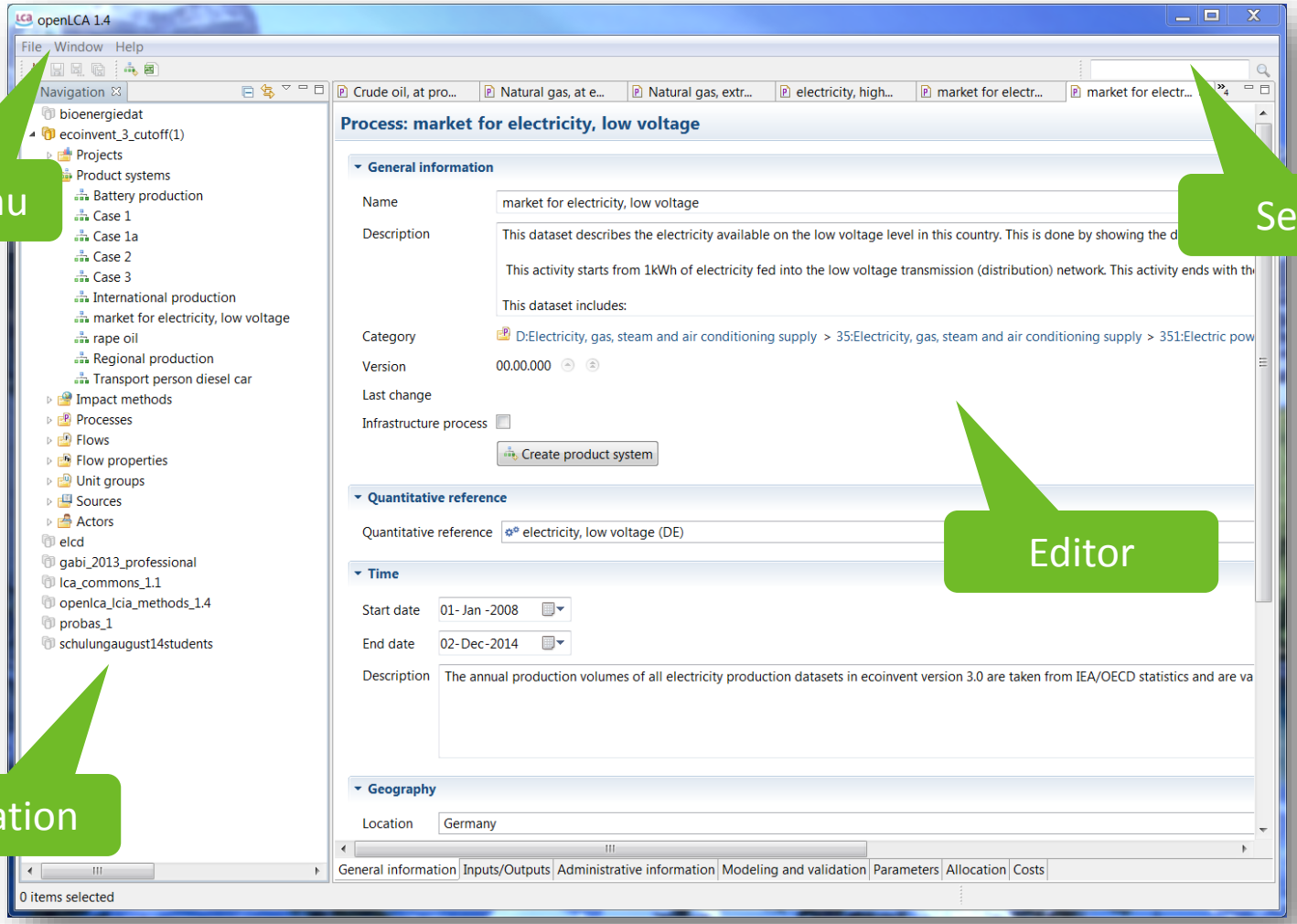


The name should be the same as in the remote database

Exercise 1: start

- Install openLCA on your computer and run it.
- Create a local database.
- Accept default values.
- 5 min

Database view



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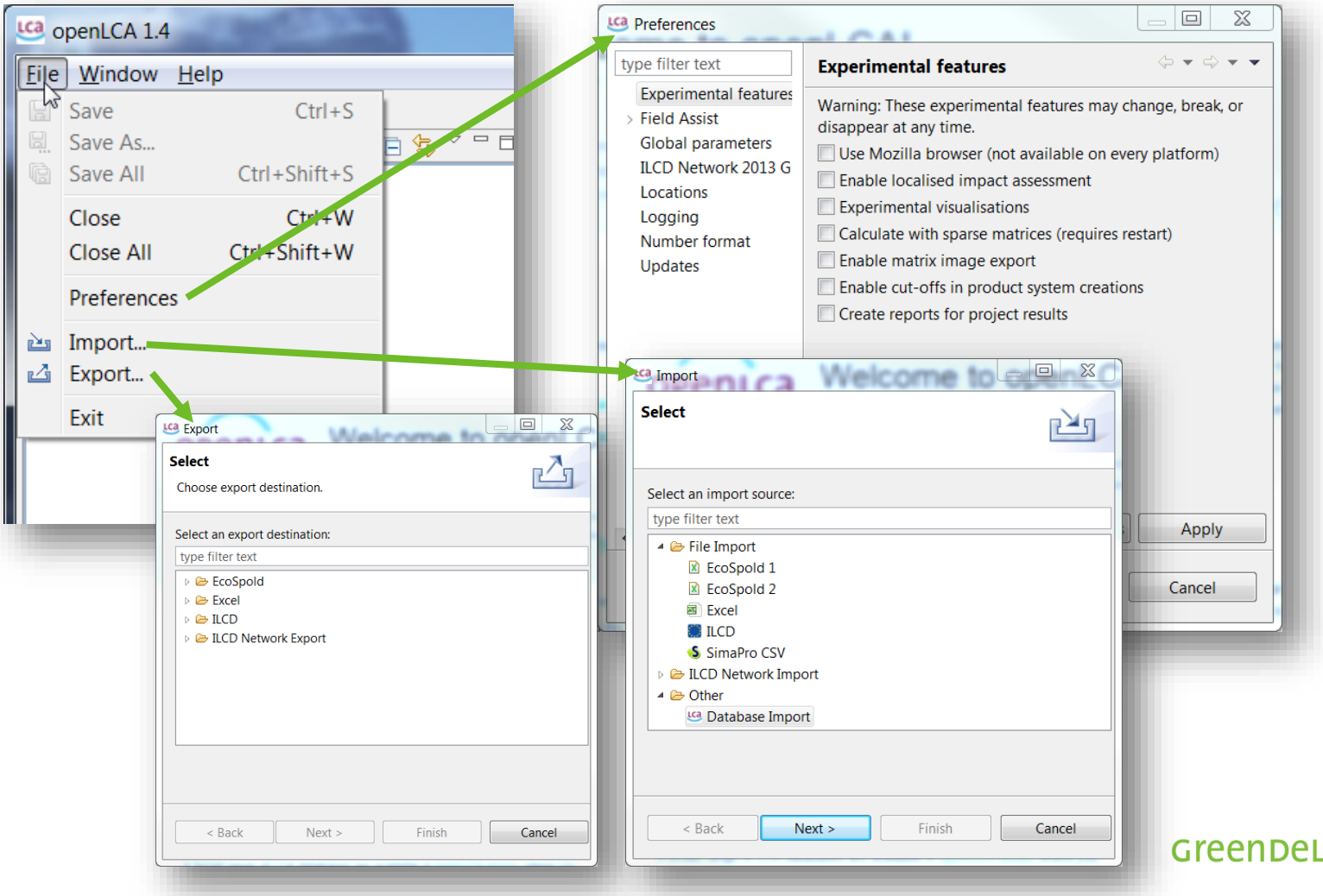
Main menu functions



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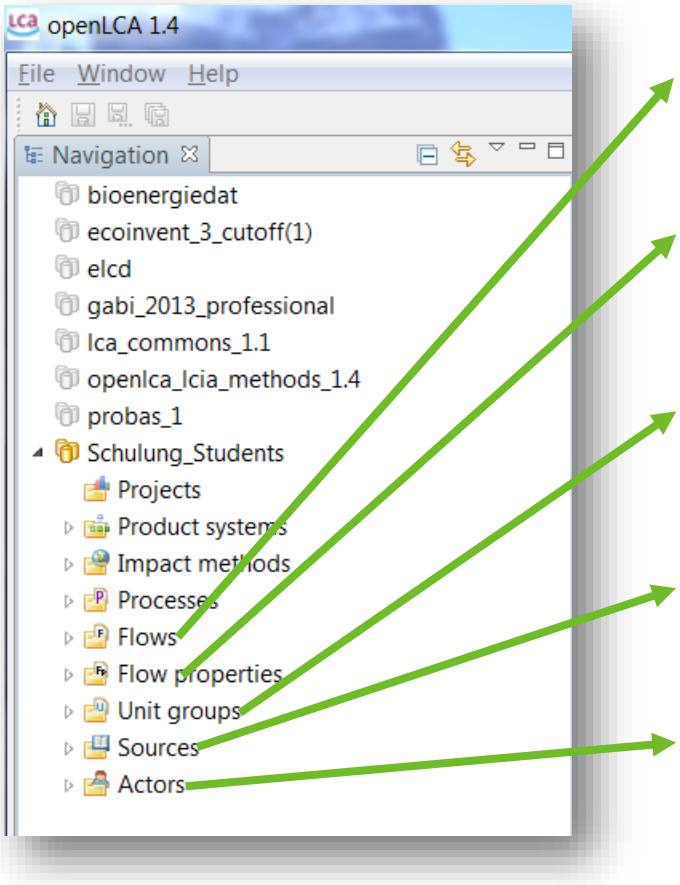
Database elements (I)



Flows: flow of products and materials

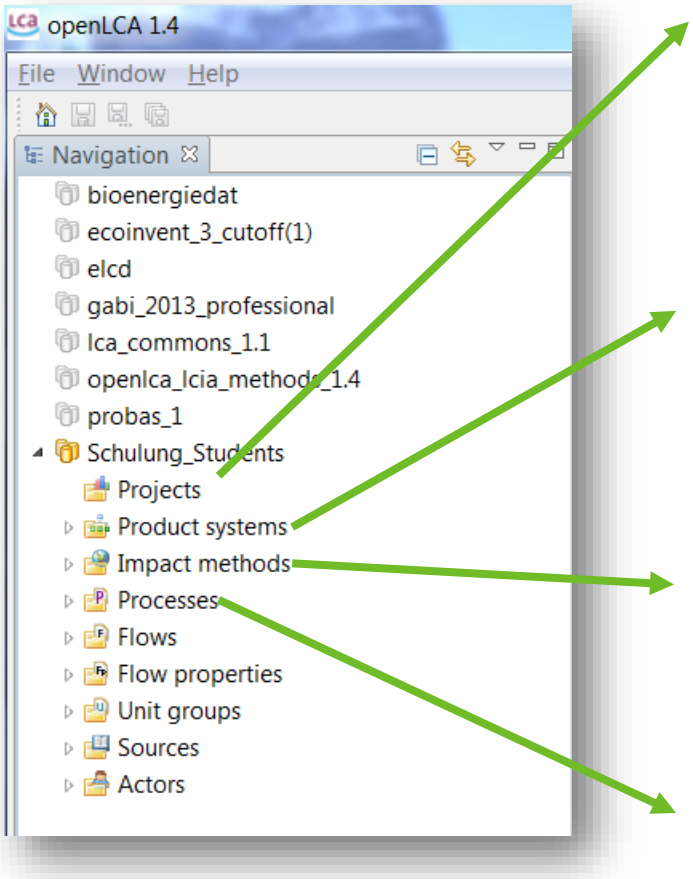
Flow properties: i.e. Length, Mass, etc

Unit groups: Groups of units

Sources: Literature

Actors: People who have provided data or modified models

Database elements (II)



Projects: comparison of numerous product systems

Product systems: process networks (necessary to calculate inventory results and impact assessment)

LCIA Methods: can be downloaded at openlca.org/downloads

Processes: Production or modification of materials/products

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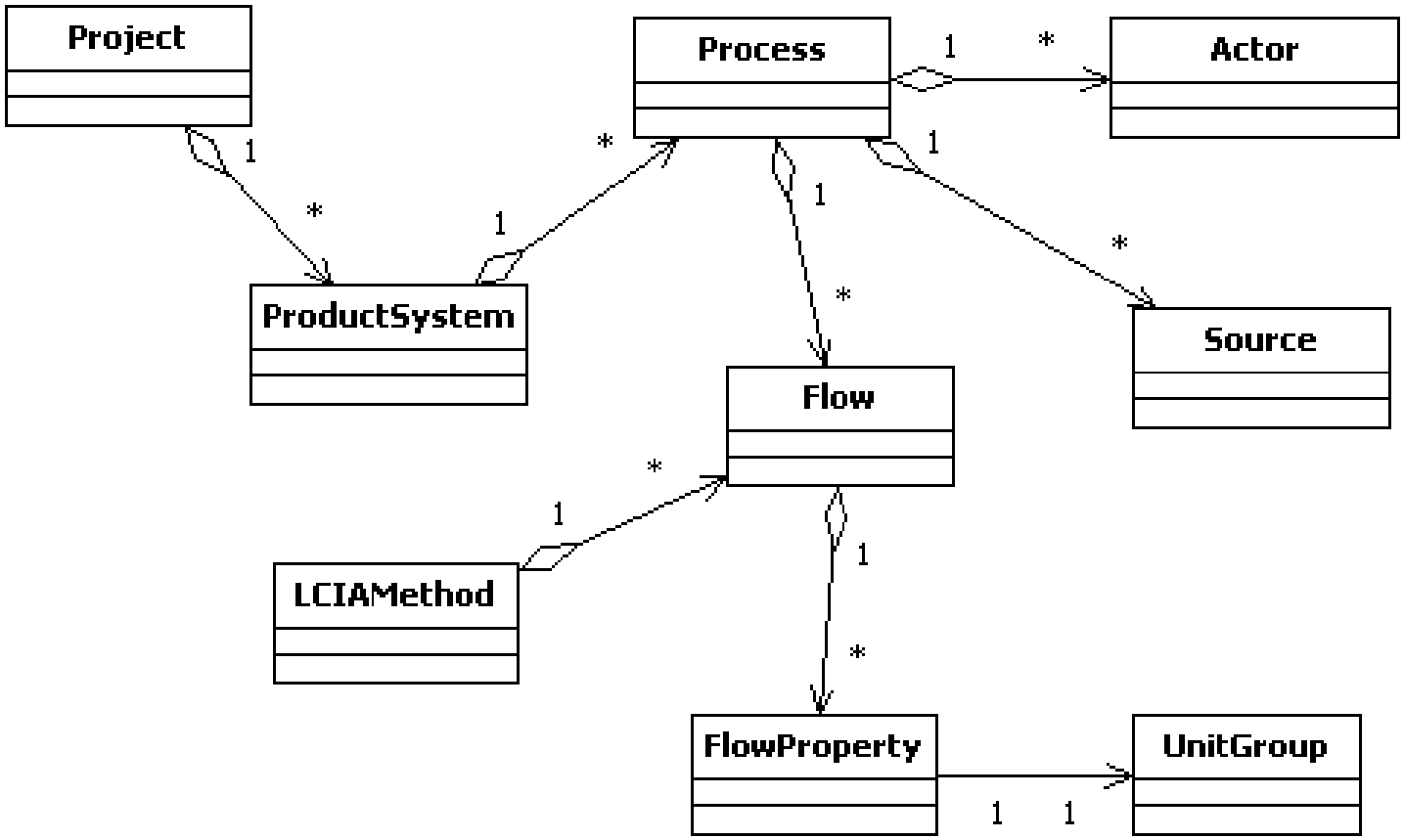
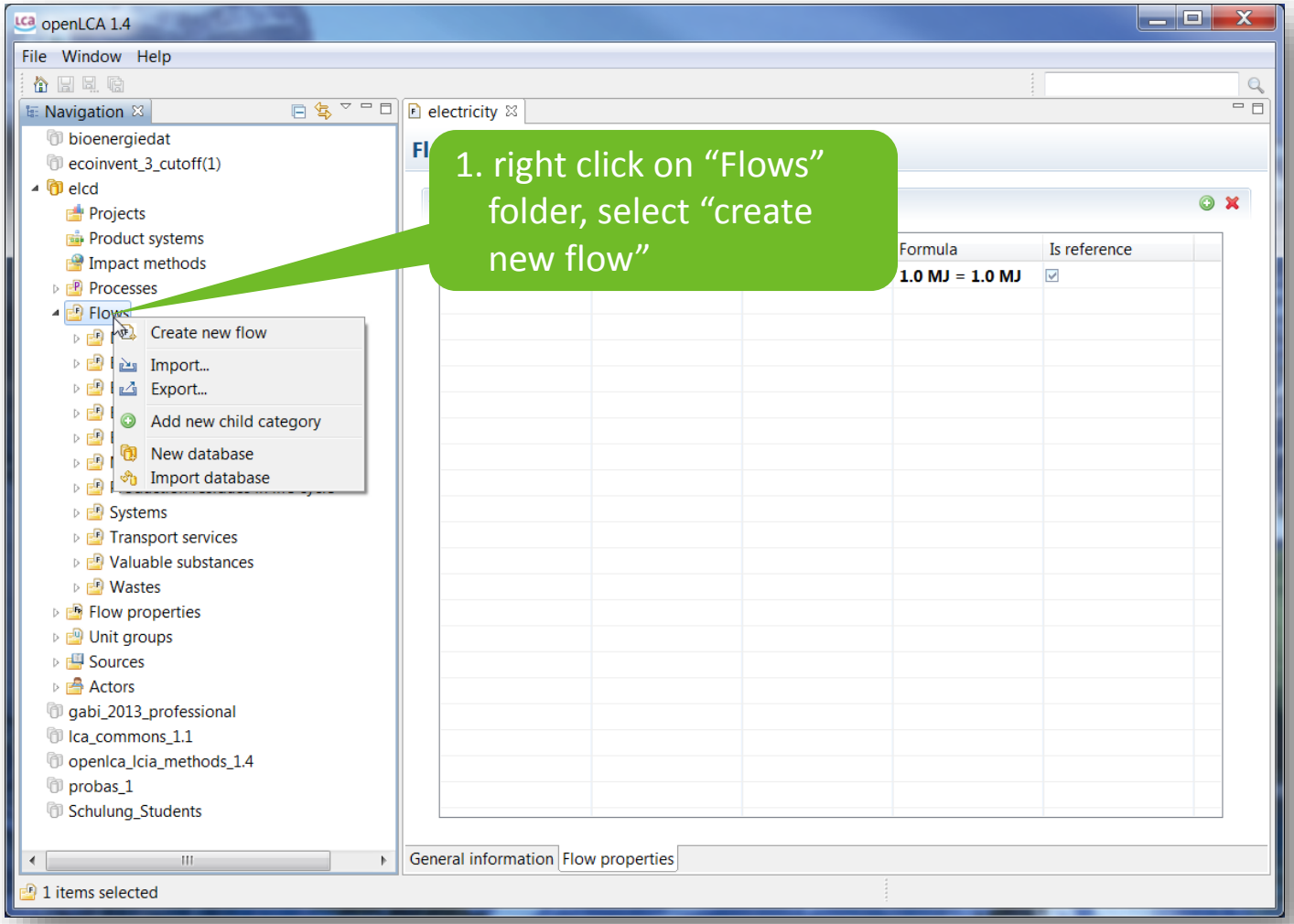
Element structure in openLCA



Flows: Create new flow (I)



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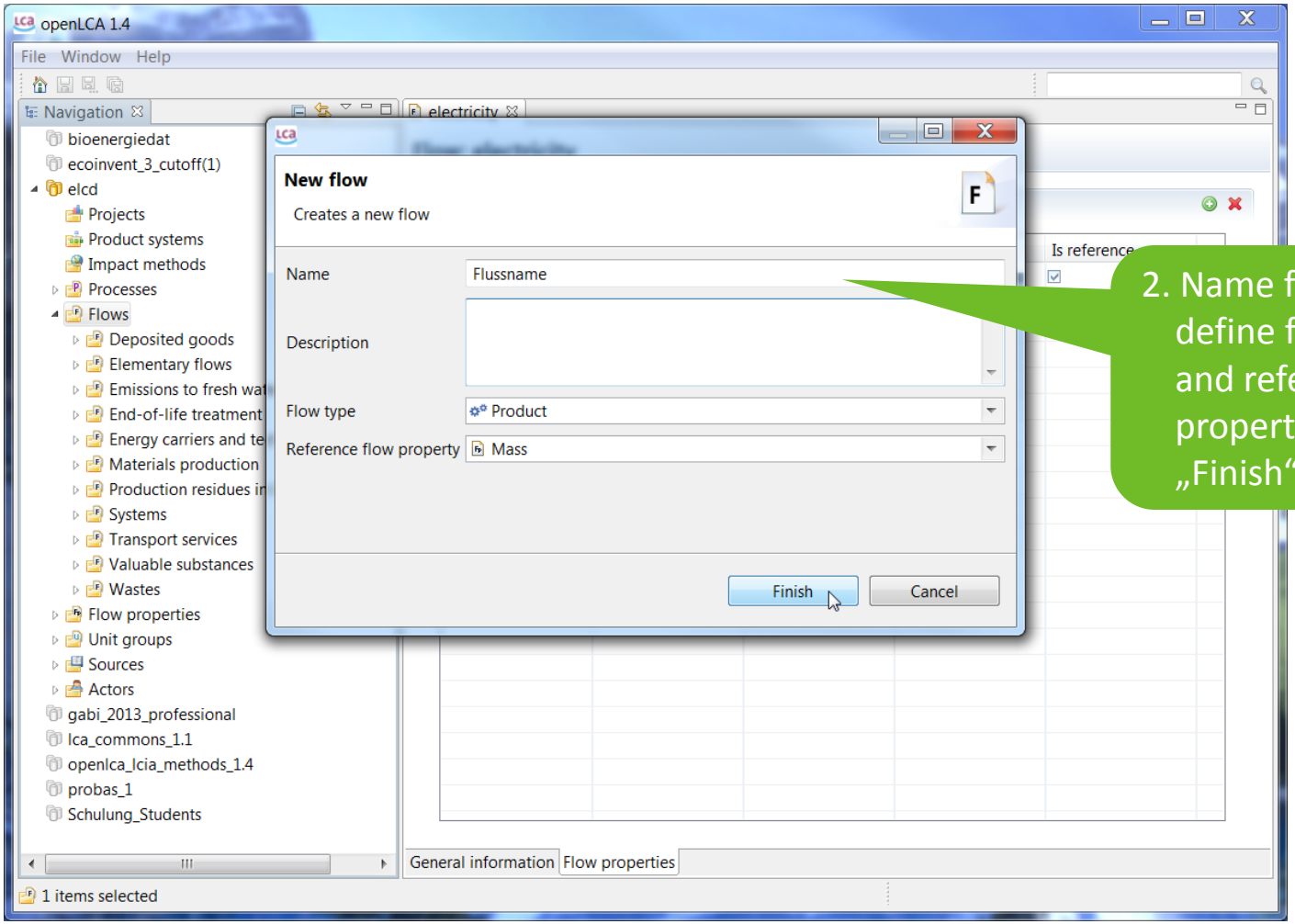
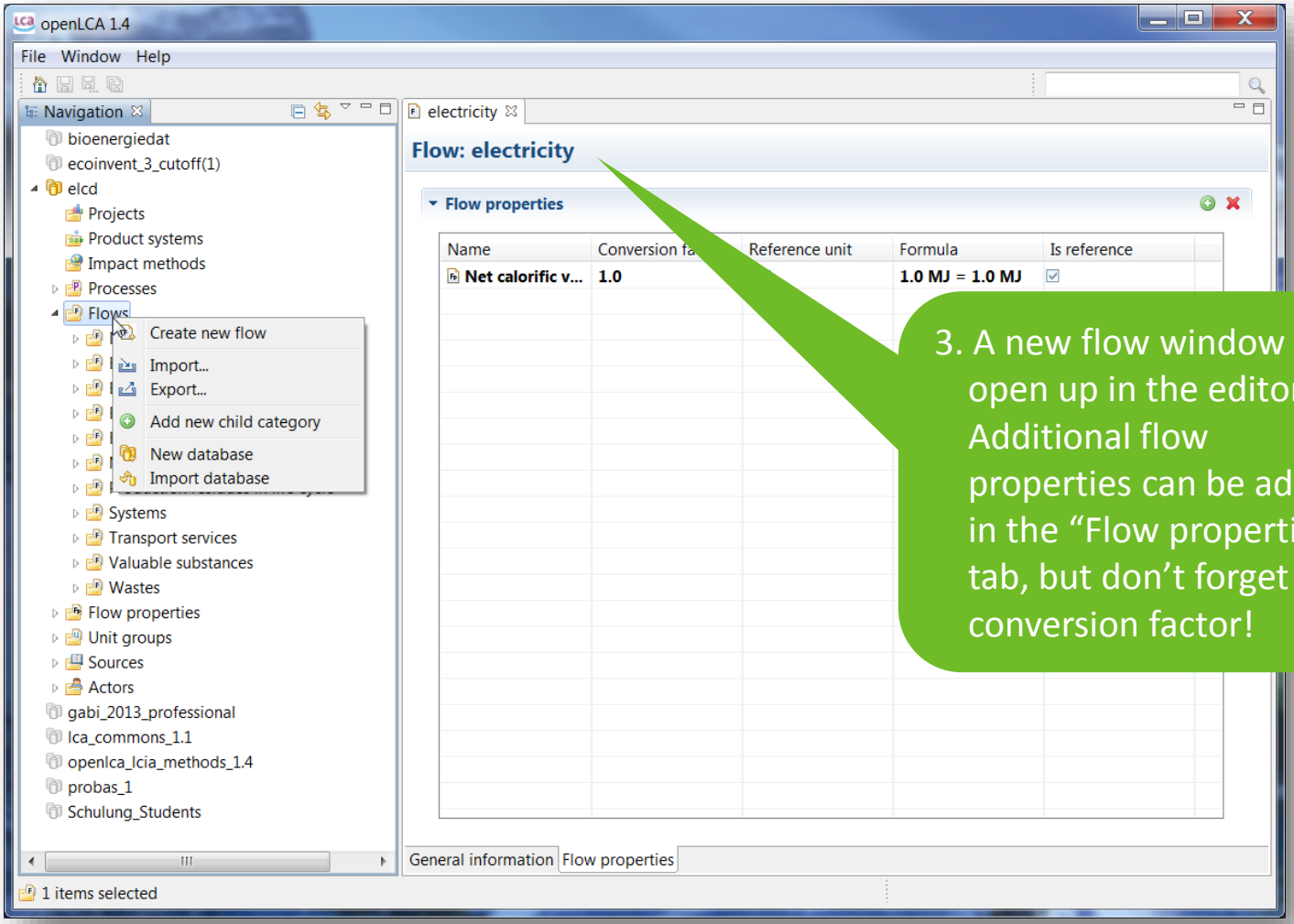
Flows: Create new flow (II)



Flows: Create new flow (III)



3. A new flow window will open up in the editor. Additional flow properties can be added in the “Flow properties” tab, but don’t forget the conversion factor!

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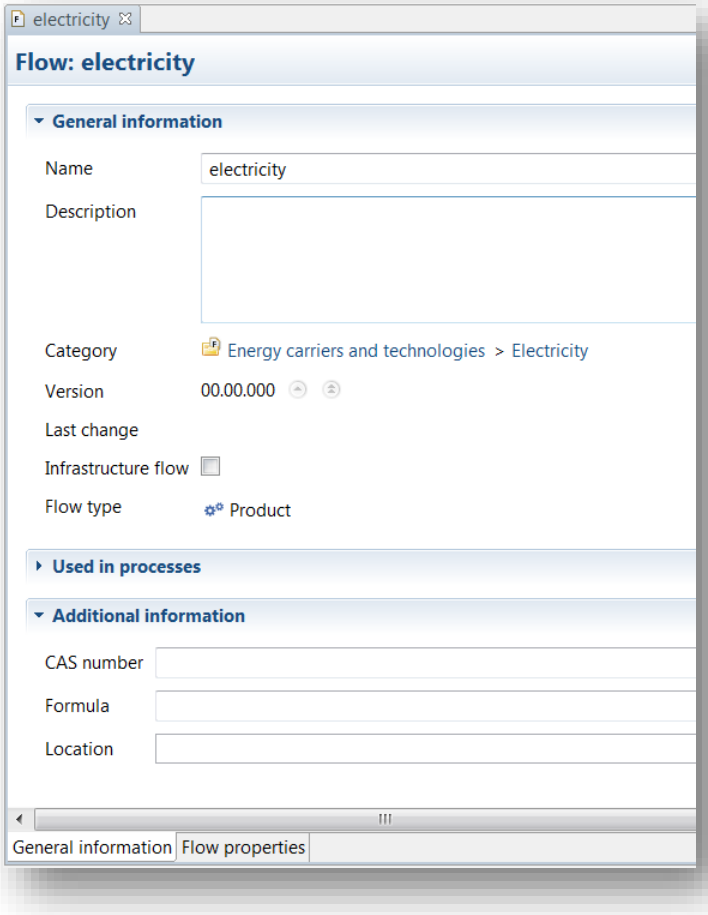
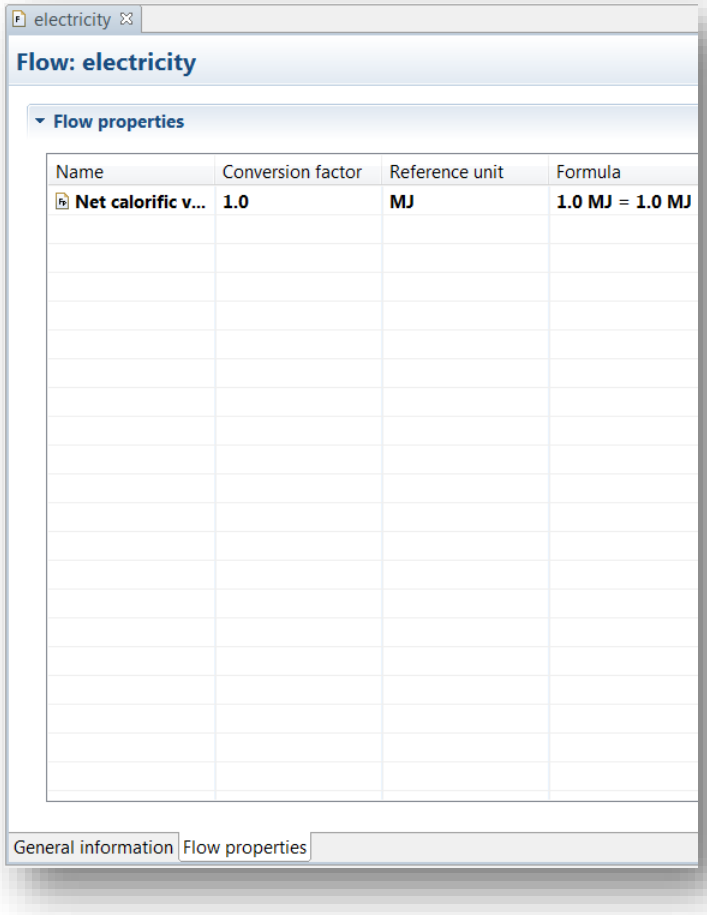
Flow: Information & properties





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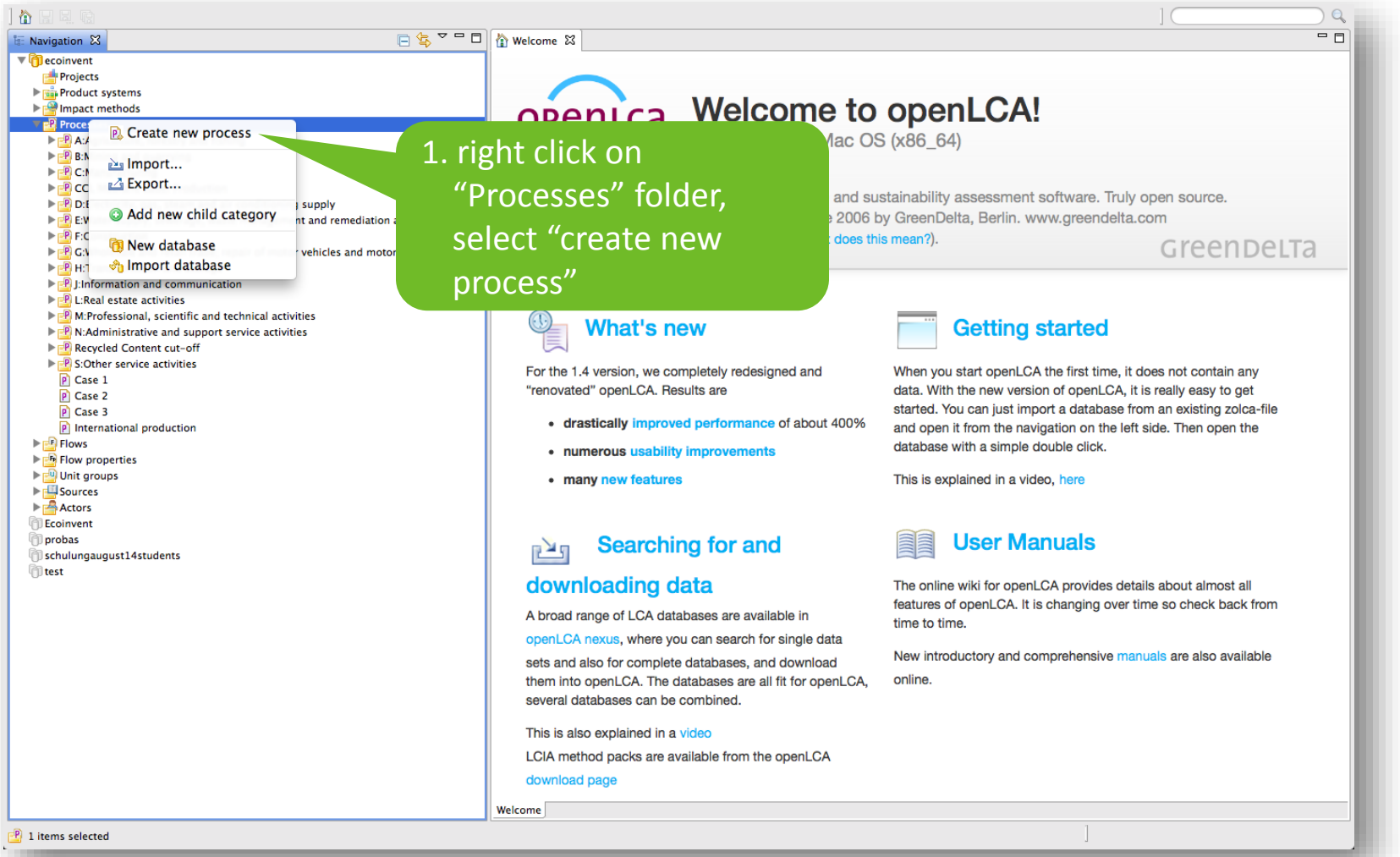
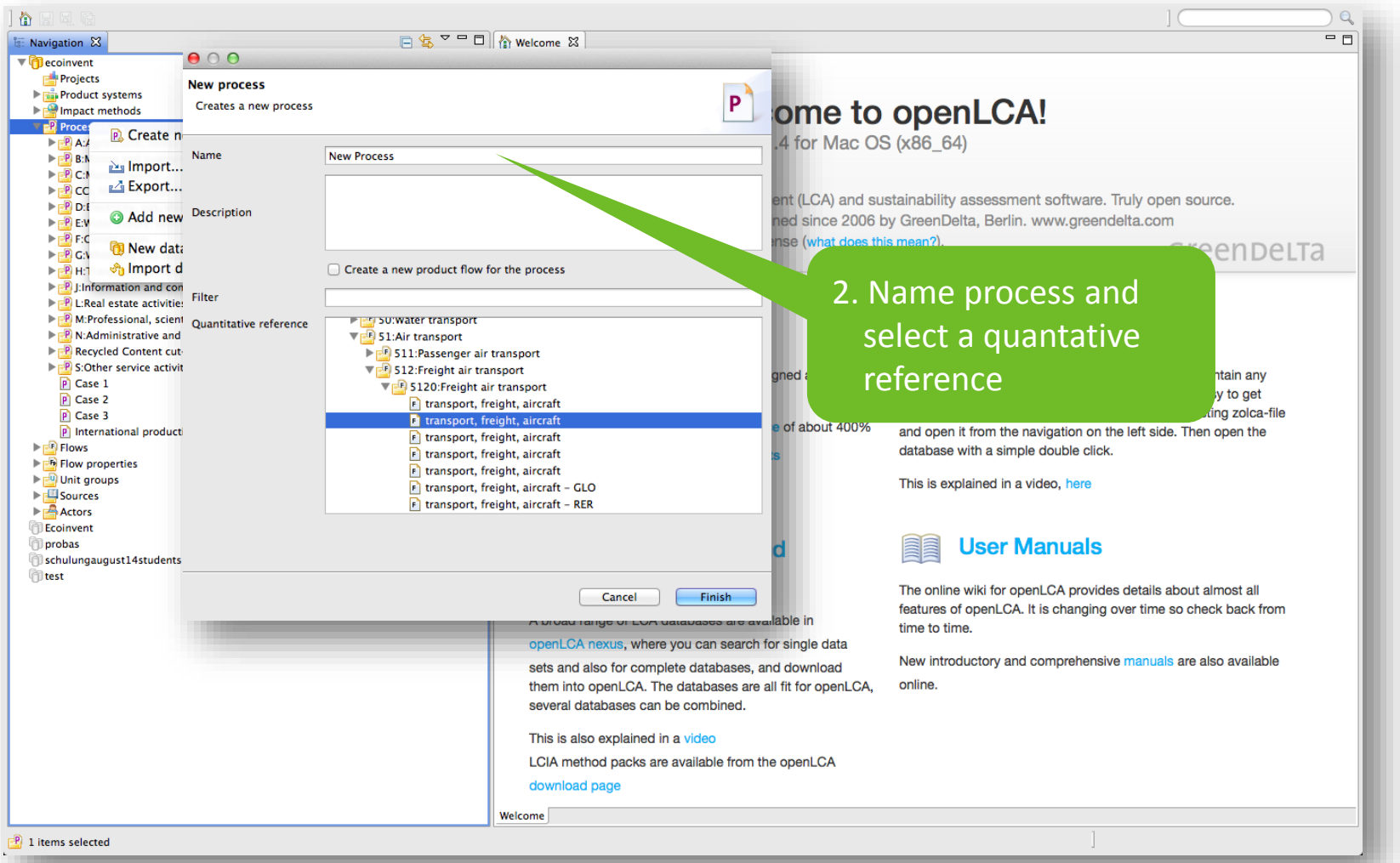
Process: Create new process (I)



Process: Create new process (II)



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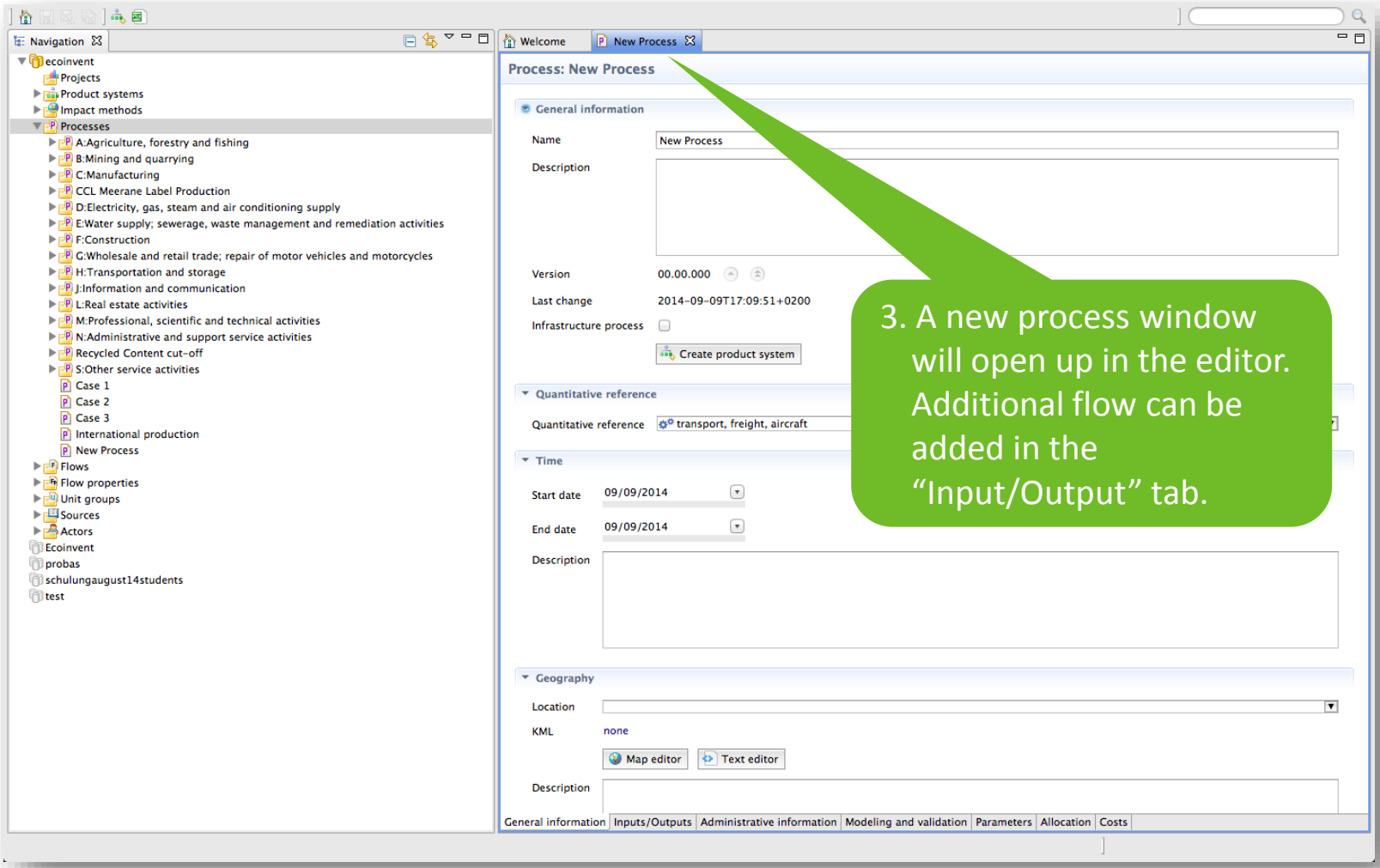
Process: Create new process (III)



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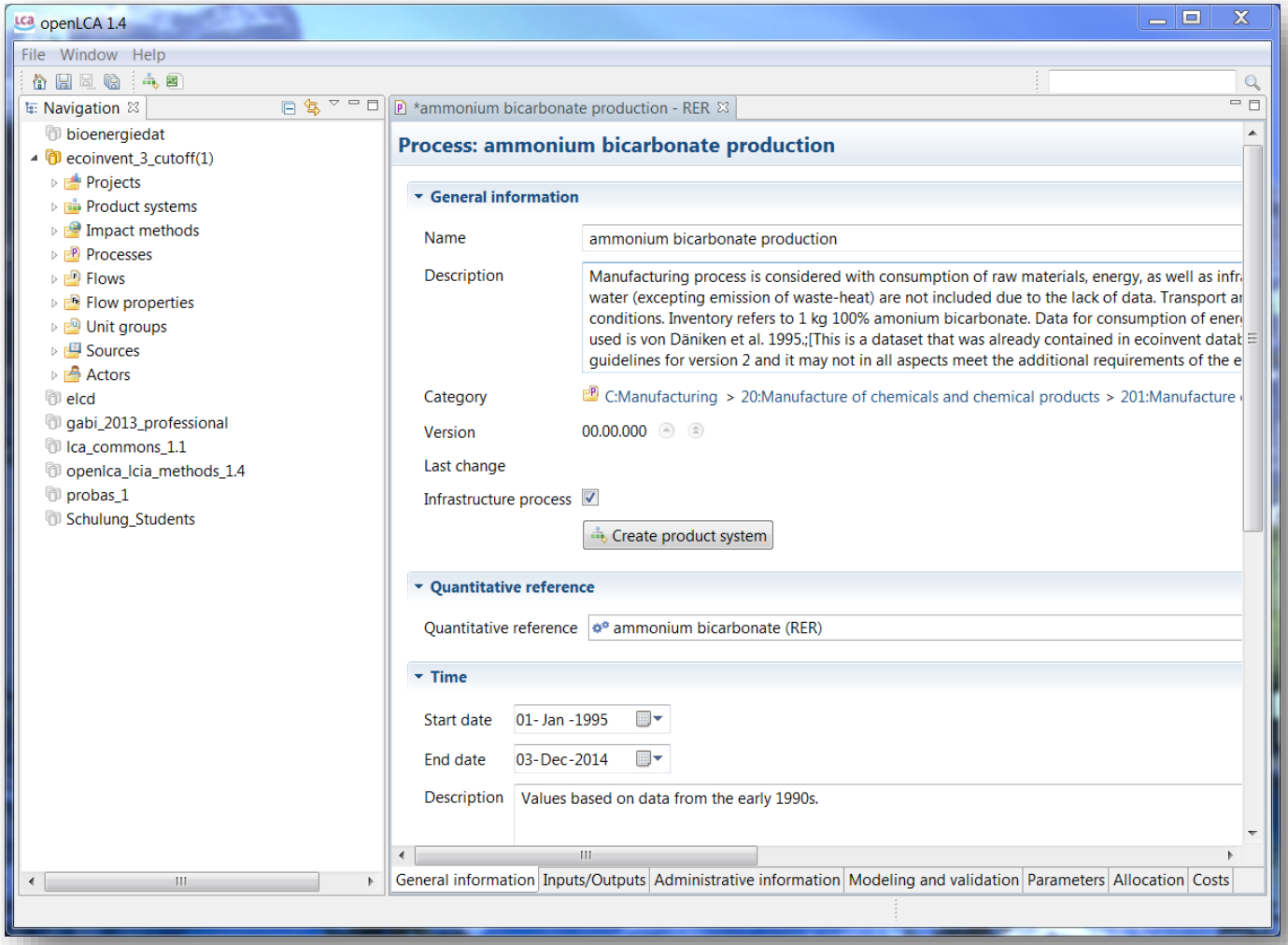
Process: General information



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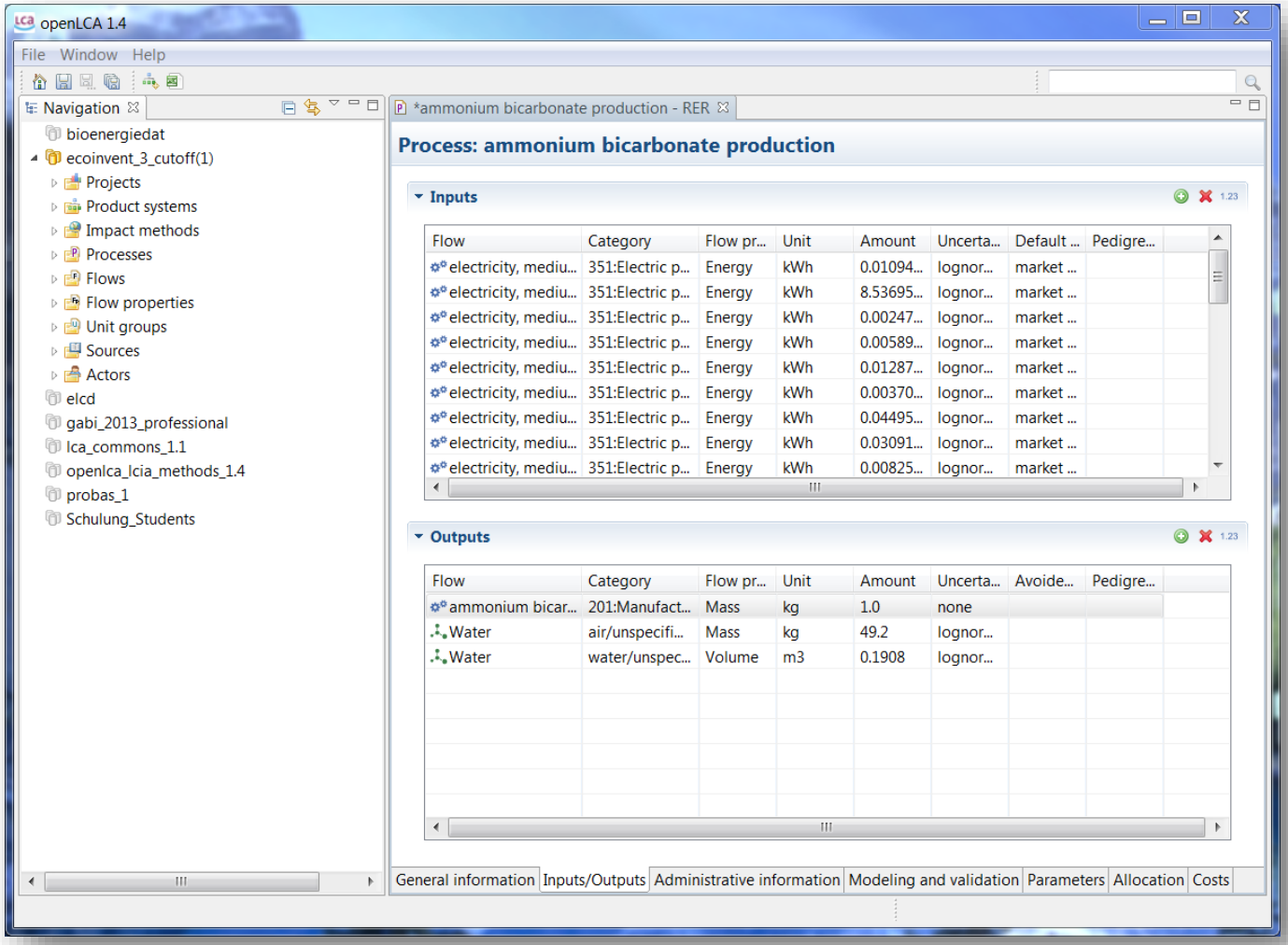
Process: Inputs/Outputs



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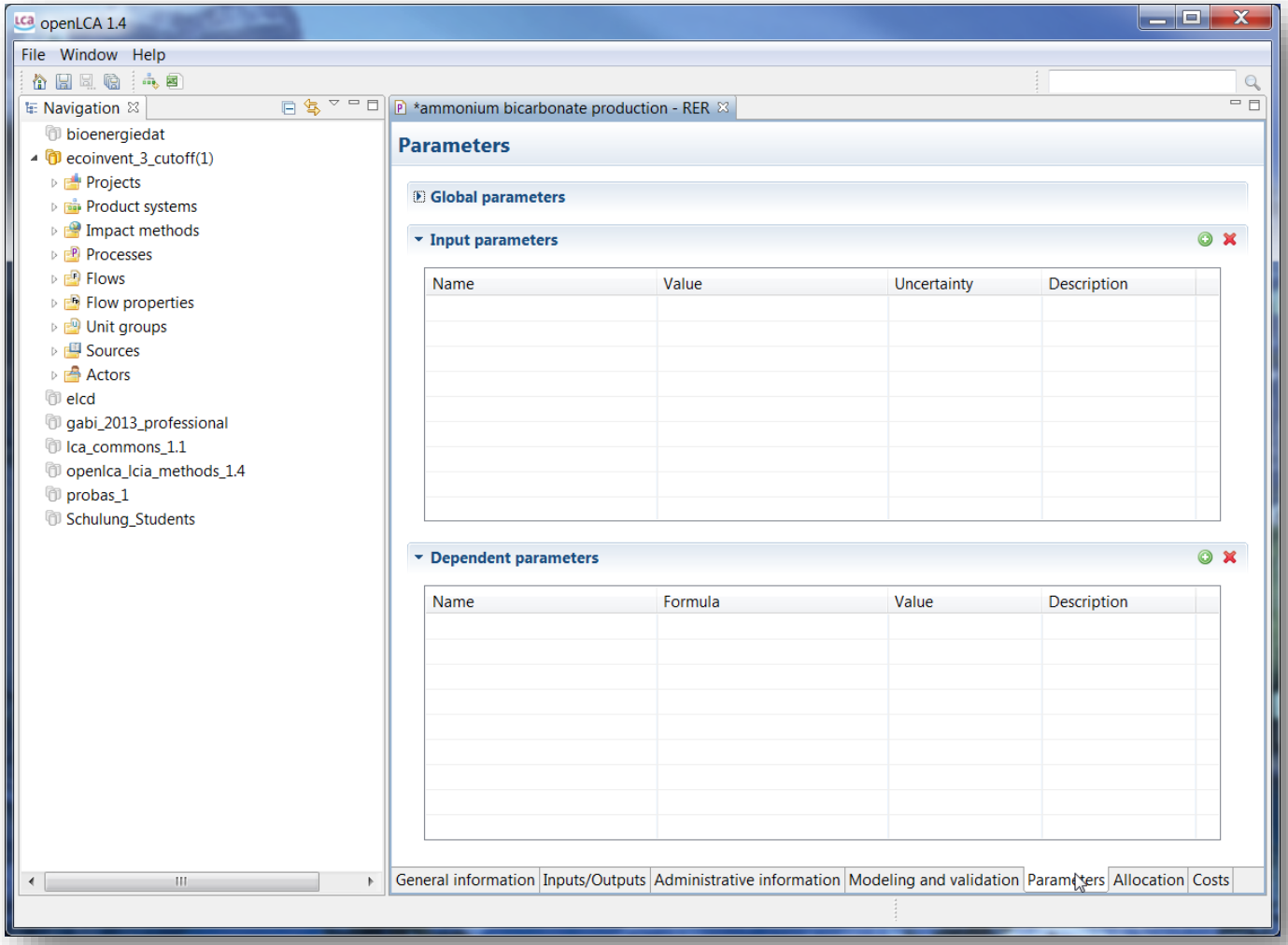
Process: Parameters (I)



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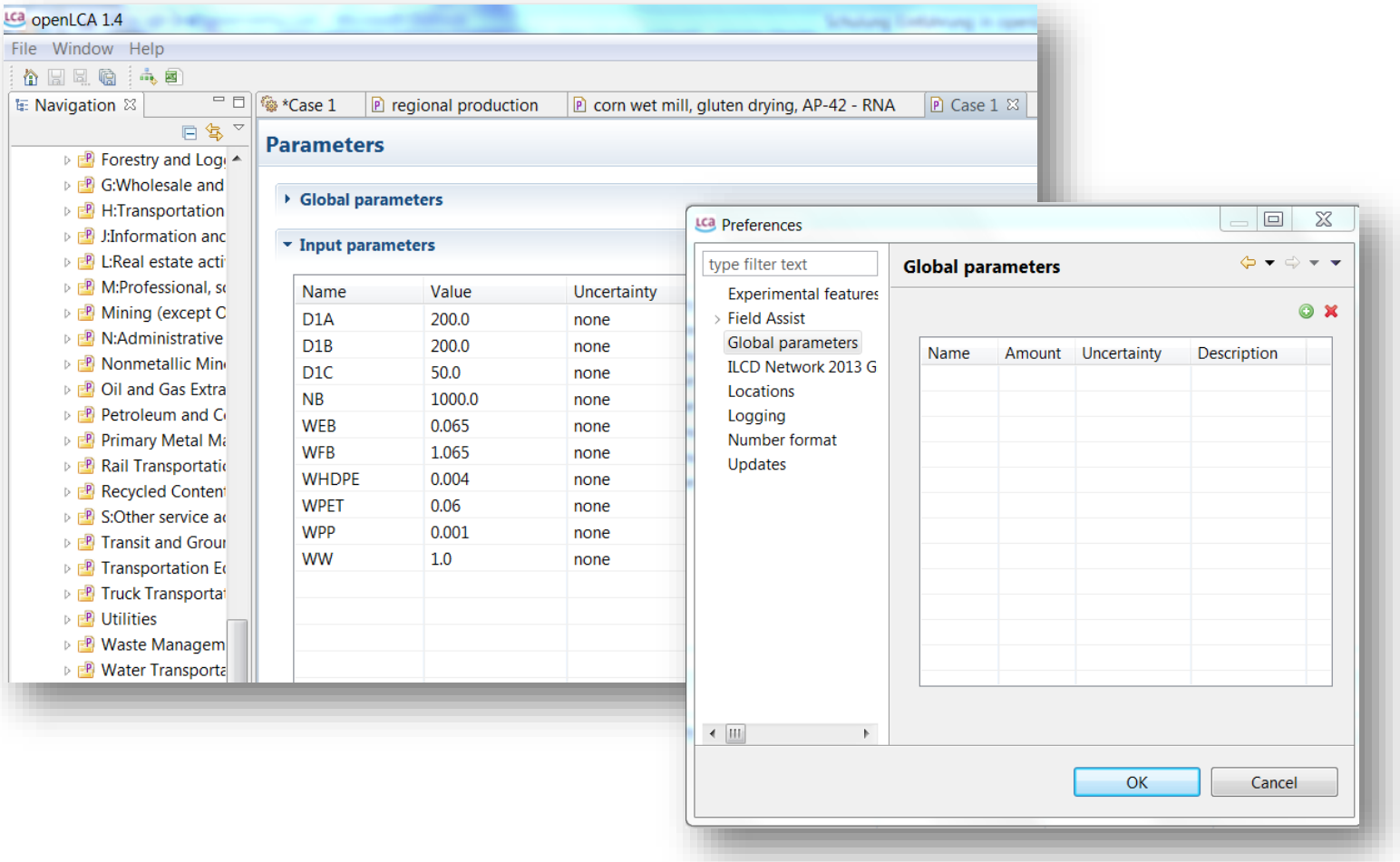
Process: Parameters (II)



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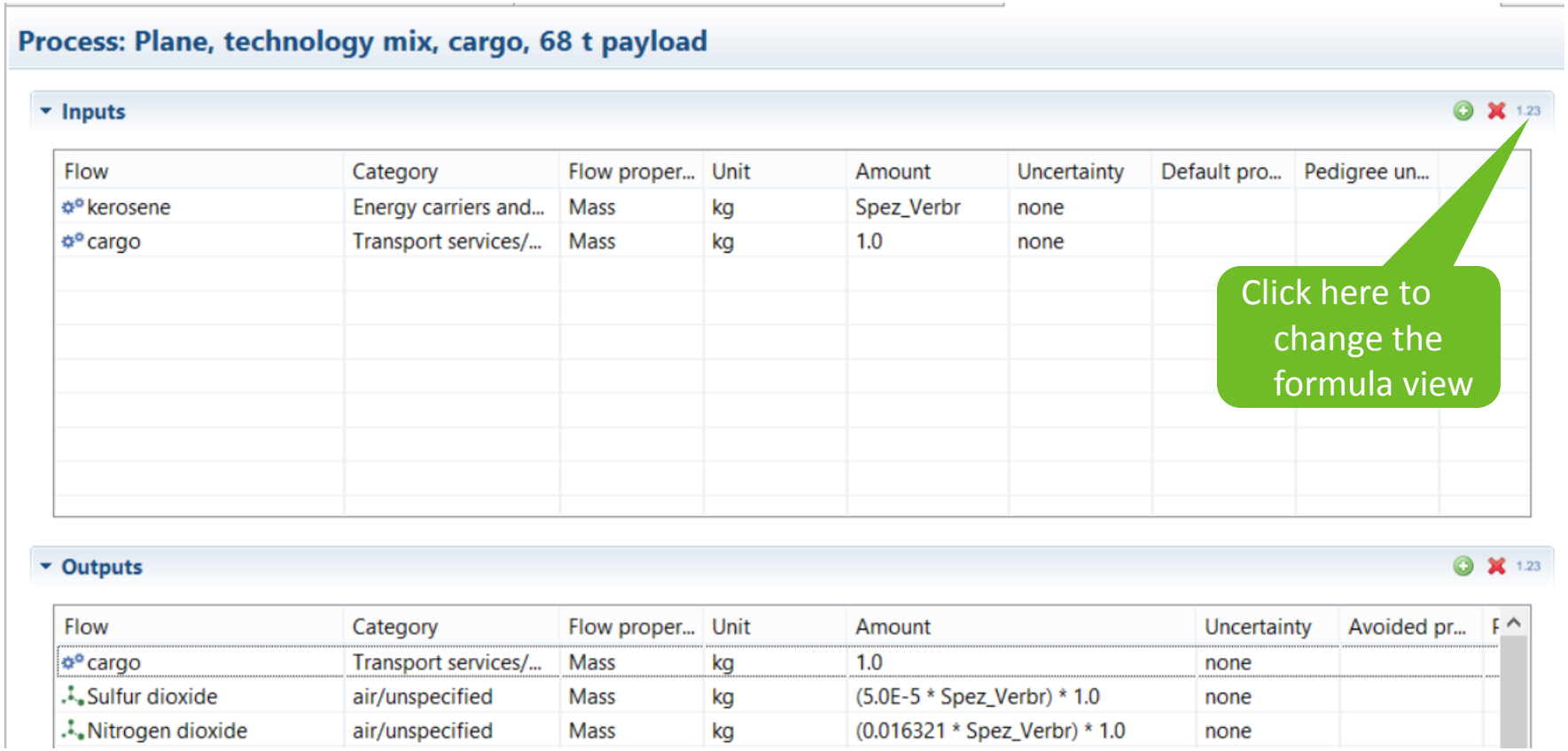
Process: Parameters (III)

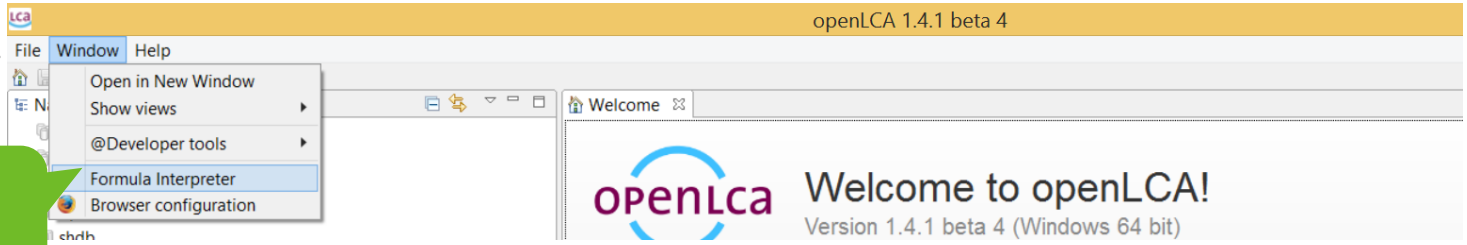


Parameters: rules

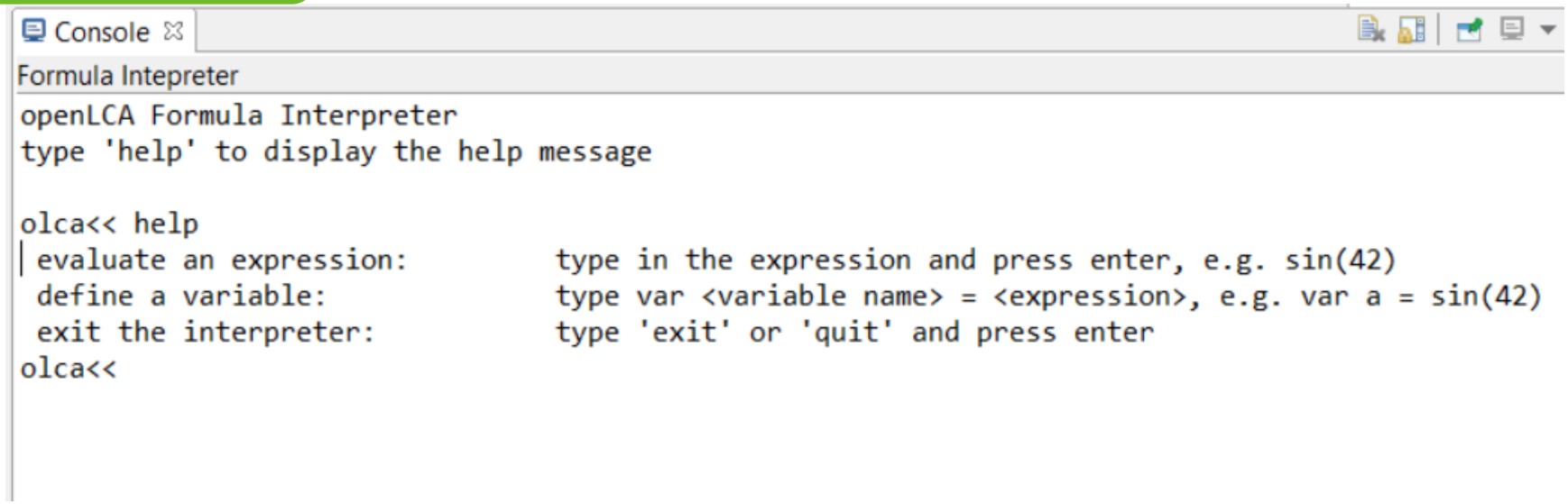
- Parameter names...
  - ... must be written with small characters.
  - ... must be one word.
  - ... cannot contain special characters.
  - ... cannot have more than 255 characters.
- Parameter formulas...
  - ... can contain single values, simple equations, or complex functions including logical expressions.
  - ... do not contain units, so please add them in the comment field.
  - ... cannot have more than 255 characters.
- The amount of parameters is, theoretically, not limited.
- Use point (.) instead of comma (,) for the decimal numbers.

Parameters: checking formulas

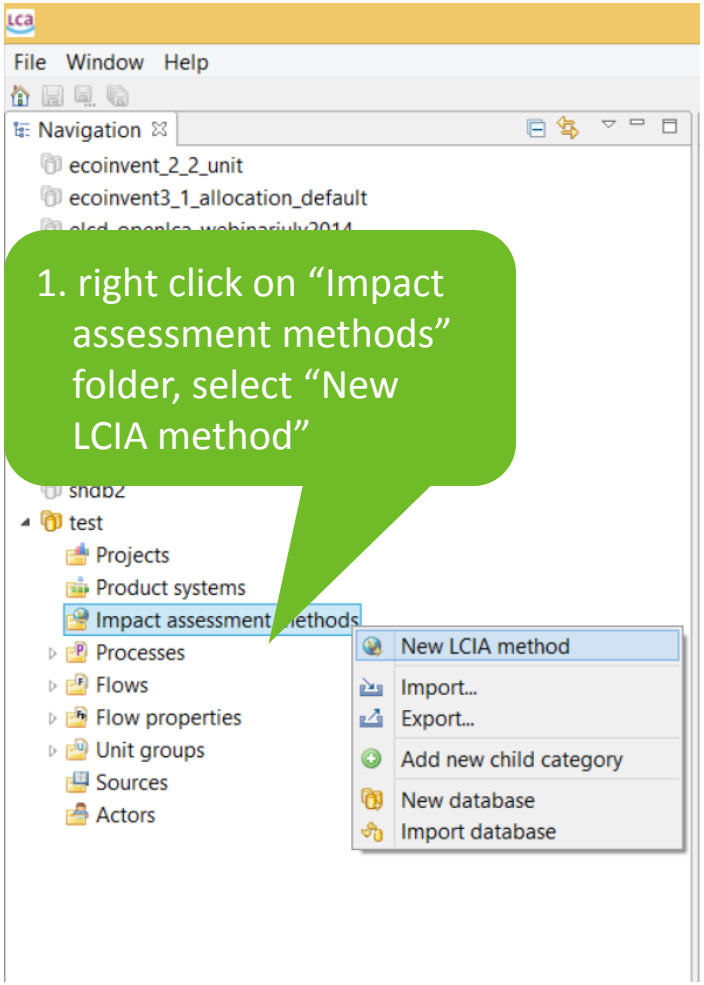
- For complex formulas must use a certain format (e.g. Tan (a), trunc(c), etc.). Use the formula interpreter to find errors.

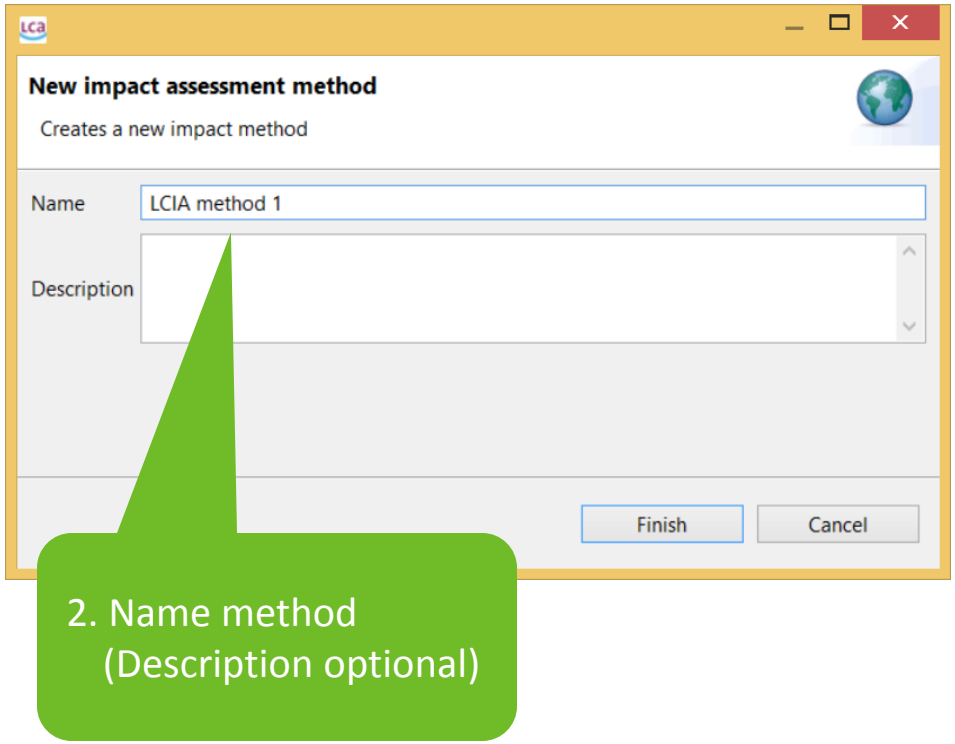


Select “Formula Interpreter” in “Window” menu

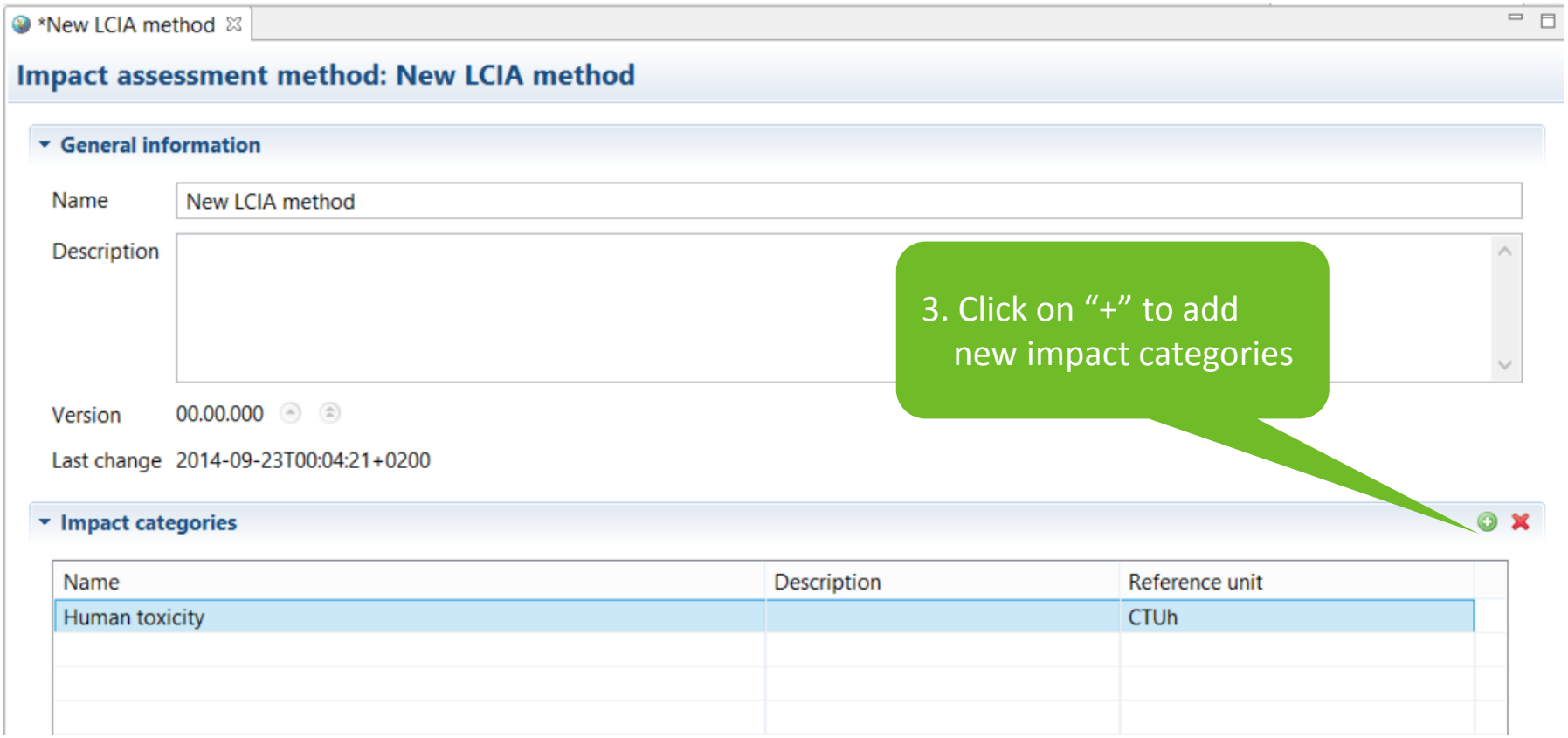


Impact assessment methods:
Creation (I)

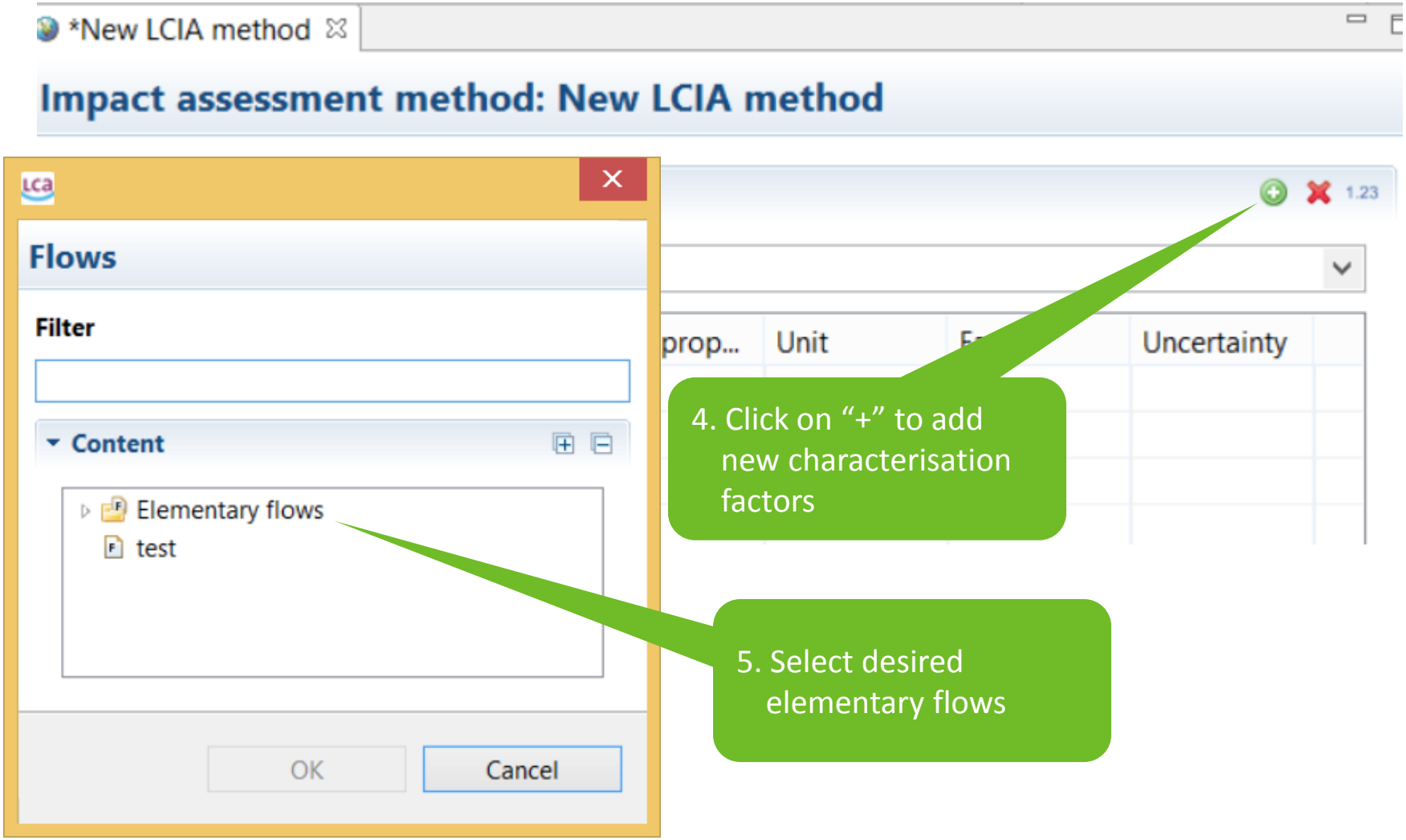




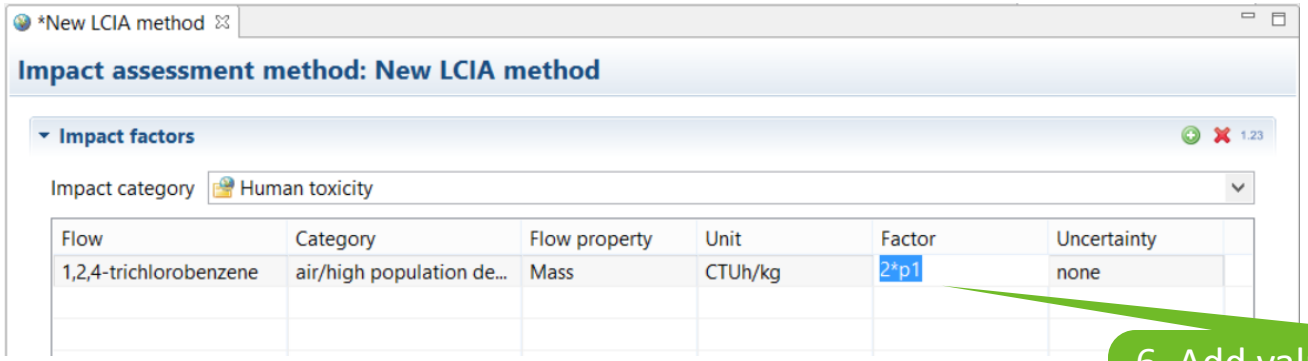
Impact assessment methods: Creation (II)



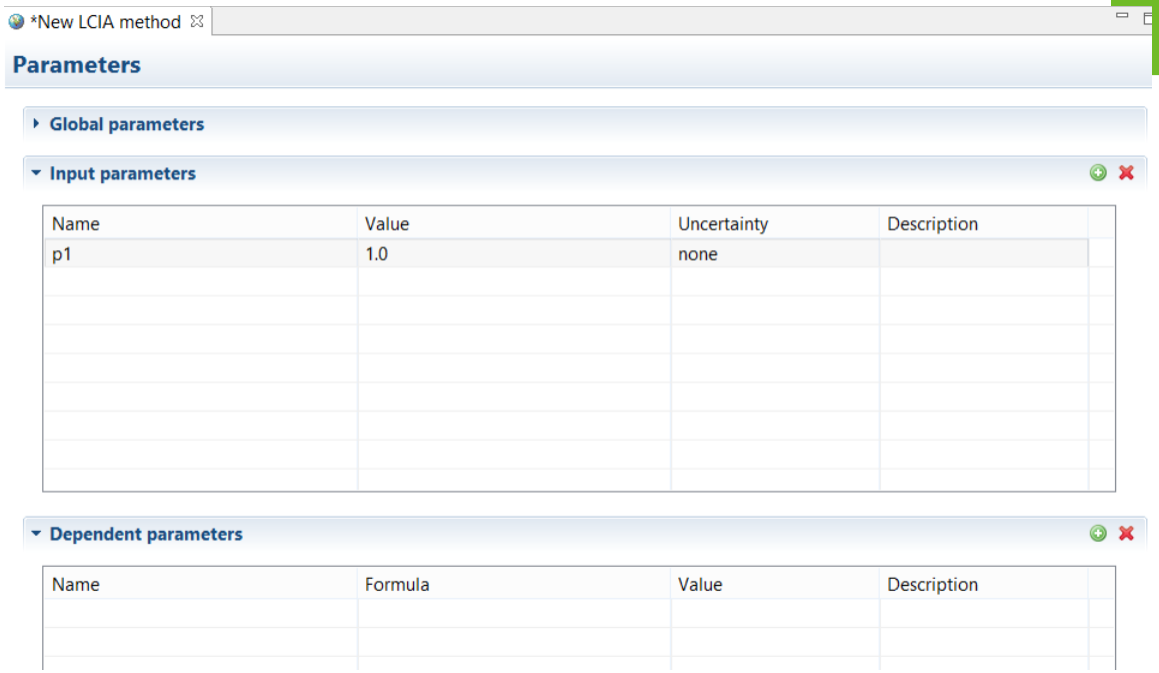
Impact assessment methods: Creation (III)



Impact assessment methods: Creation (IV)

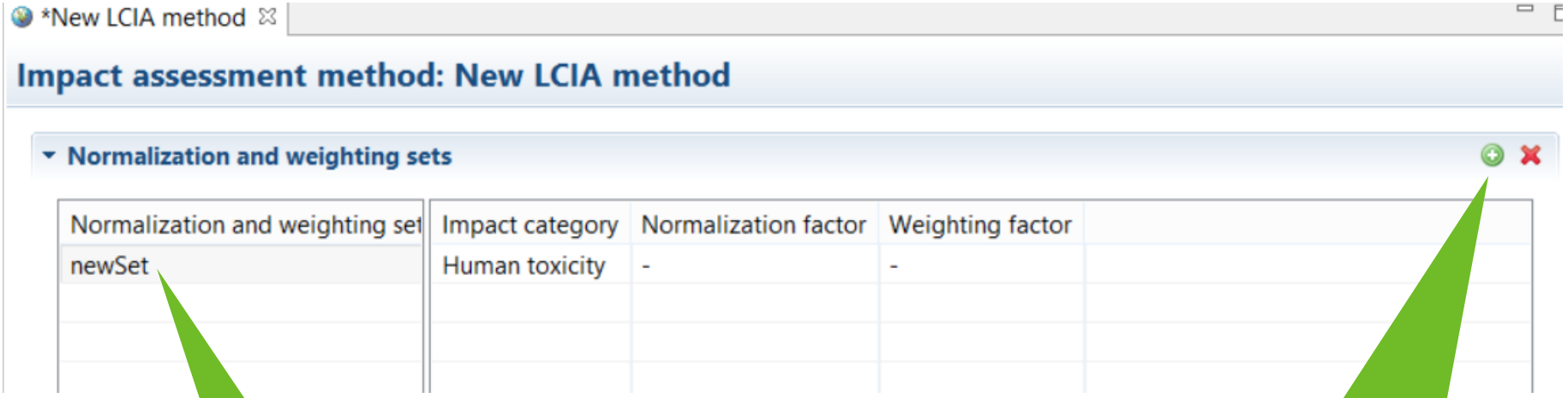


6. Add value for the factor (parameters can be used as in processes!)



GreenDelta

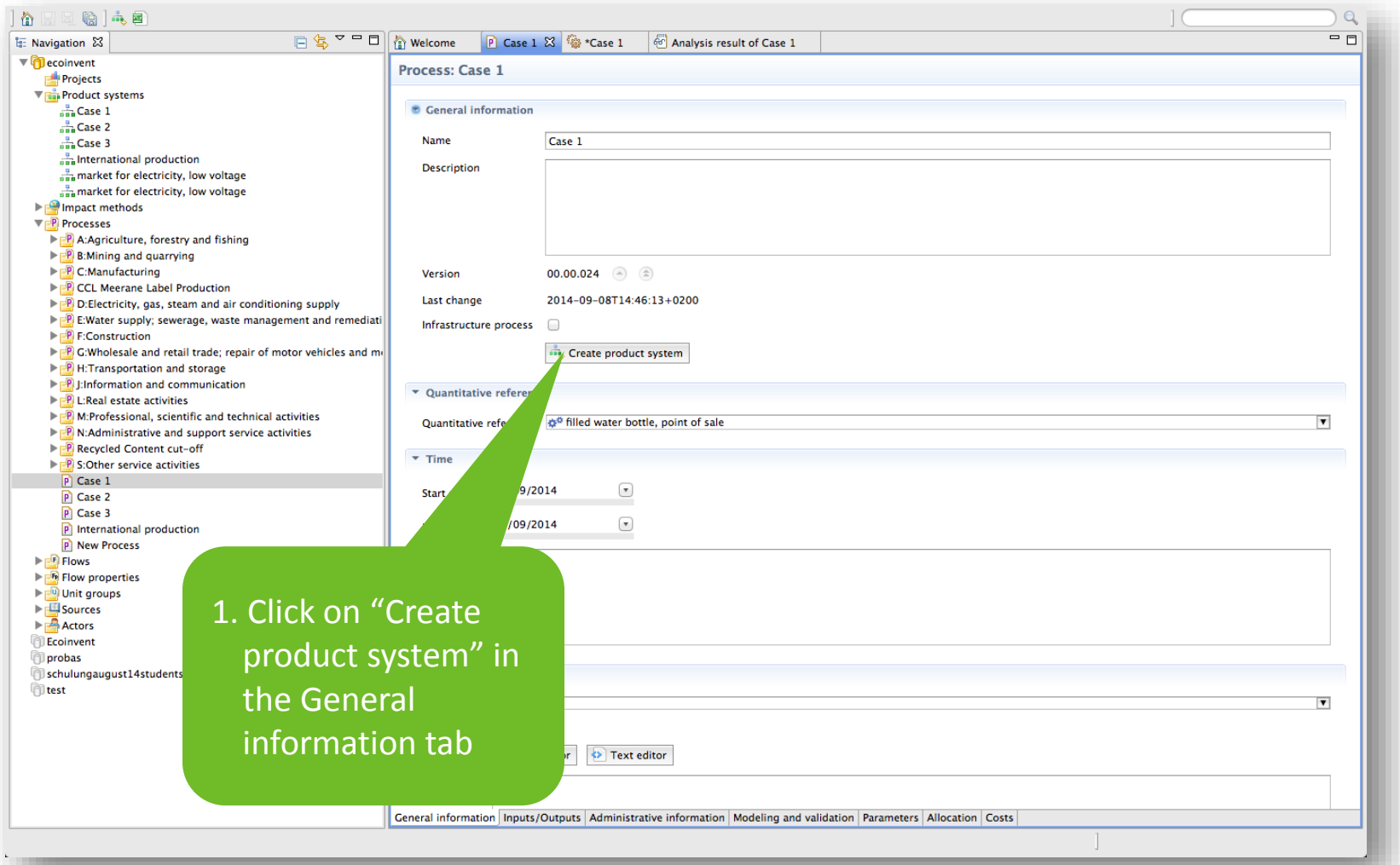
Impact assessment methods: Creation (V)



7. Click “+” to add new normalization/weighting set

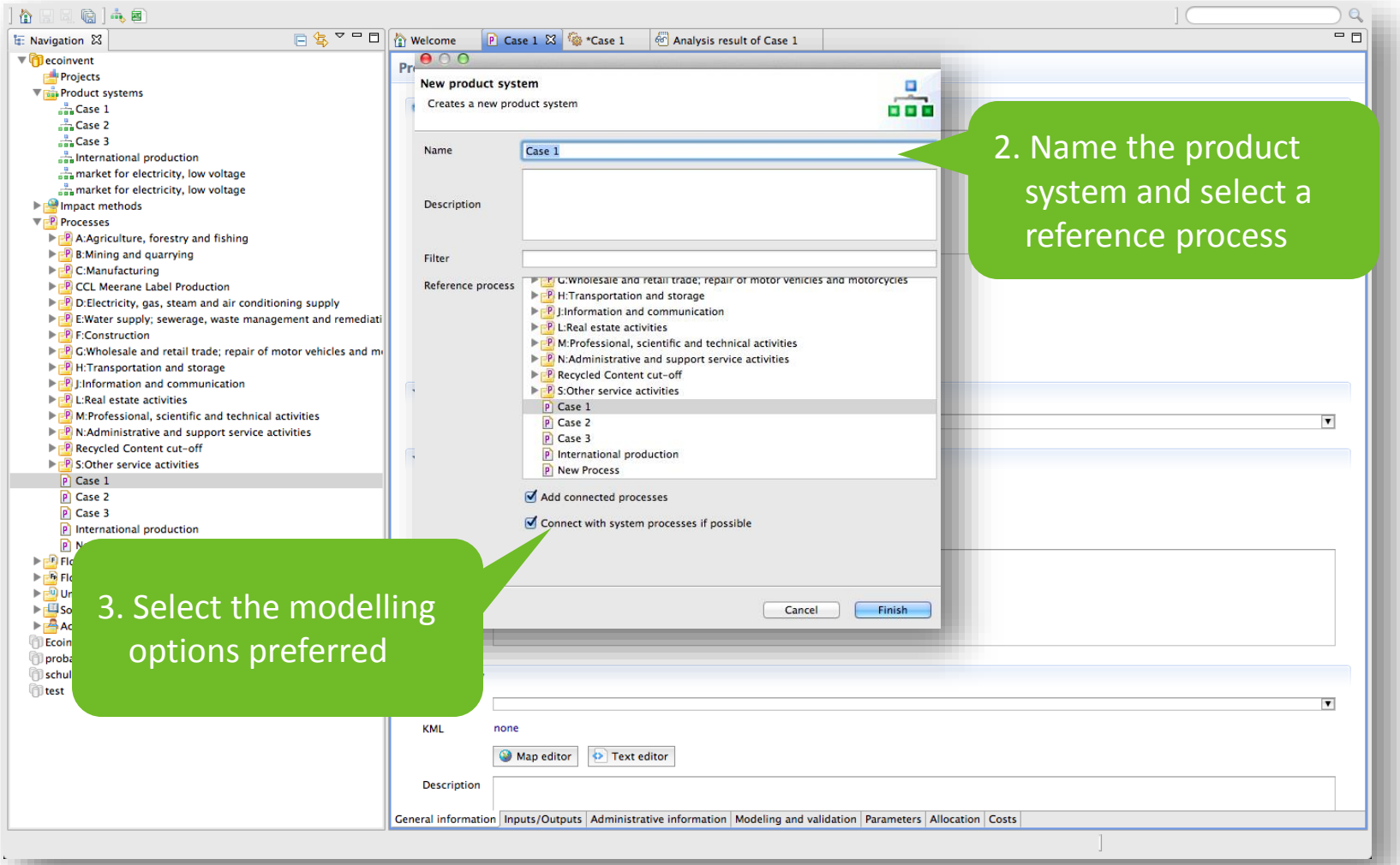
8. Click on the set name to automatically add the impact categories of the method

Product system: Creation (I)

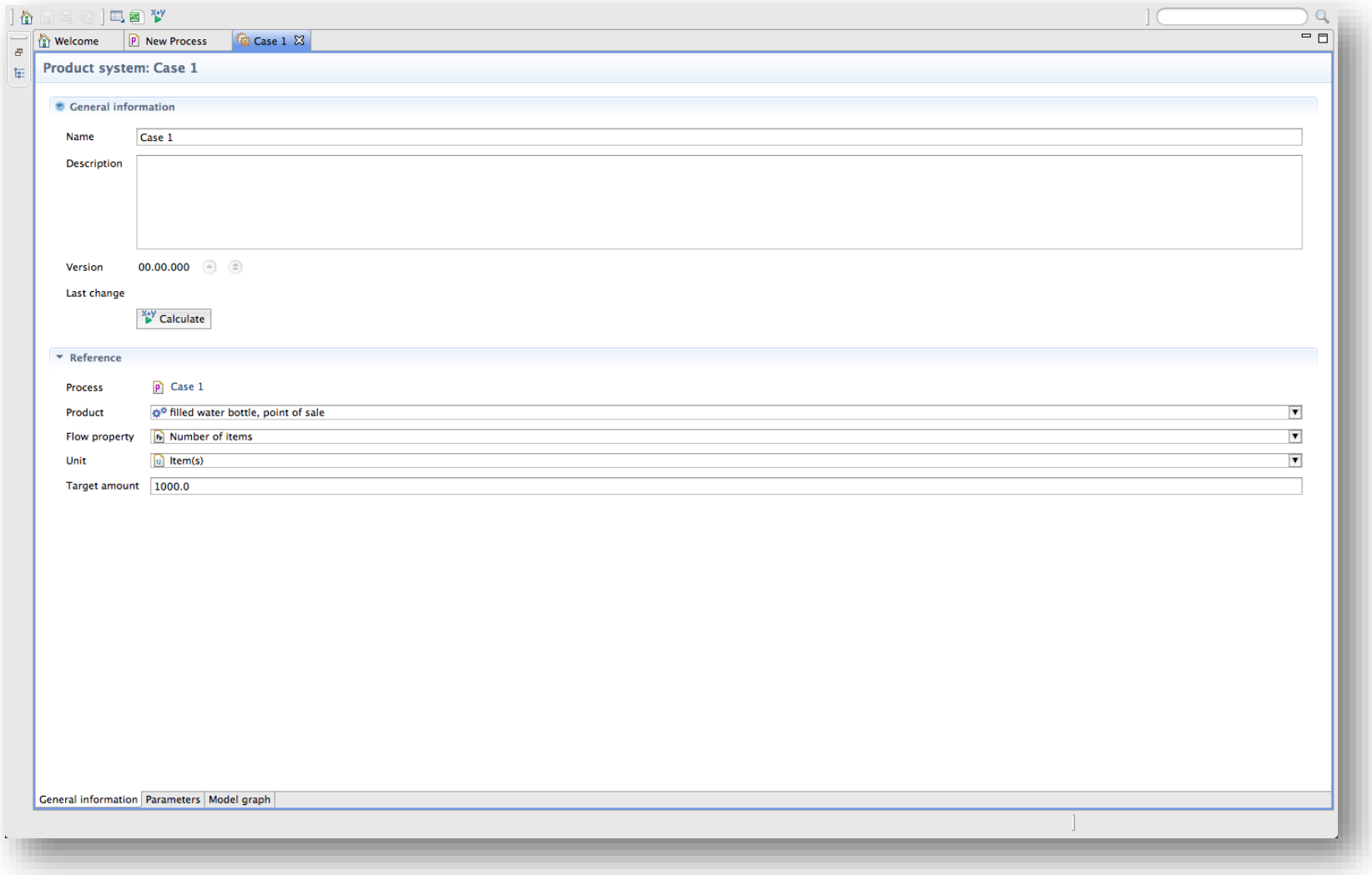


GreenDeLTa

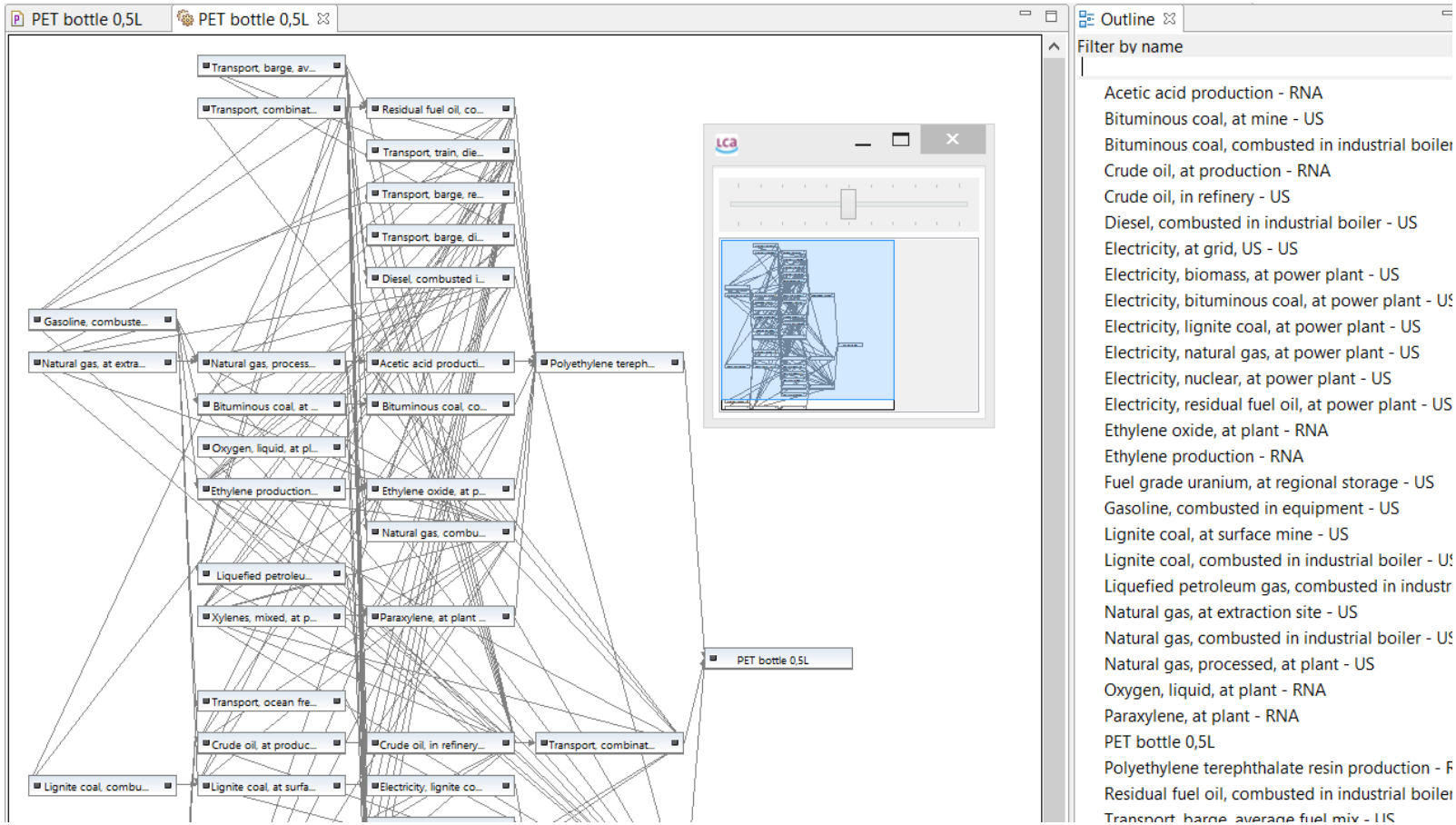
Product system: Creation (II)



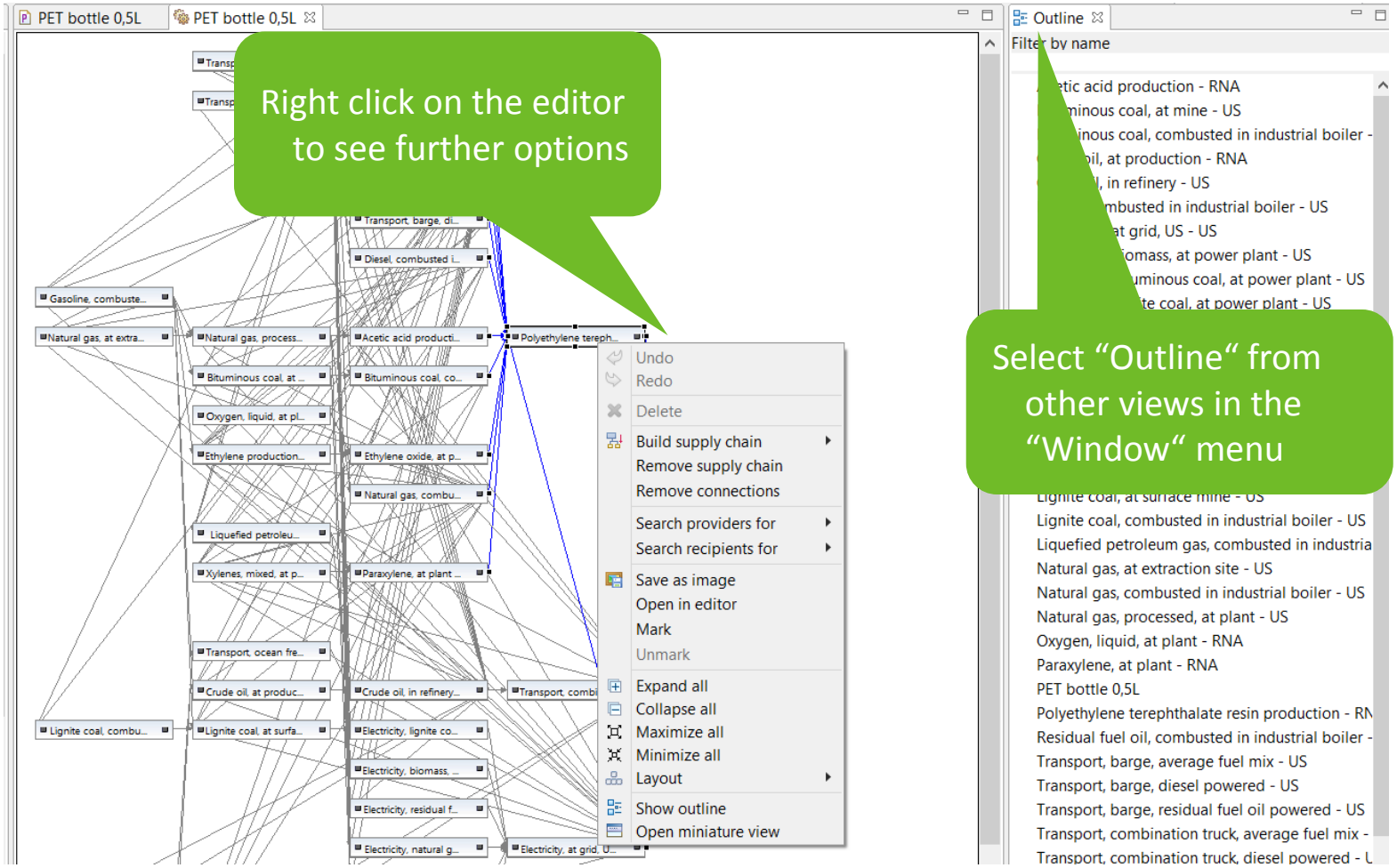
Product system: General information



Product system: Model graph (I)

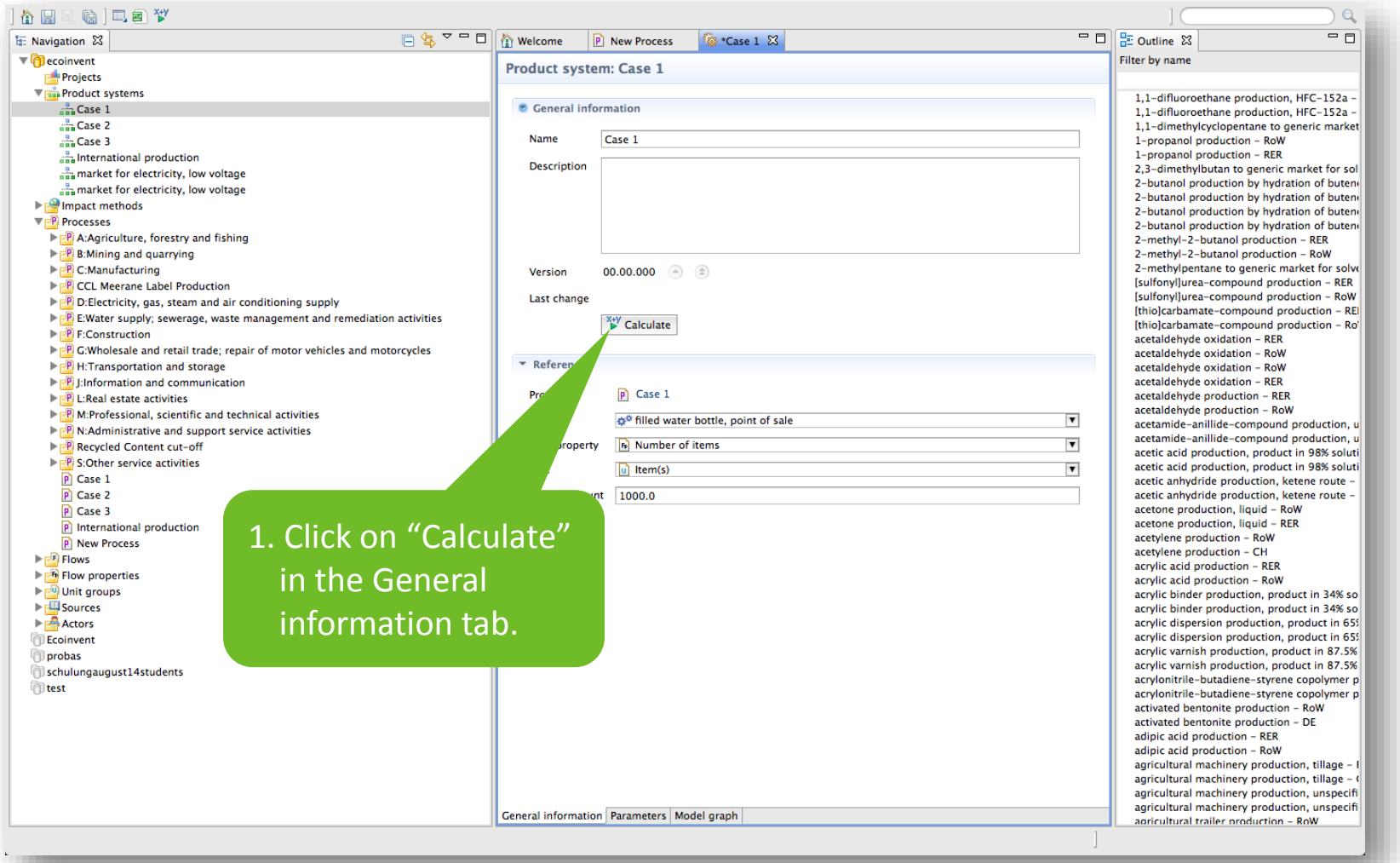


Product system: Model graph (II)



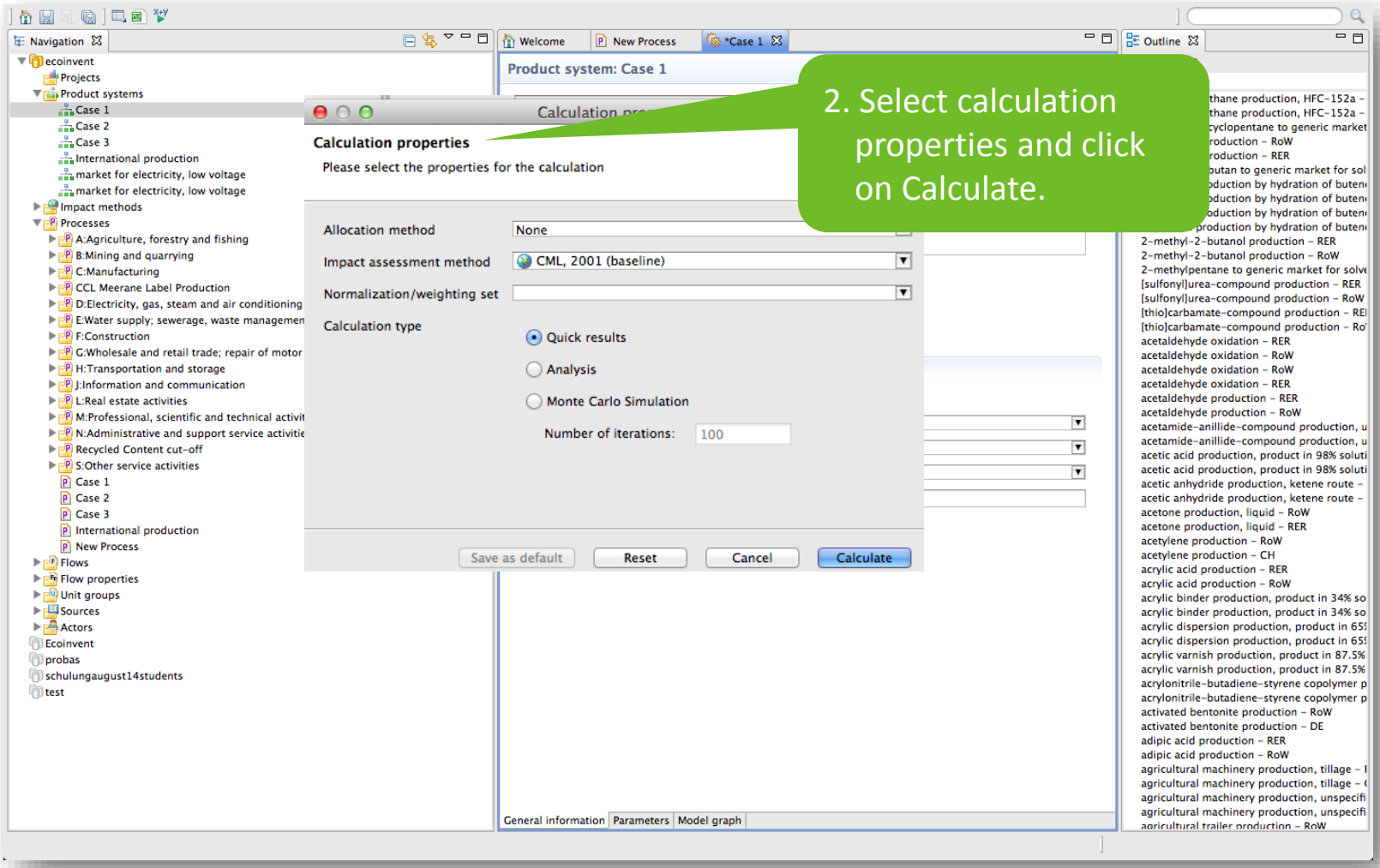
GreenDelta

Product system: Calculation (I)



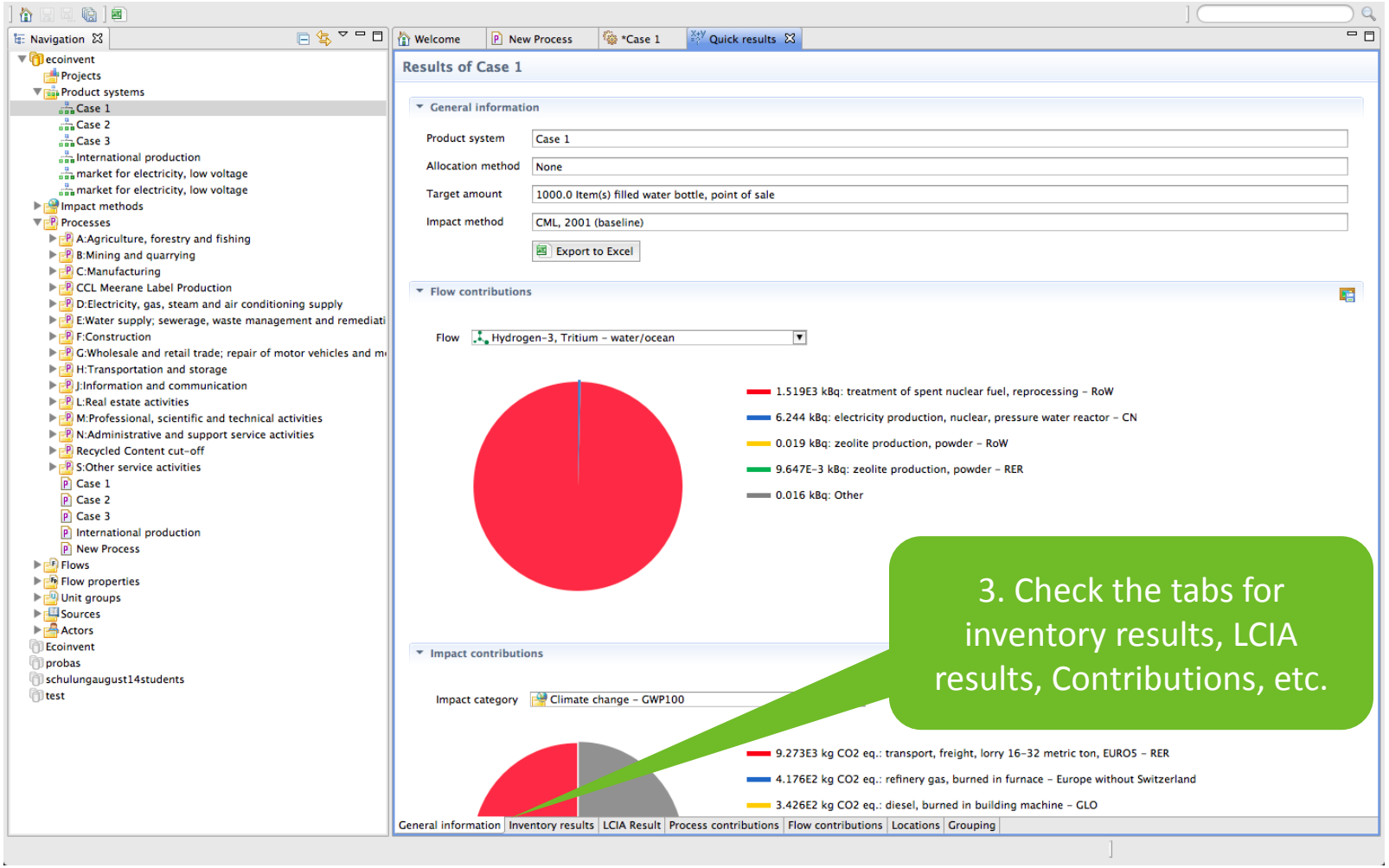
GreenDeLTa

Product system: Calculation (II)

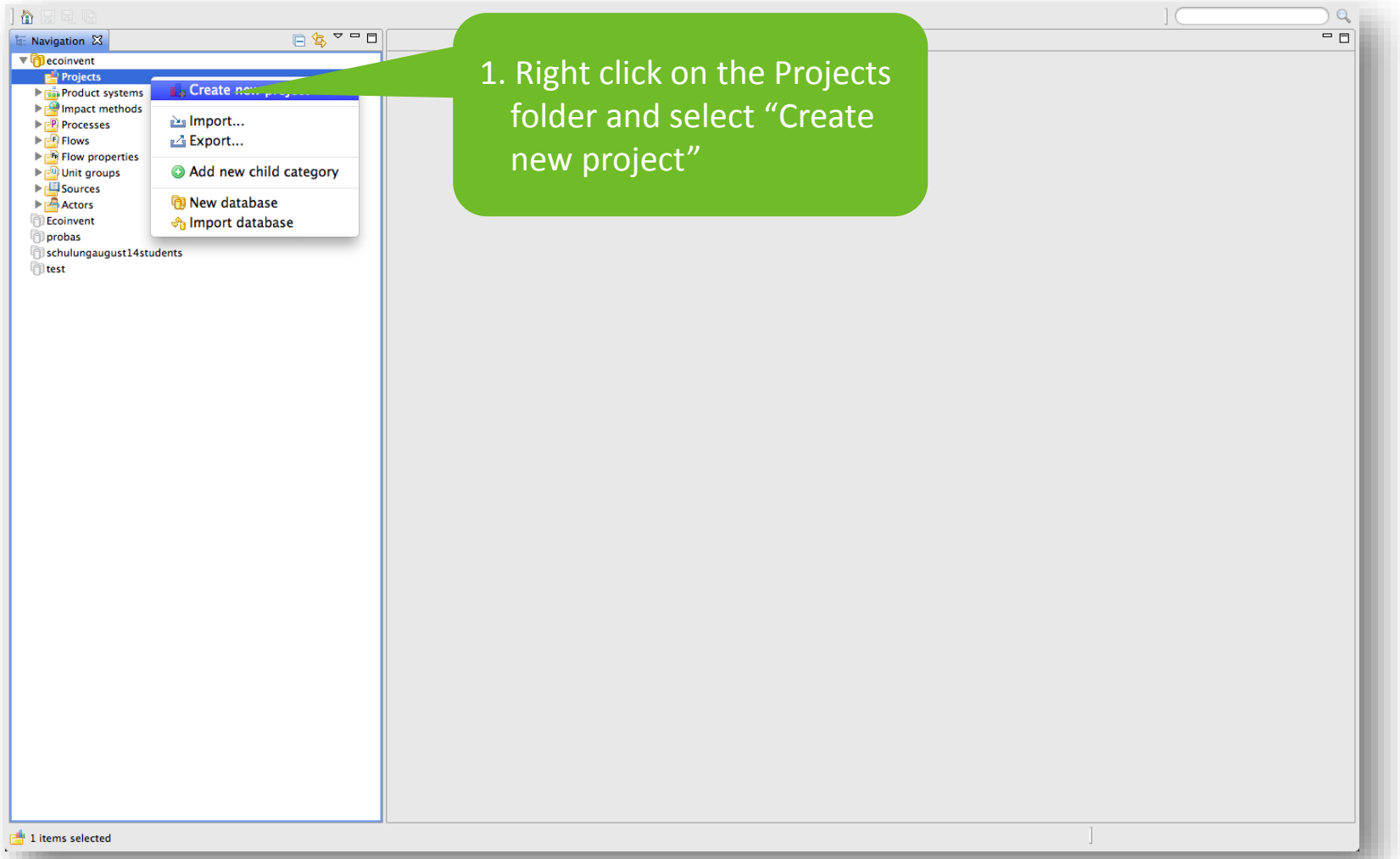


GreenDeLTa

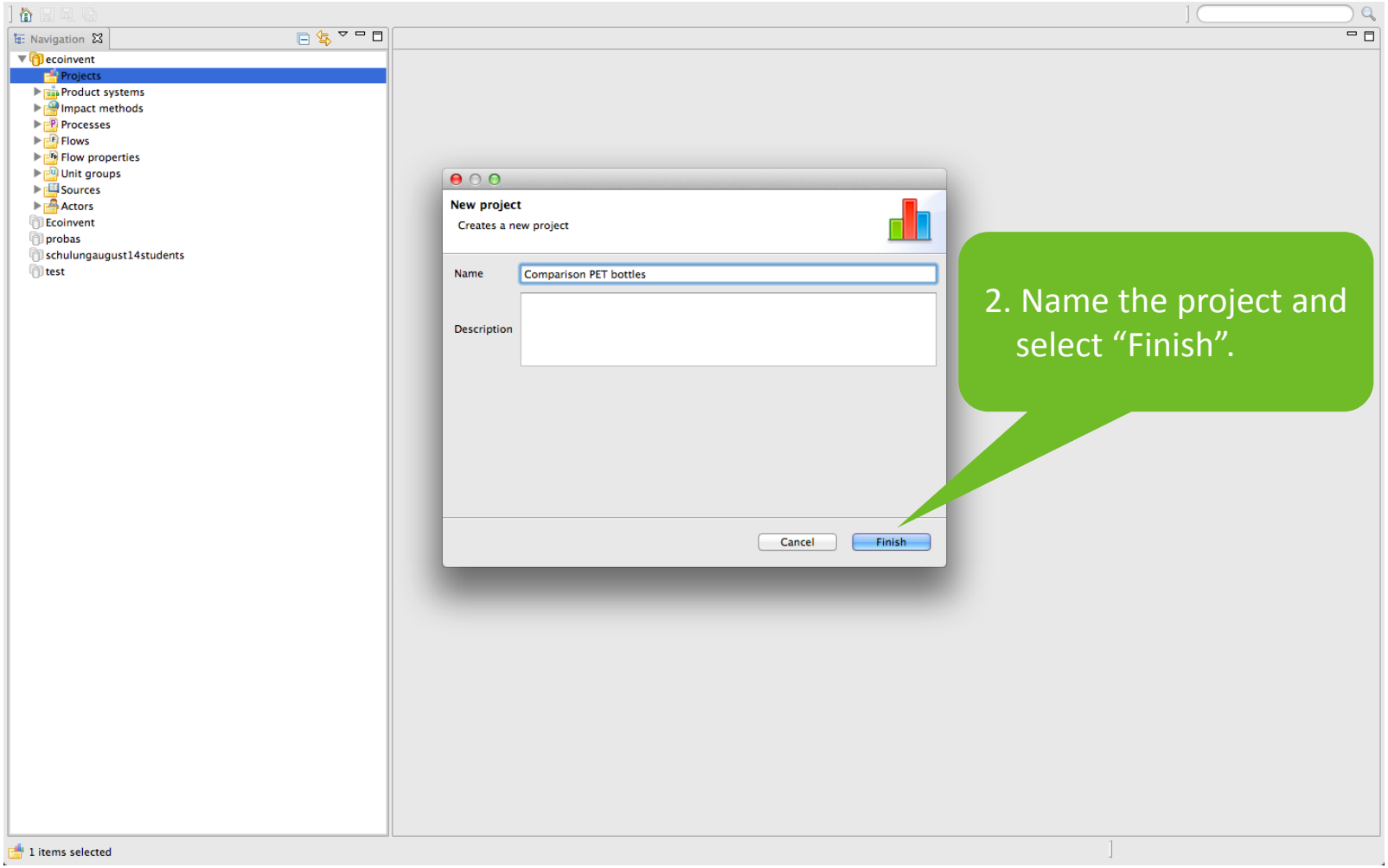
Product system: Calculation (III)



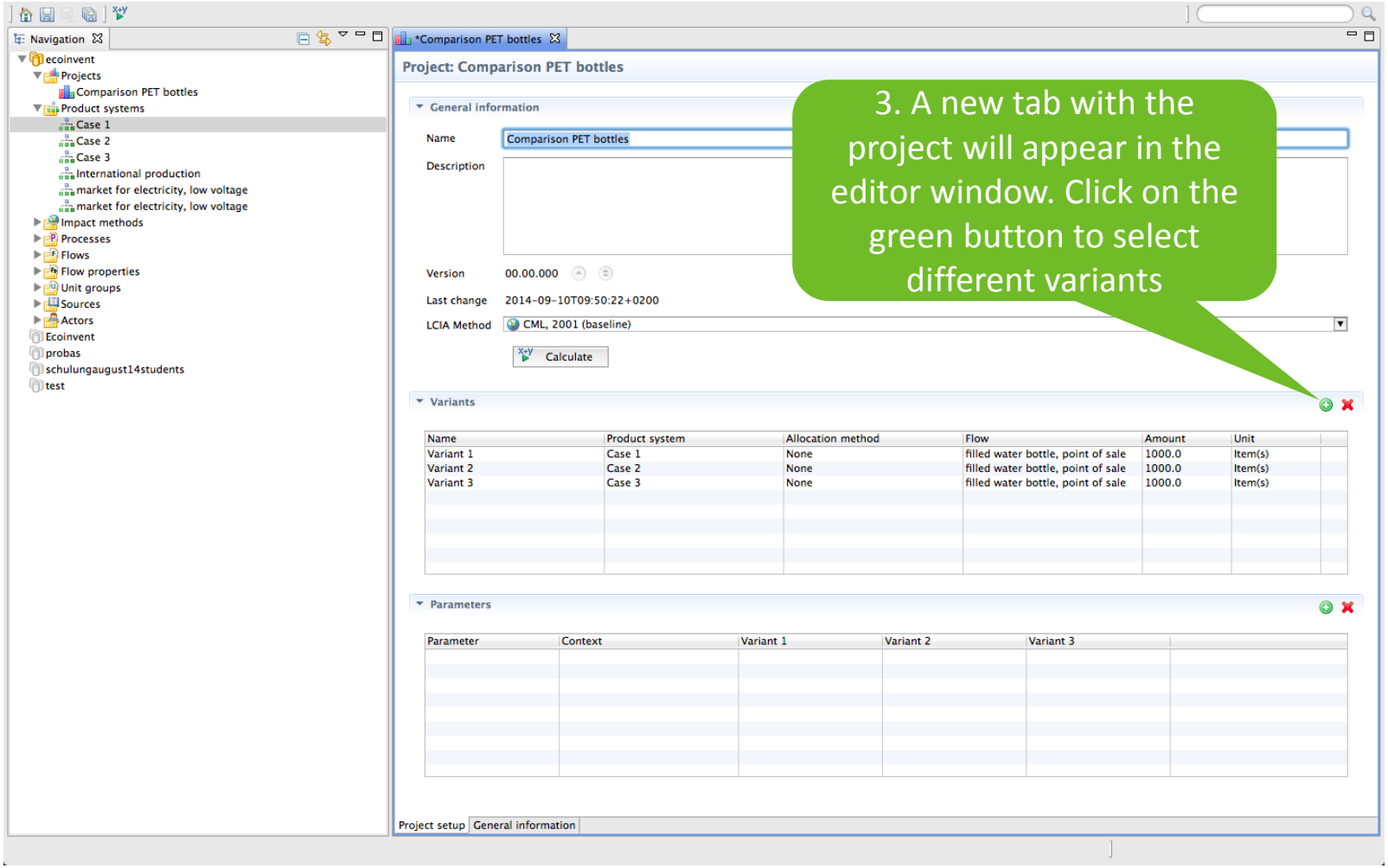
Project: Creation (I)



Project: Creation (II)

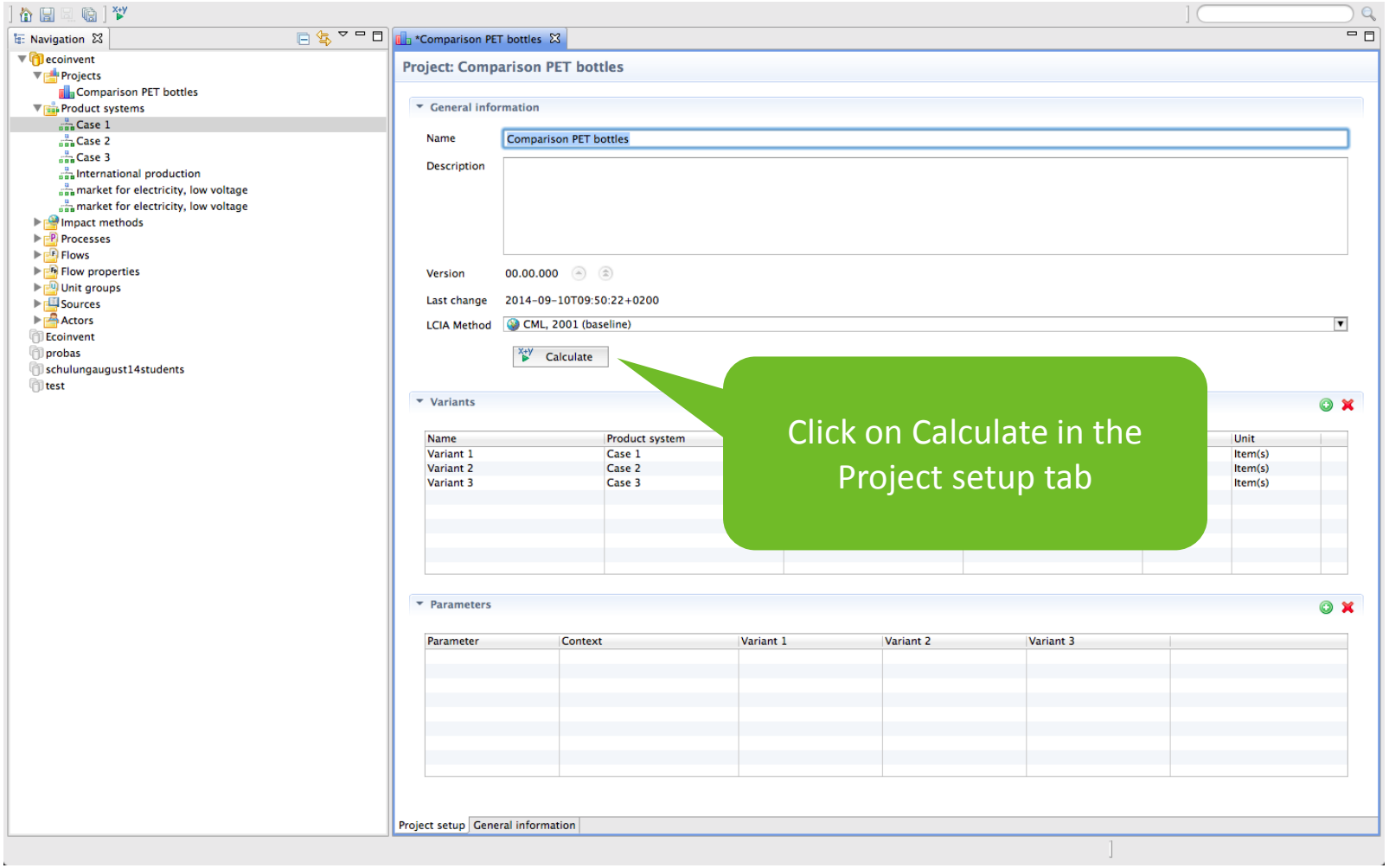


Project: Creation (III)



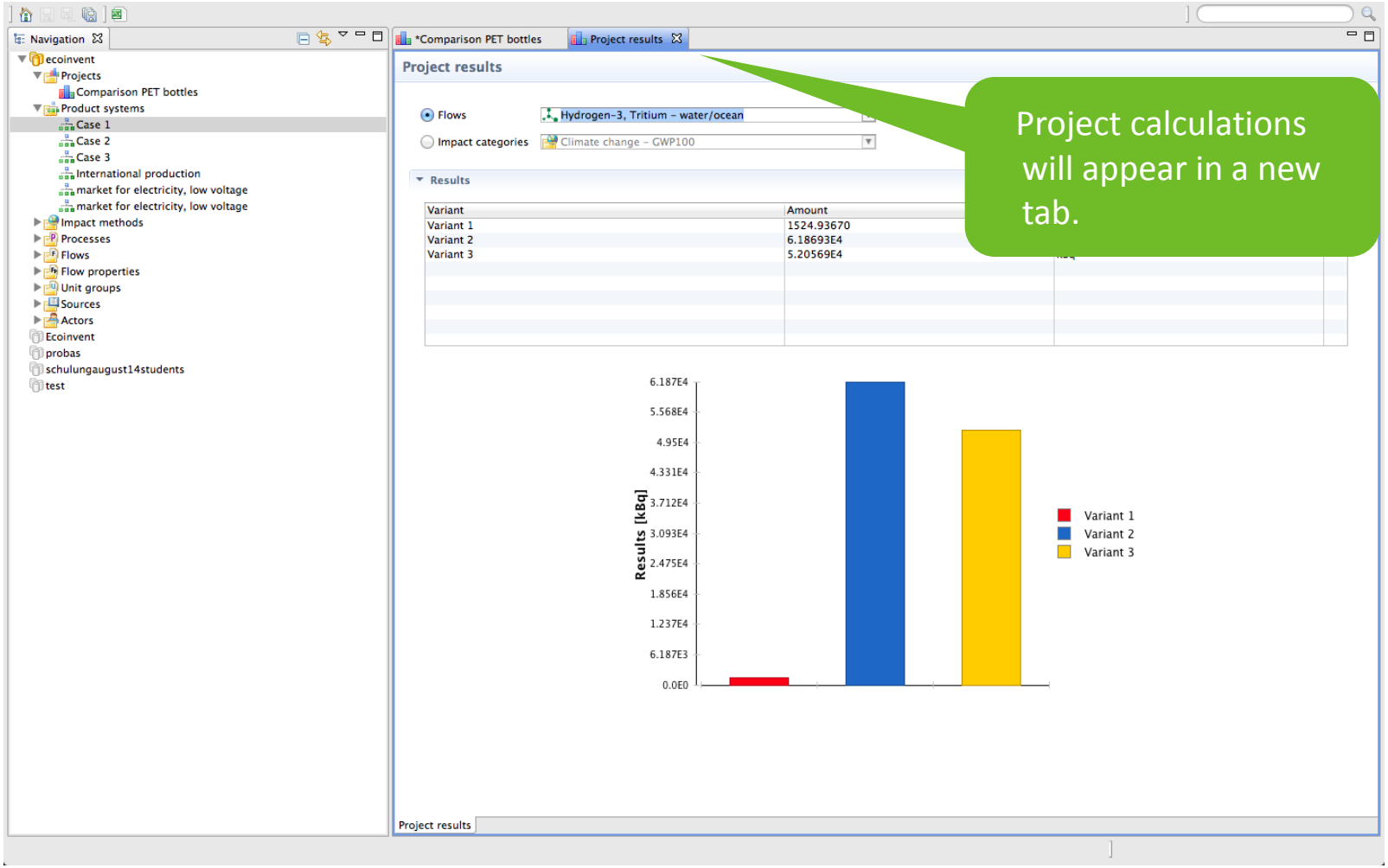
GreenDelta

Project: Calculation (I)



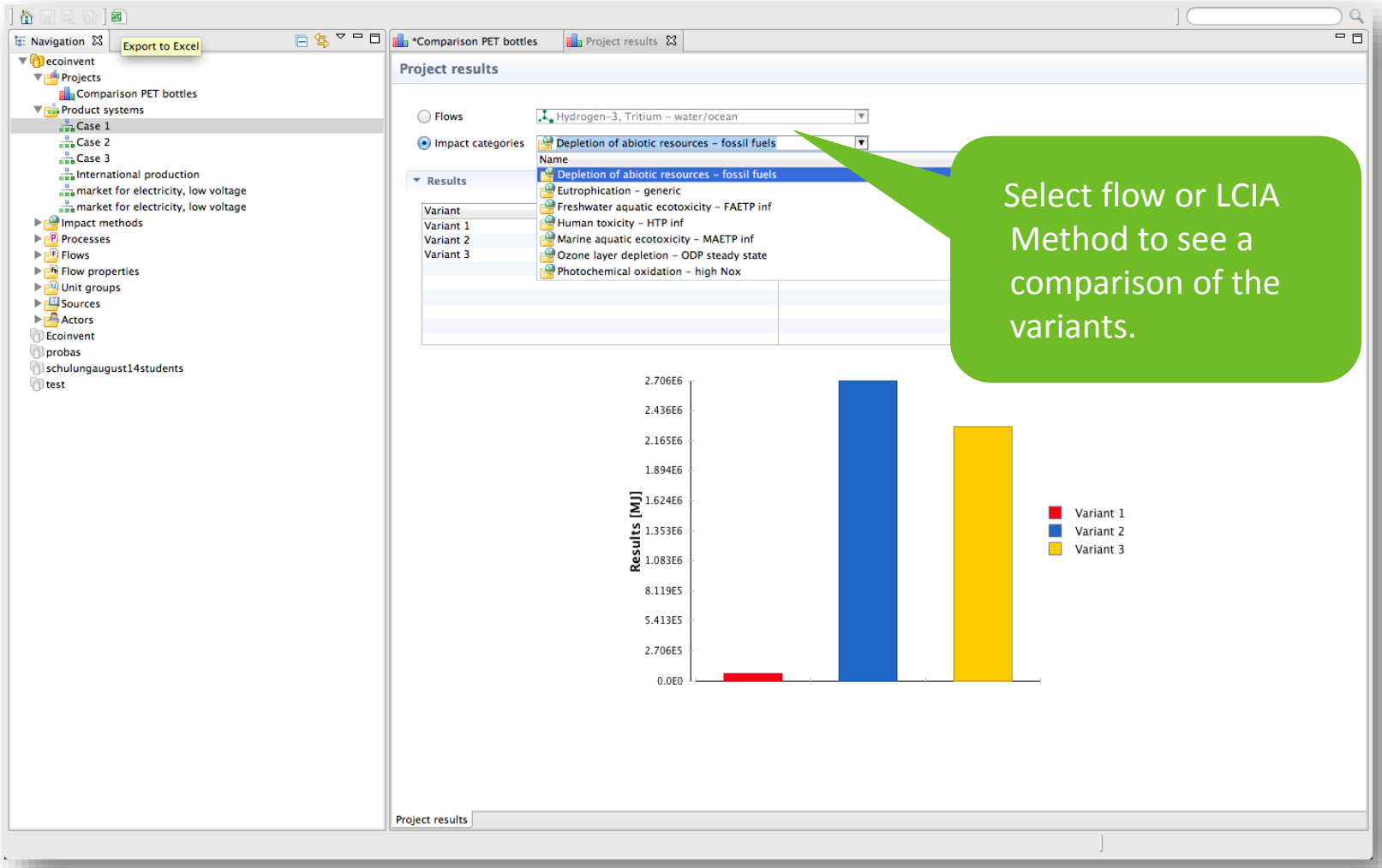
GreenDelta

Project: Calculation (II)



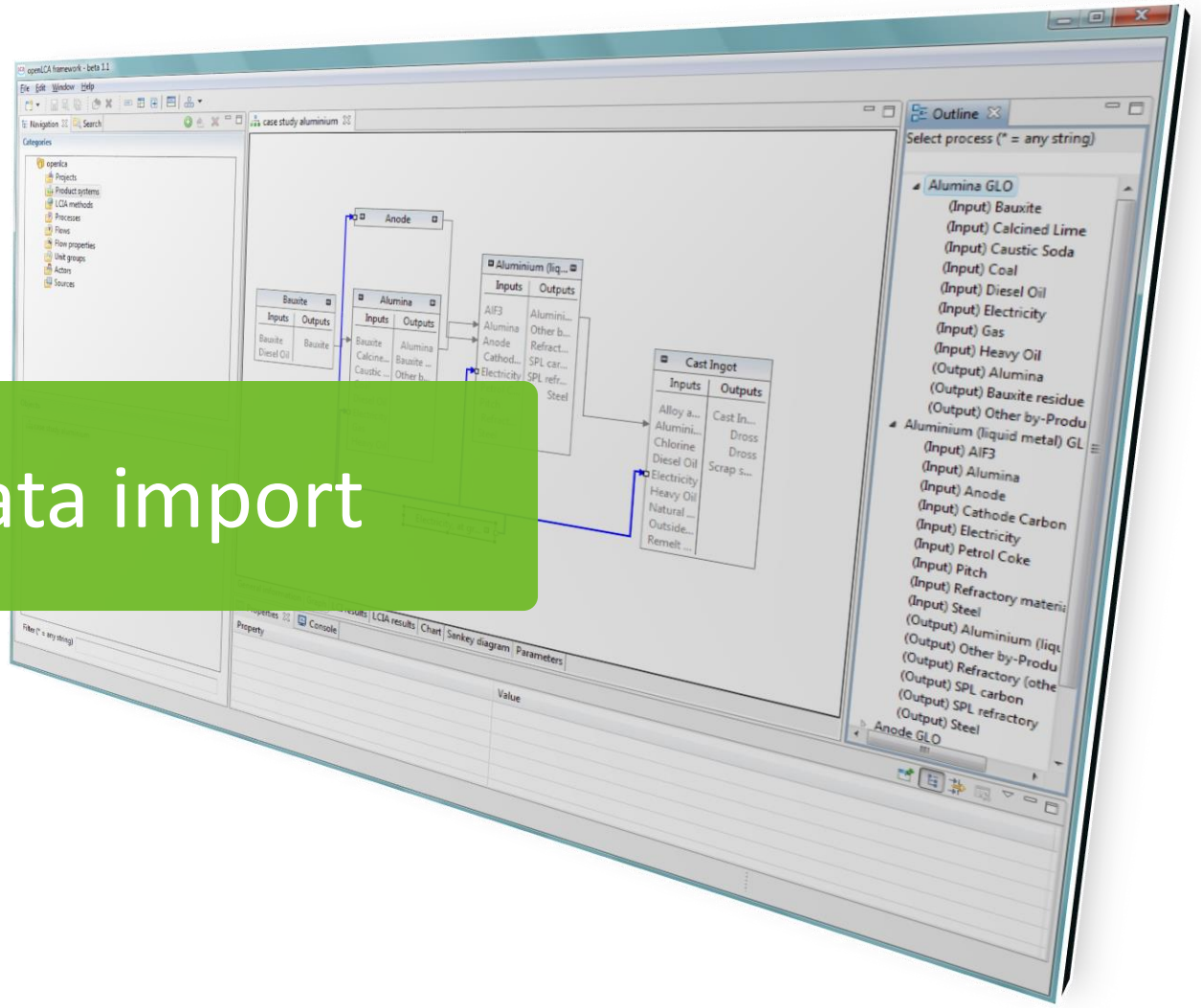
GreenDelta

Project: Calculation (III)



GreenDelta

LCA data import

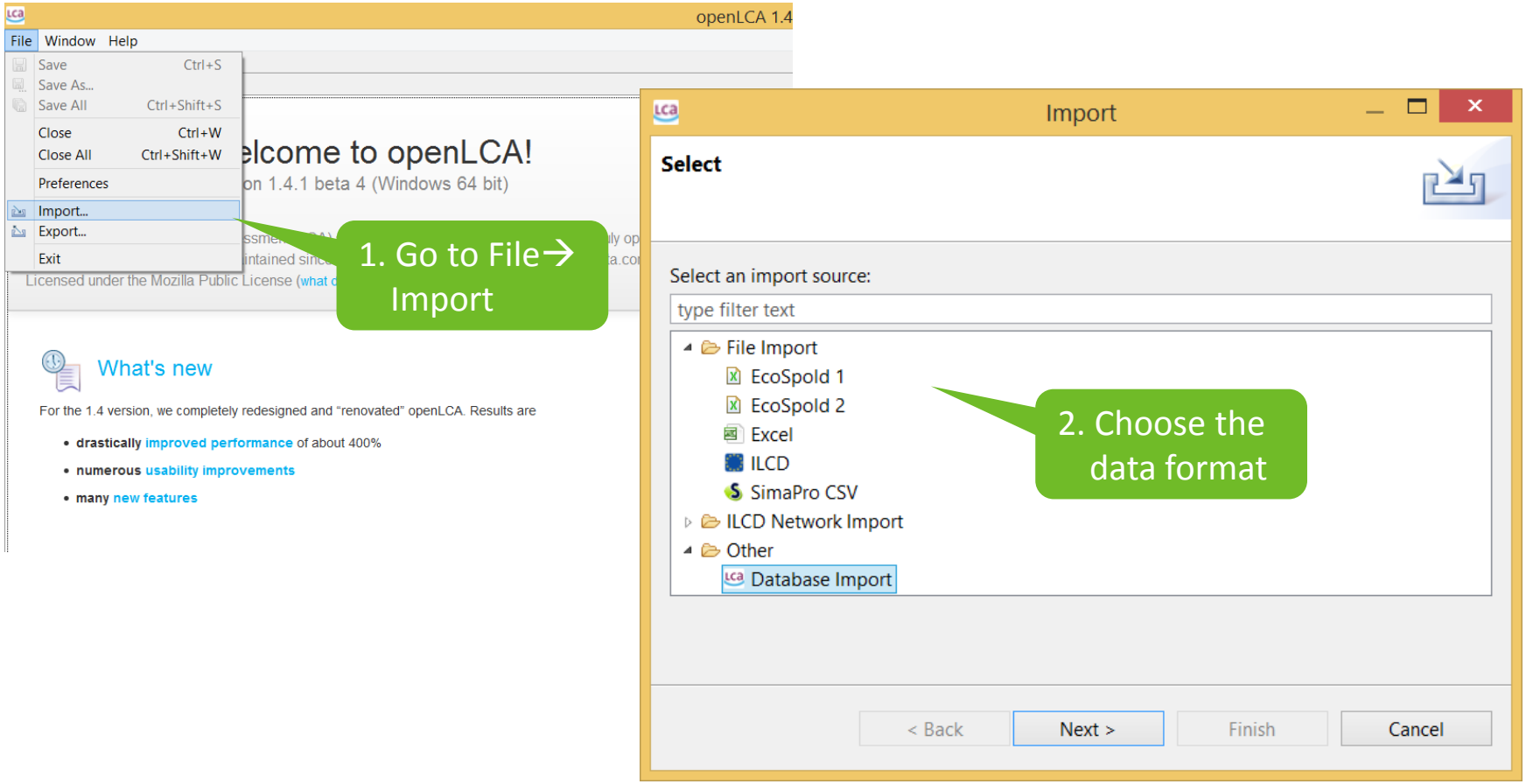


GreenDeLTa

Data management in openLCA

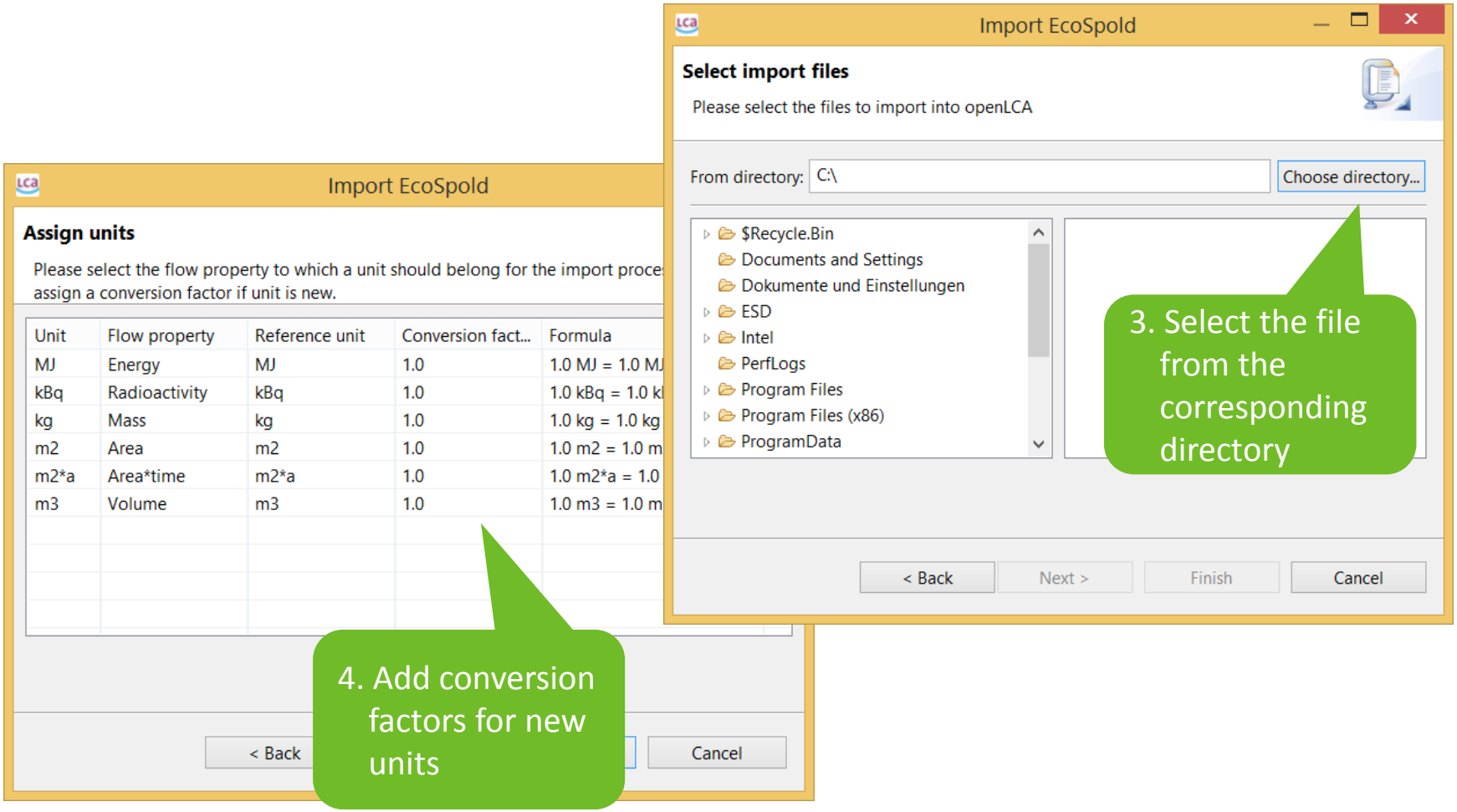
- New databases in openLCA are empty at first (with the exception of reference data), but data can be imported easily
- Supported Import und Export formats:
  - EcoSpold1
  - ILCD
  - EcoSpold2
  - Excel
  - SimaPro CSV
  - zolca
- It is possible to use more than one database; databases are independent of one another and only one database is “active” at a time, all of the others are “deactivated”
- It is possible to save own data; every element of the software can be personalised

Import of data sets (I)



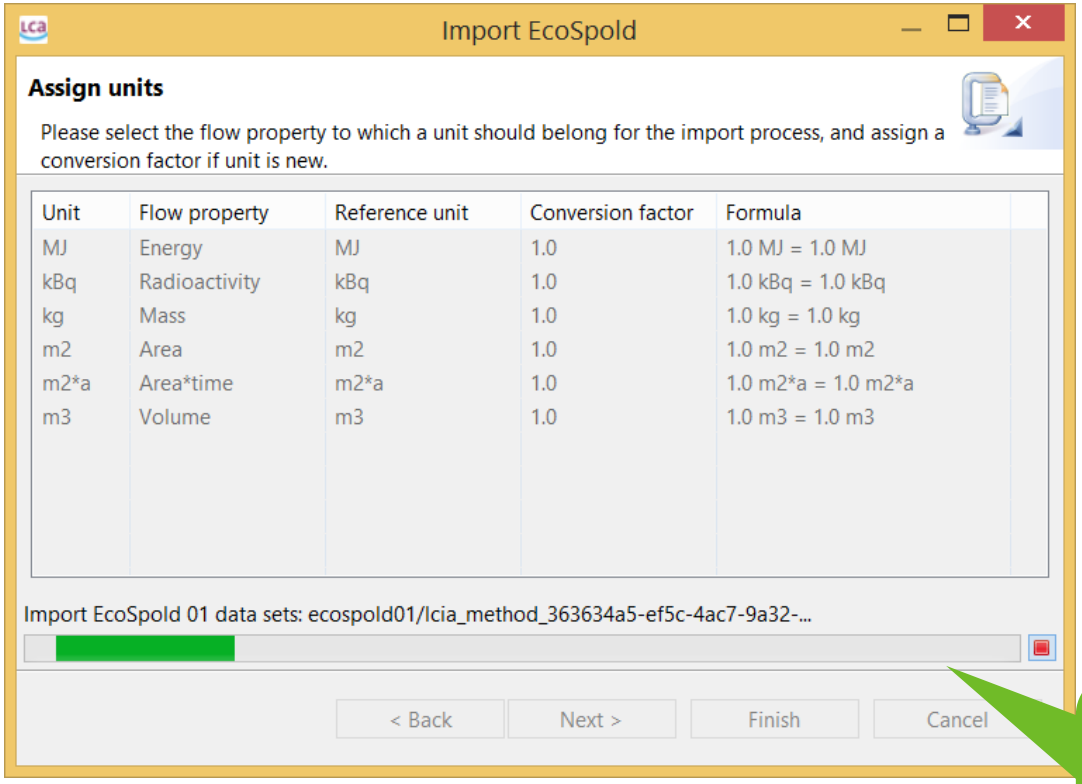
GreenDelta

Import of data sets (II)



GreenDeLTa

Import of data sets (III)

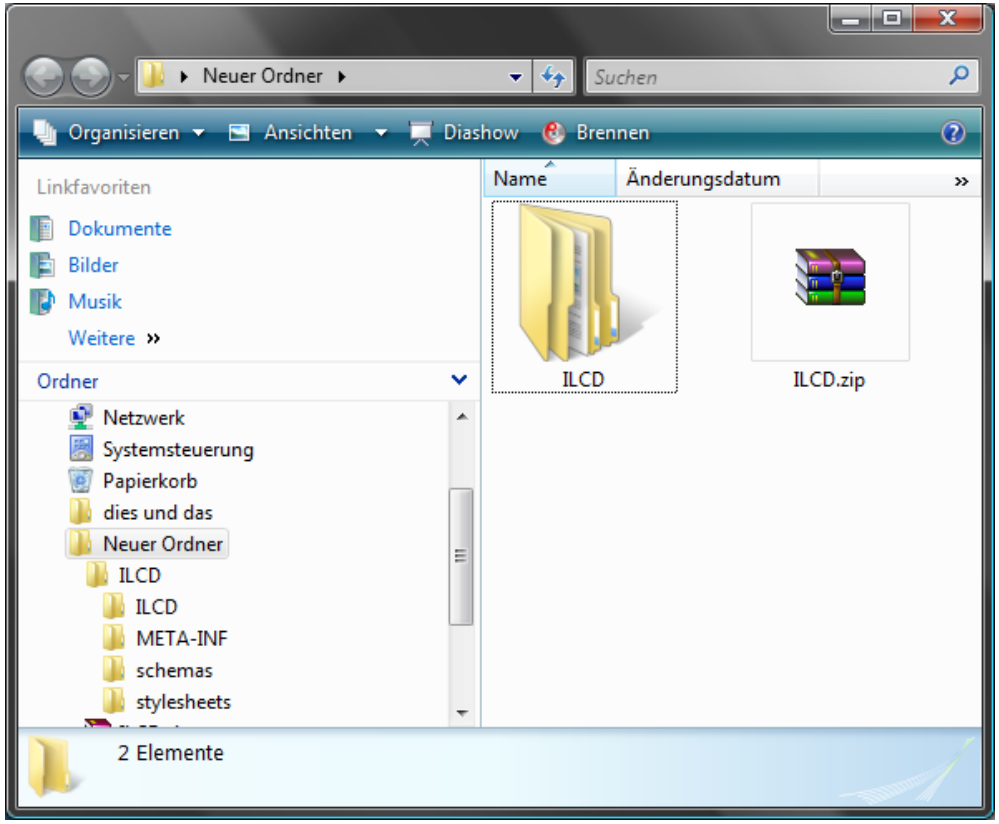


5. Data will be imported in your active database

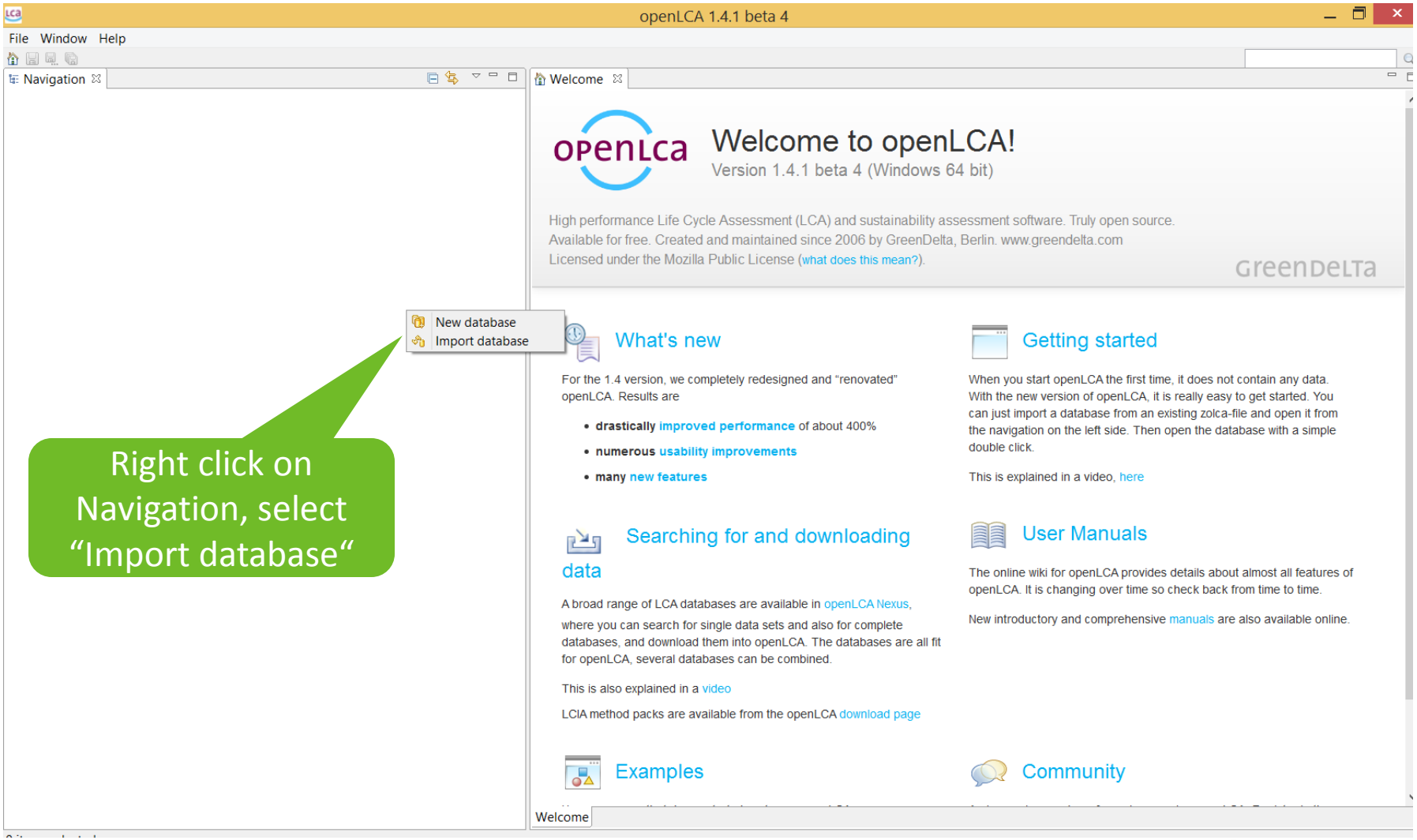
GreenDelta

Import of ILCD

- Data sets in ILCD must be imported as zip file:



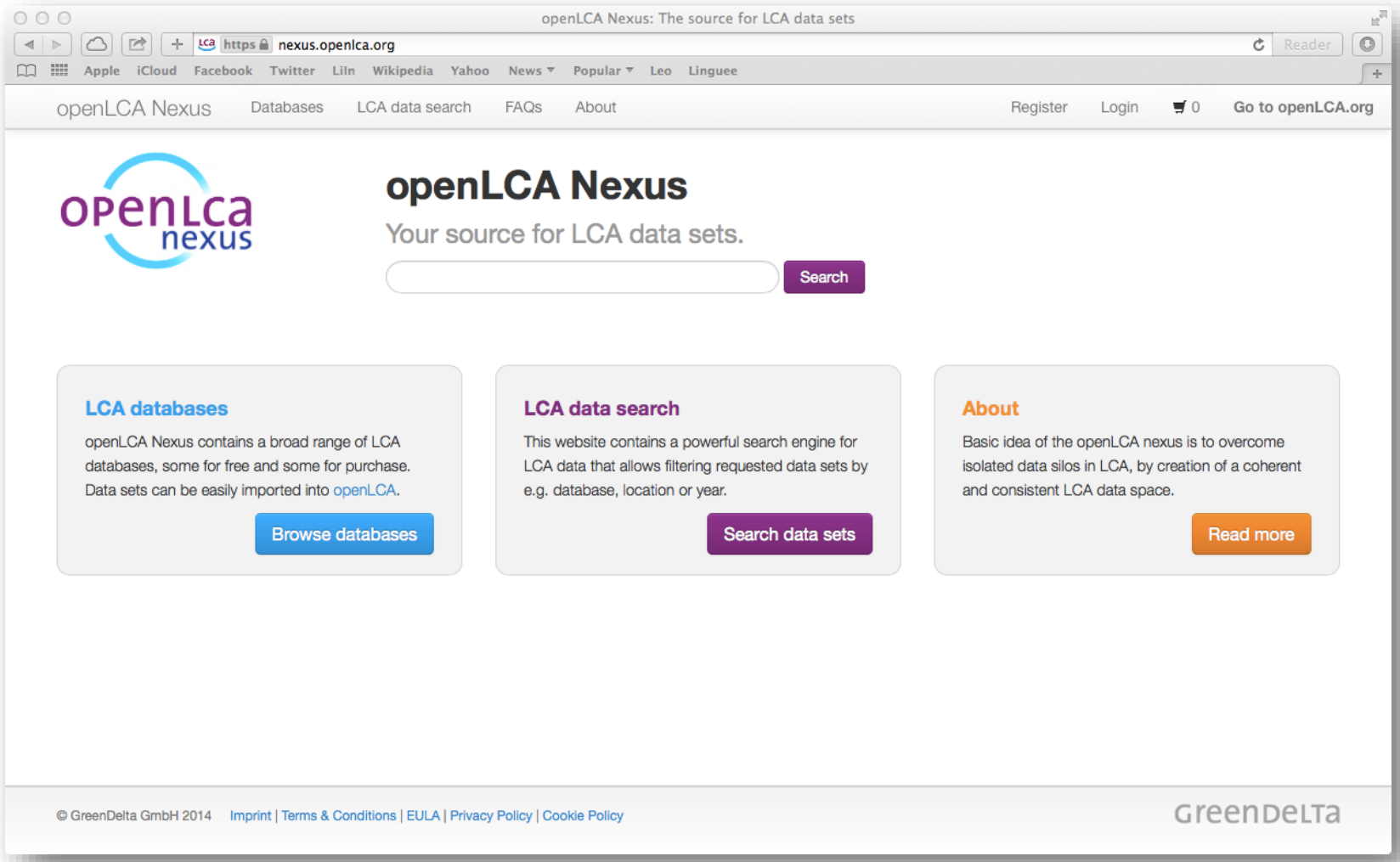
Import of openLCA database



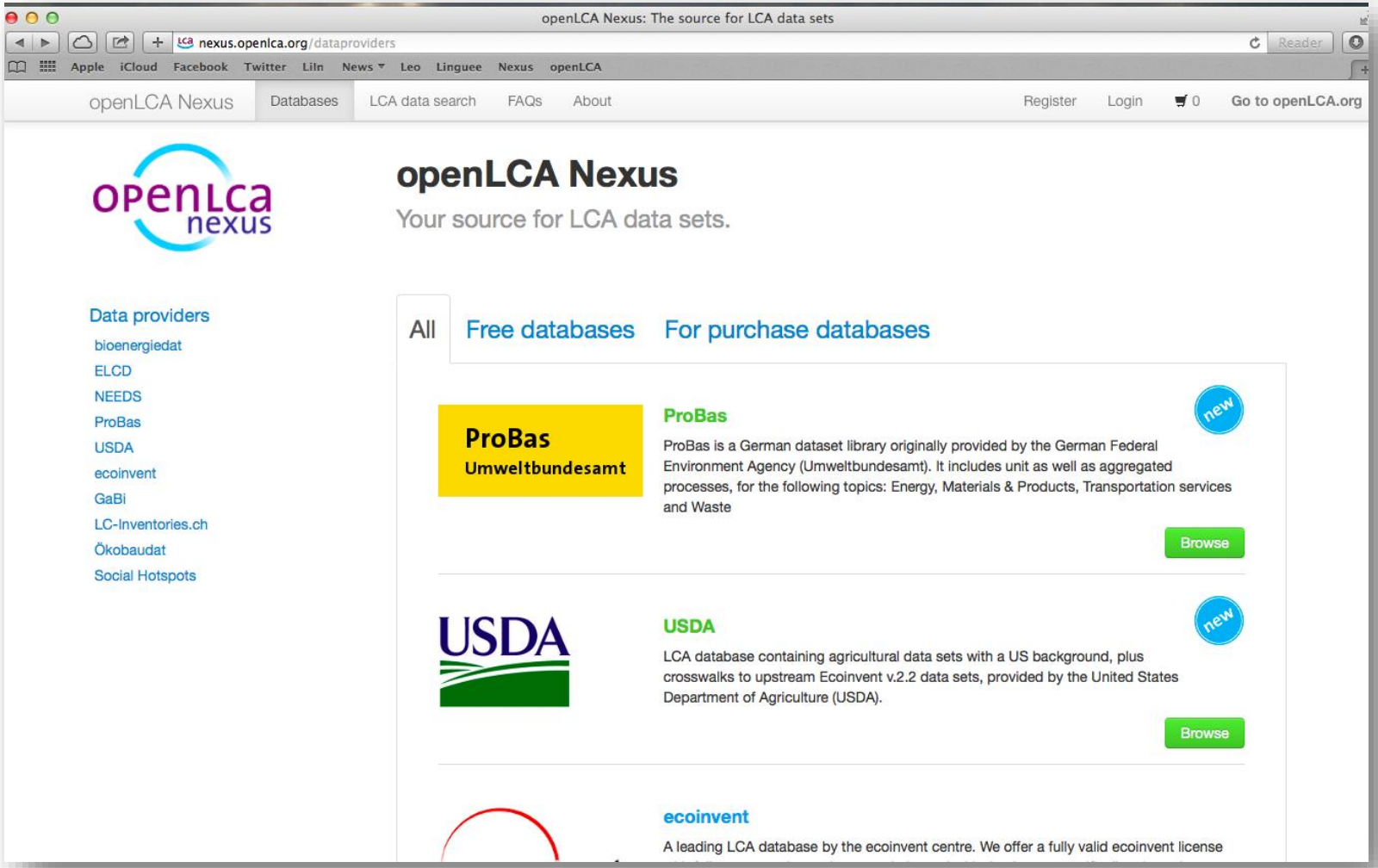
openLCA Nexus

- Search for and download data
- Search for„provider, country, other location, category, price, and start of validity“ oder type search direct into search engine window
- Direct purchase/download of data fur use in openLCA

openLCA Nexus



openLCA Nexus

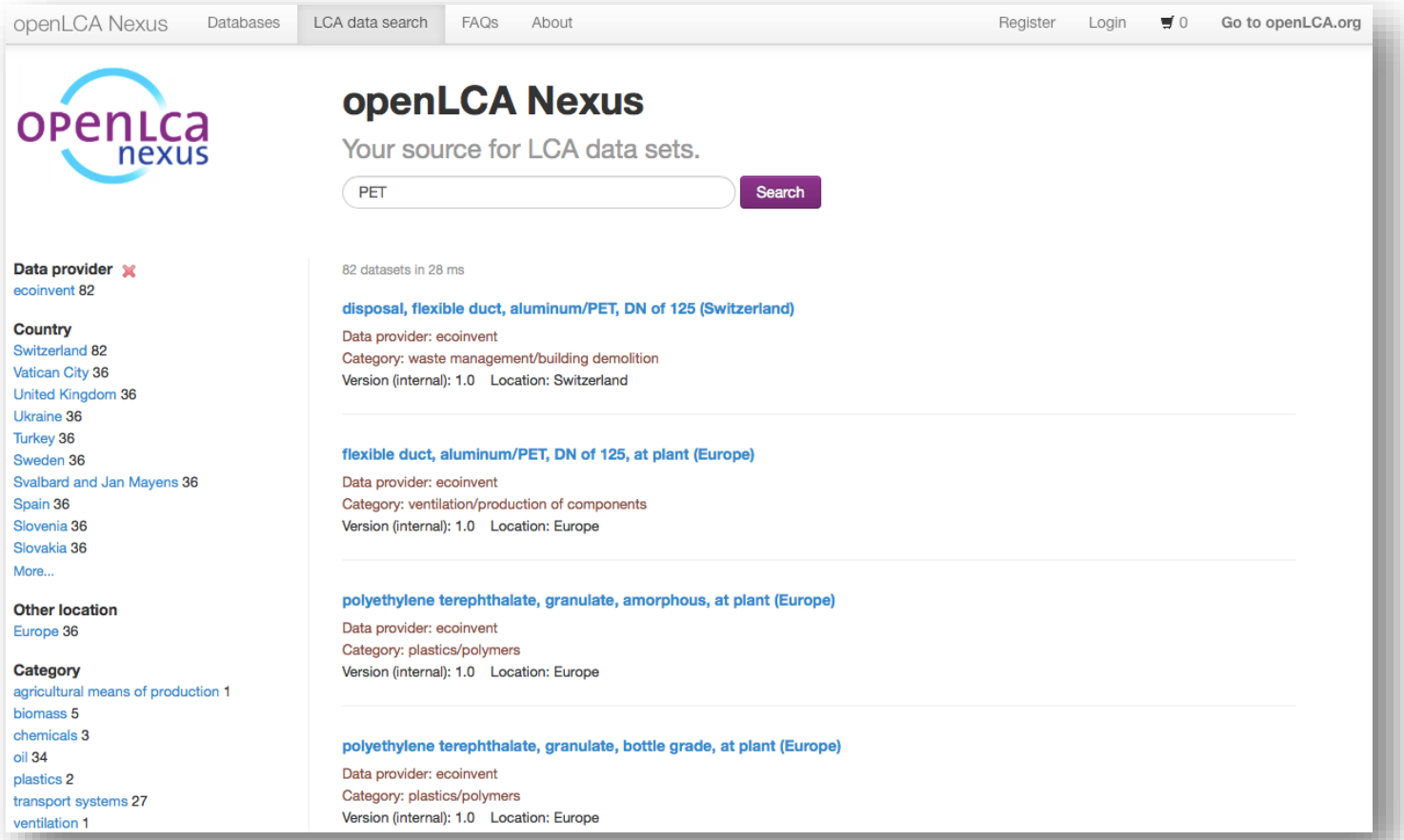


openLCA Nexus

www.LC-Inventories.ch

BIOENERGIEDAT

openLCA Nexus search engine

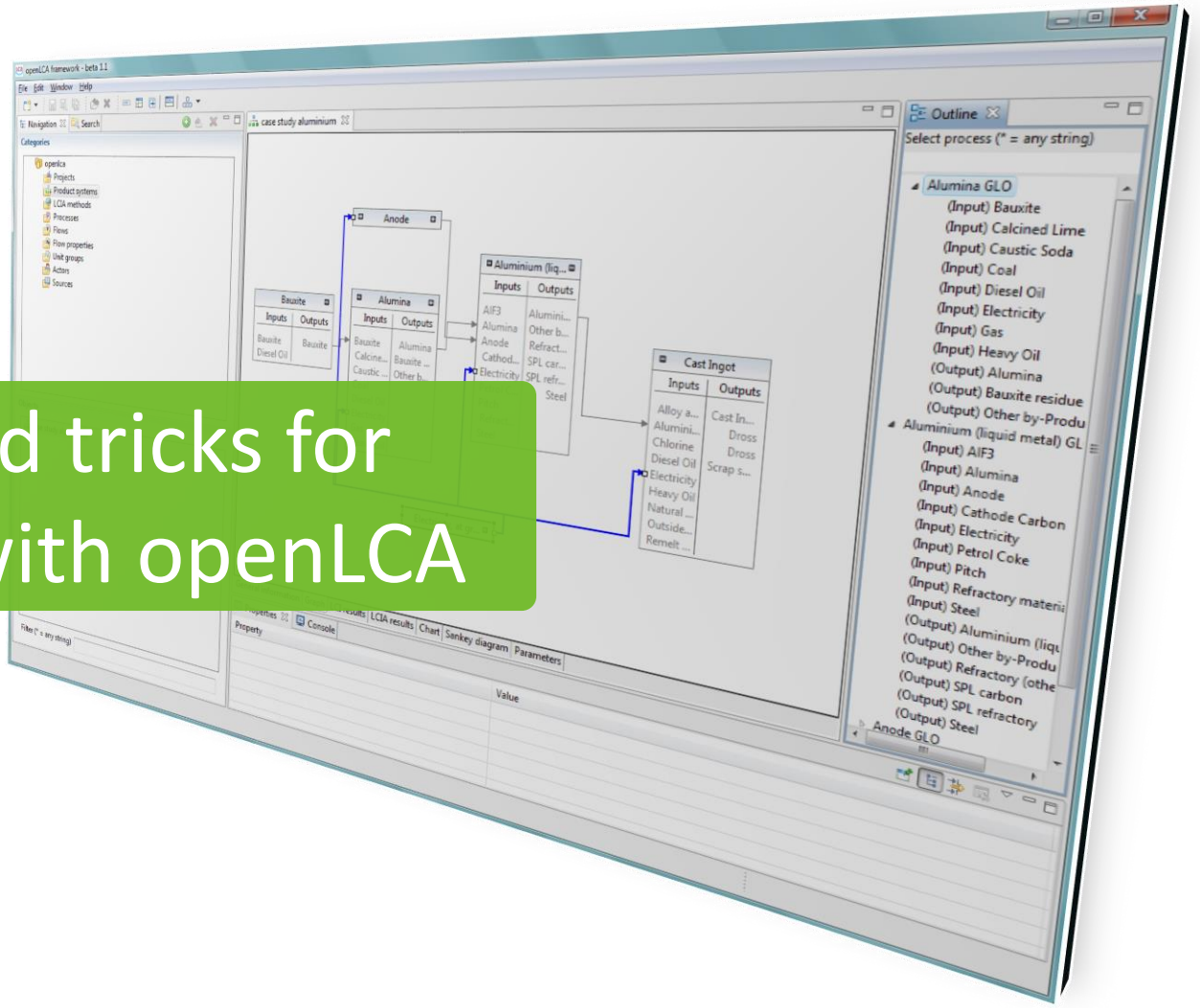


GreenDelta

Exercise 2: import

- Import the openLCA database file “openlca4students.olca” in openLCA.
- Import the file “impact-methods.zip” (EcoSpold1) in the imported database.
- 10 min

Tips and tricks for dealing with openLCA



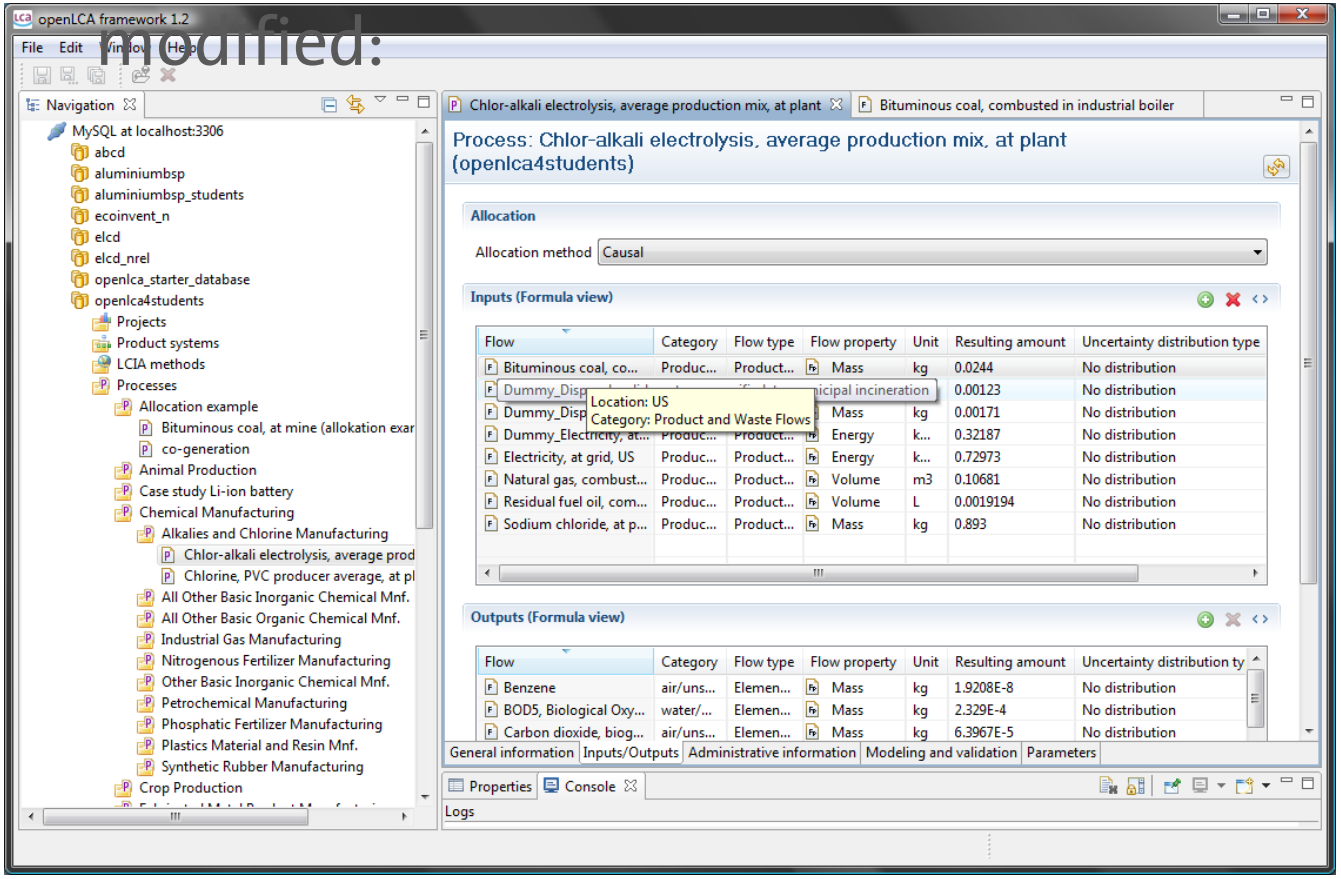
GreenDeLTa

Basic commands

- Open element: double click
- Copy element: right mouse button→ copy
- Paste element: right mouse button →paste
- Delete element: right mouse button → delete
- Save element: use saving symbol in the main menu 
- Save image: right mouse button → save image
- Minimise/maximise element: 

Basic commands

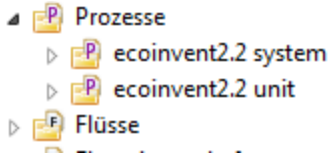
- If you double click on a flow in the process editor it will be opened in a separate window and can be modified:



GreenDeLTa

Folder structure

- Divide system and unit processes

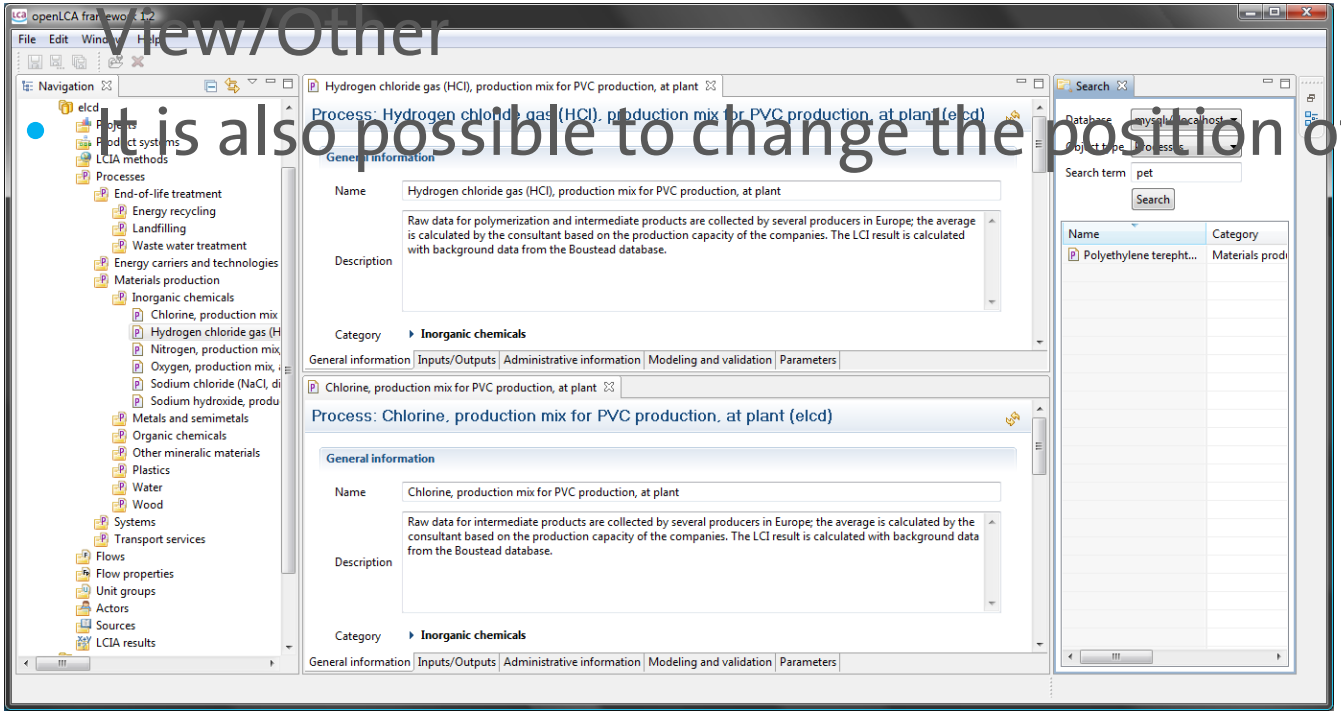


- Divide processes from different databases in one openLCA database
- Separate flows and processes that were created on your own

Do not change the folder structure of elementary flows, because LCIAM cannot find them anymore!!

Windows

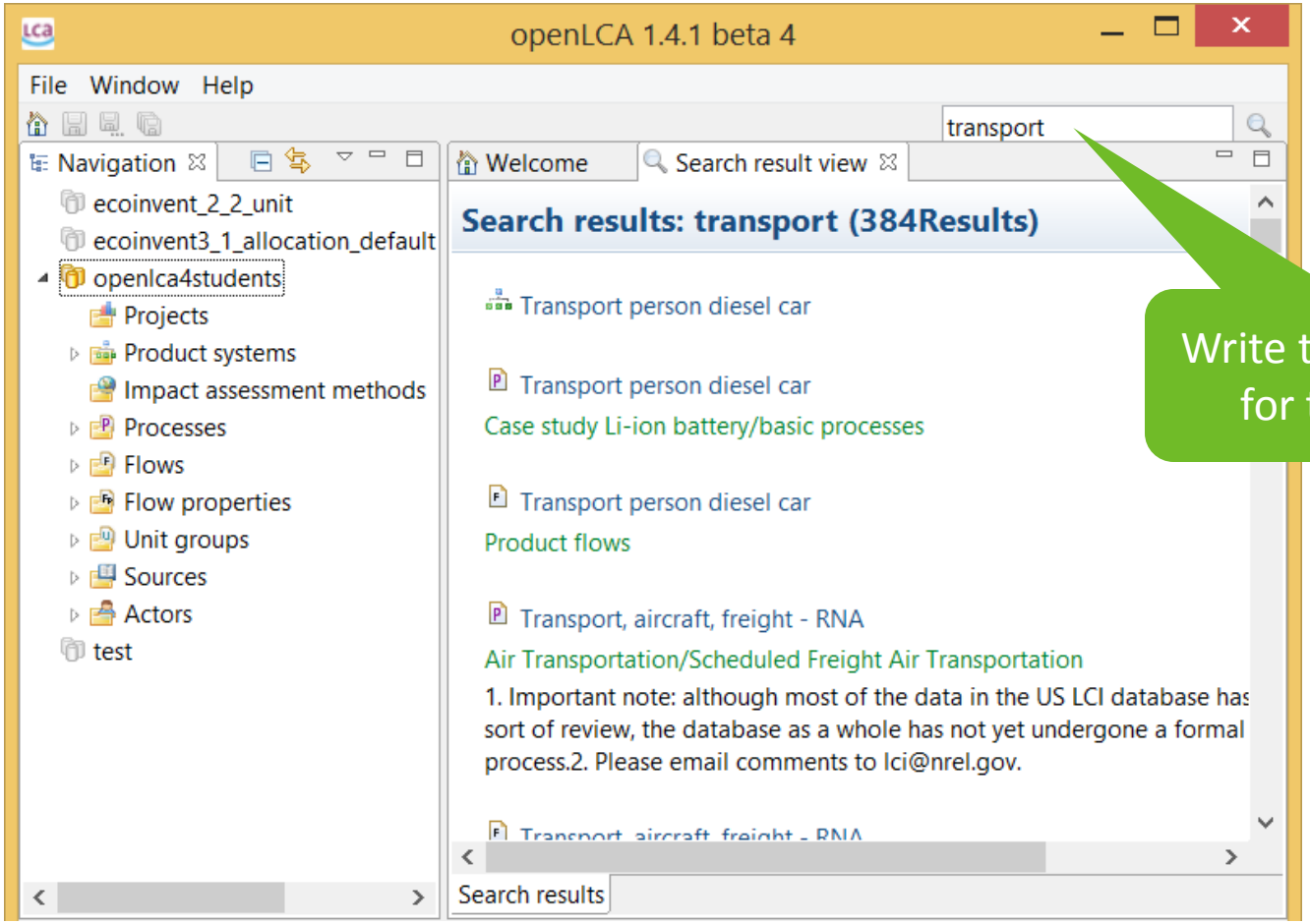
- Often users have several elements open at the same time. It is recommended to close elements you don´t need.
- To recover "missing" window: go to Window/Show View/Other
- It is also possible to change the position of a window



GreenDeLTa

Search

- Search any element from the database

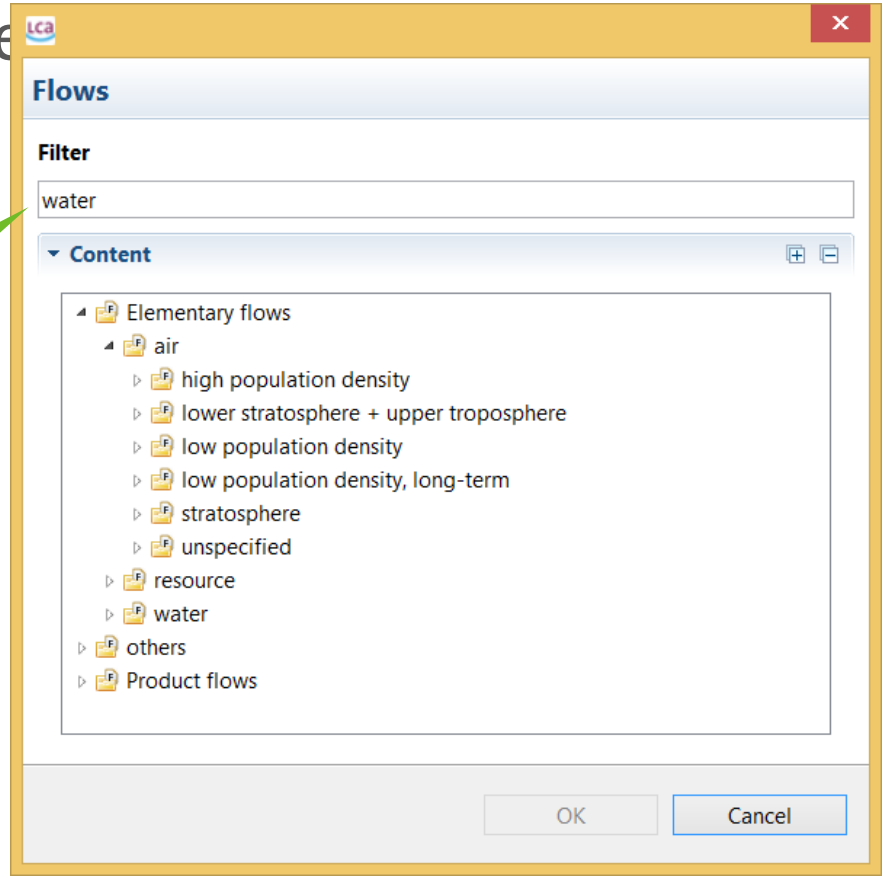


GreenDelta

Filter

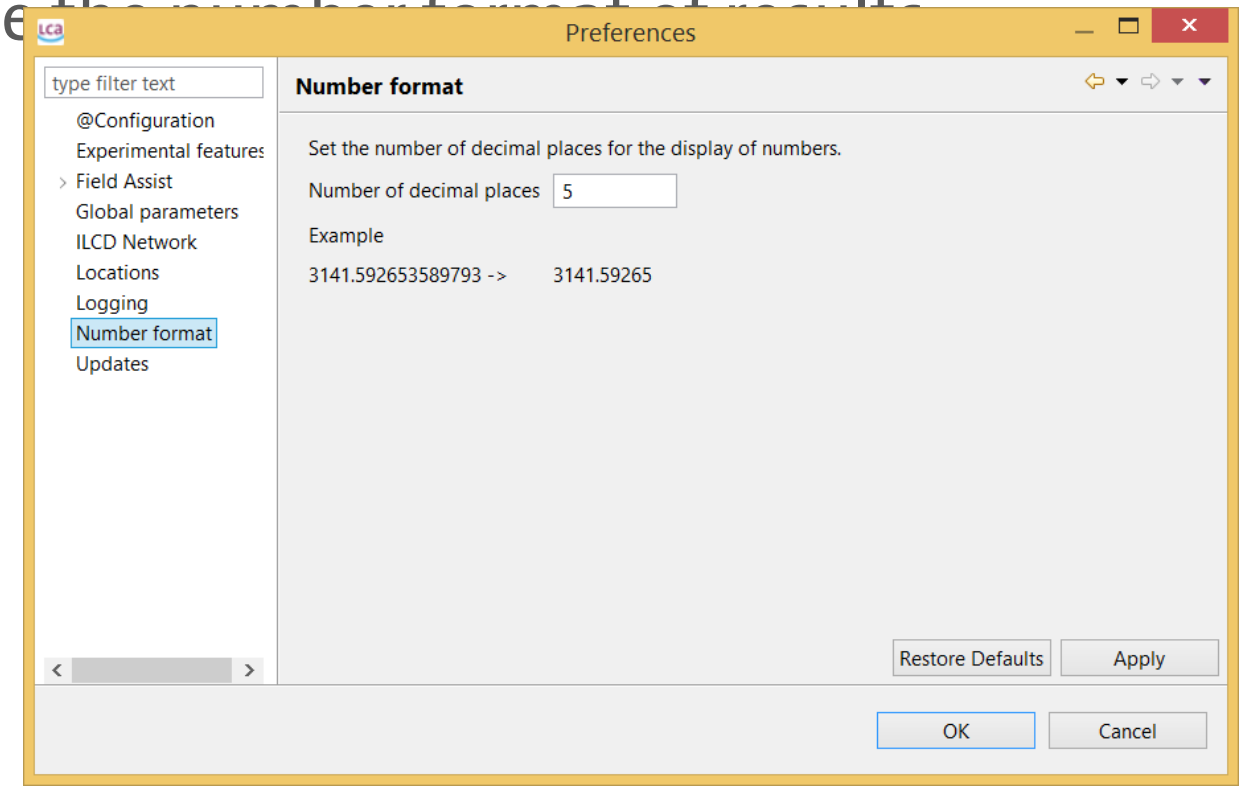
- The “Add new” editors contain a filter for facilitating the search of the desired e

Use the “Filter” when adding new flows to a process, select the reference process in a product system, etc.



Numbers

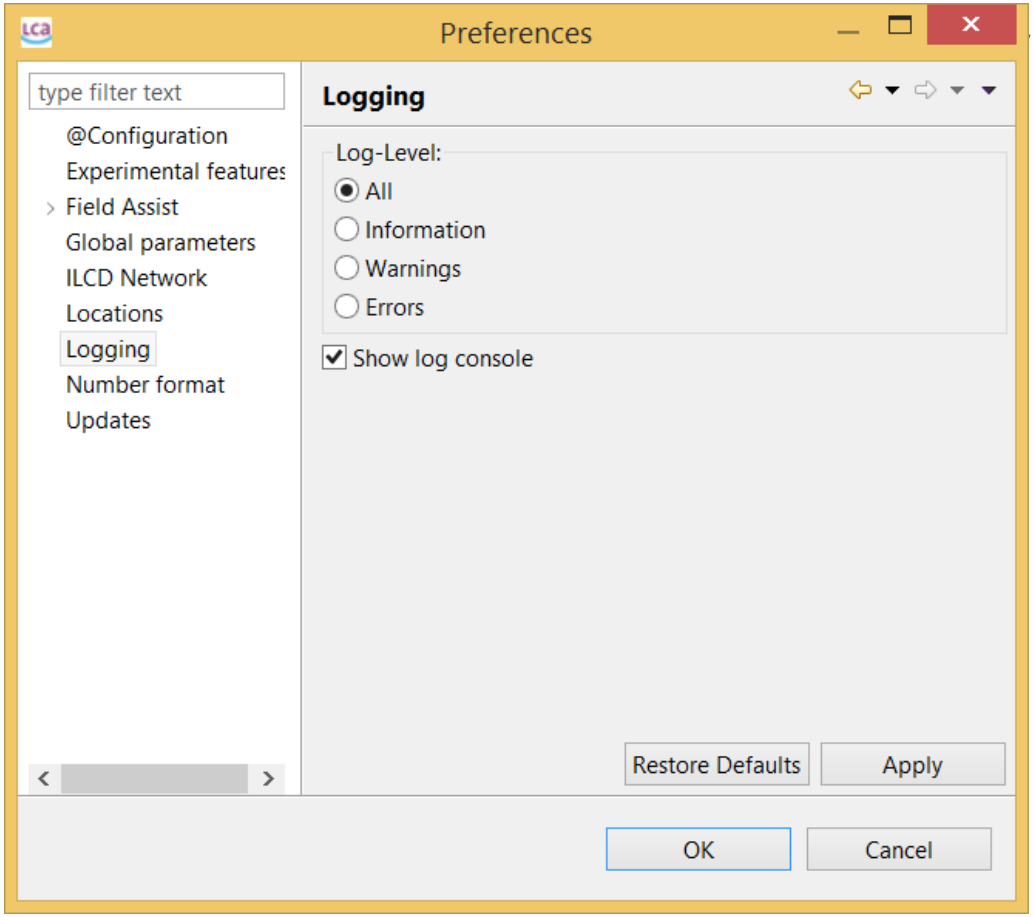
- Use always a point for floating point numbers, a comma is not accepted (=> 1.5 instead of 1,5)
- Under File/Preferences/Number format you can choose the number format of results



GreenDelta

Errors

- It is possible to report all errors in a log file automatically.



logging and check

The log file is rewritten every time openLCA is restarted!

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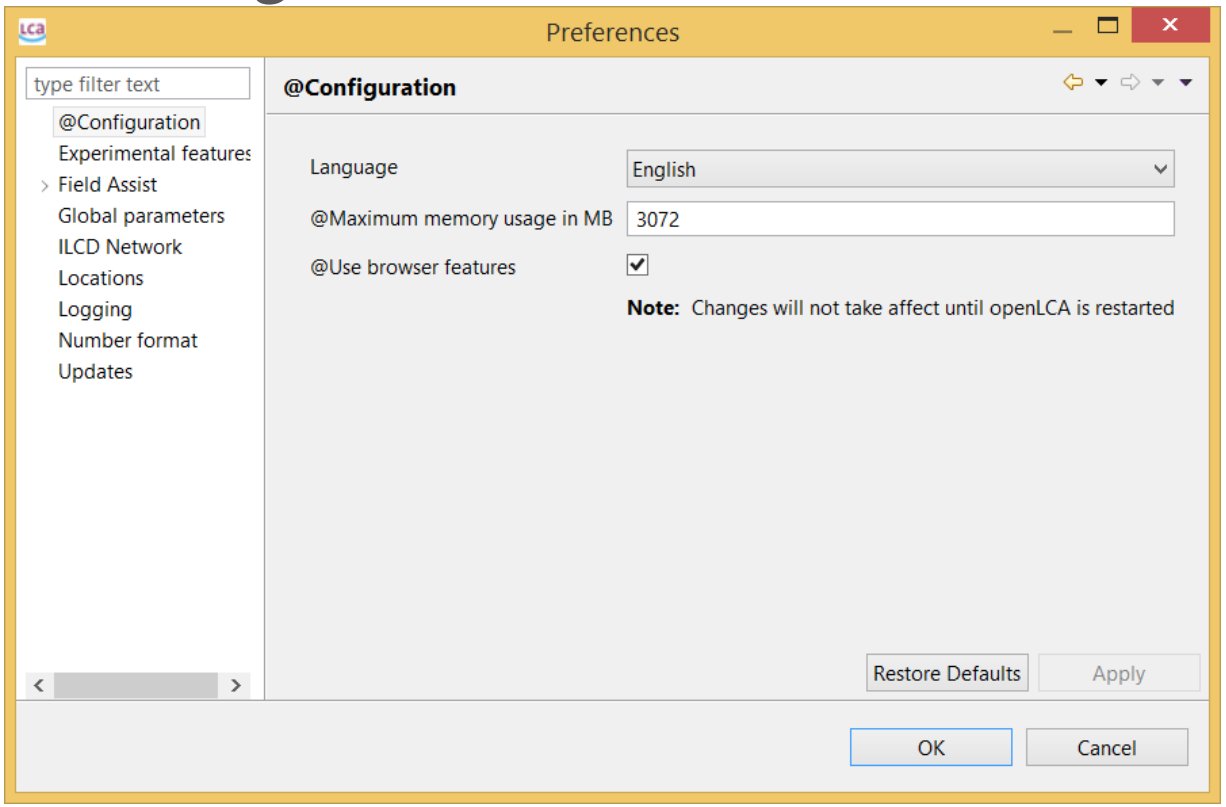
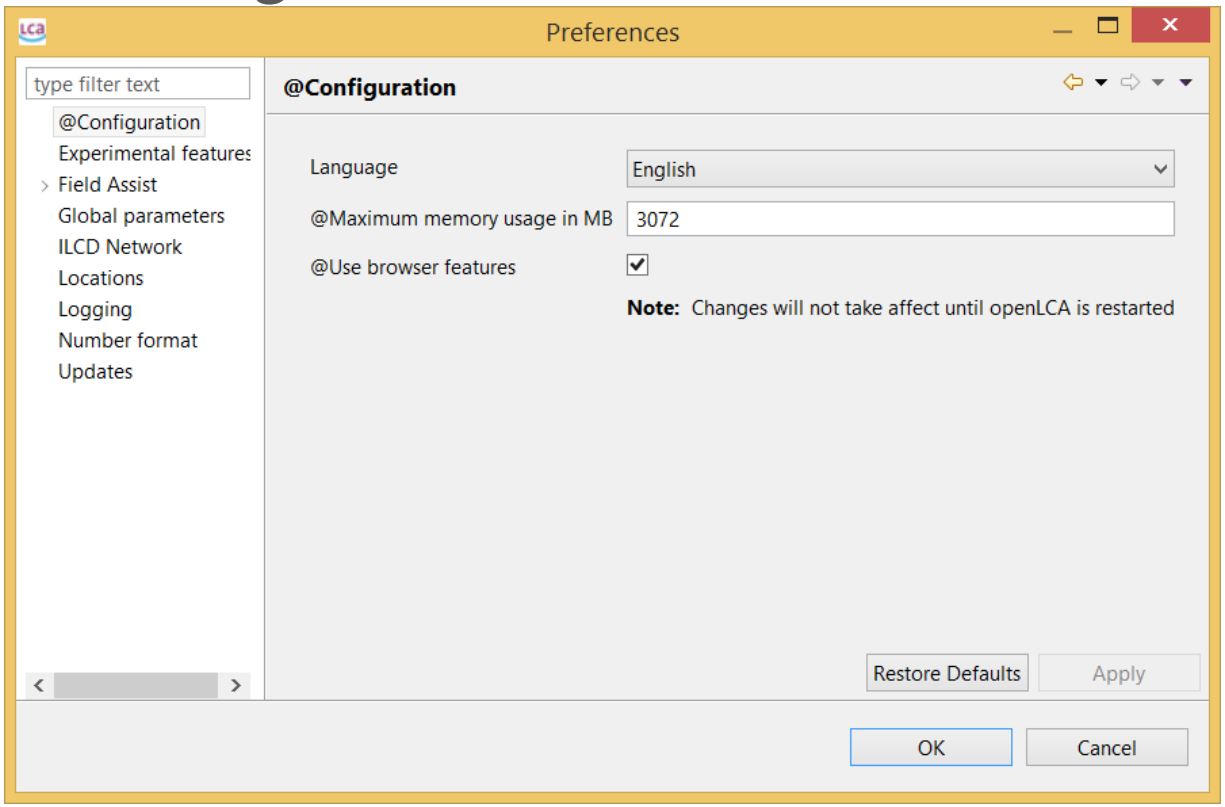
Language

- openLCA is available in Bulgarian, Chinese, English, French, German, Italian and Spanish.
- Change it under File/Preferences/@Configuration.



Memory usage

- Some databases required higher memory usage (e.g. ecoinvent 3) for the calculations.
- Change it under File/Preferences/@Configuration.



GreenDelta

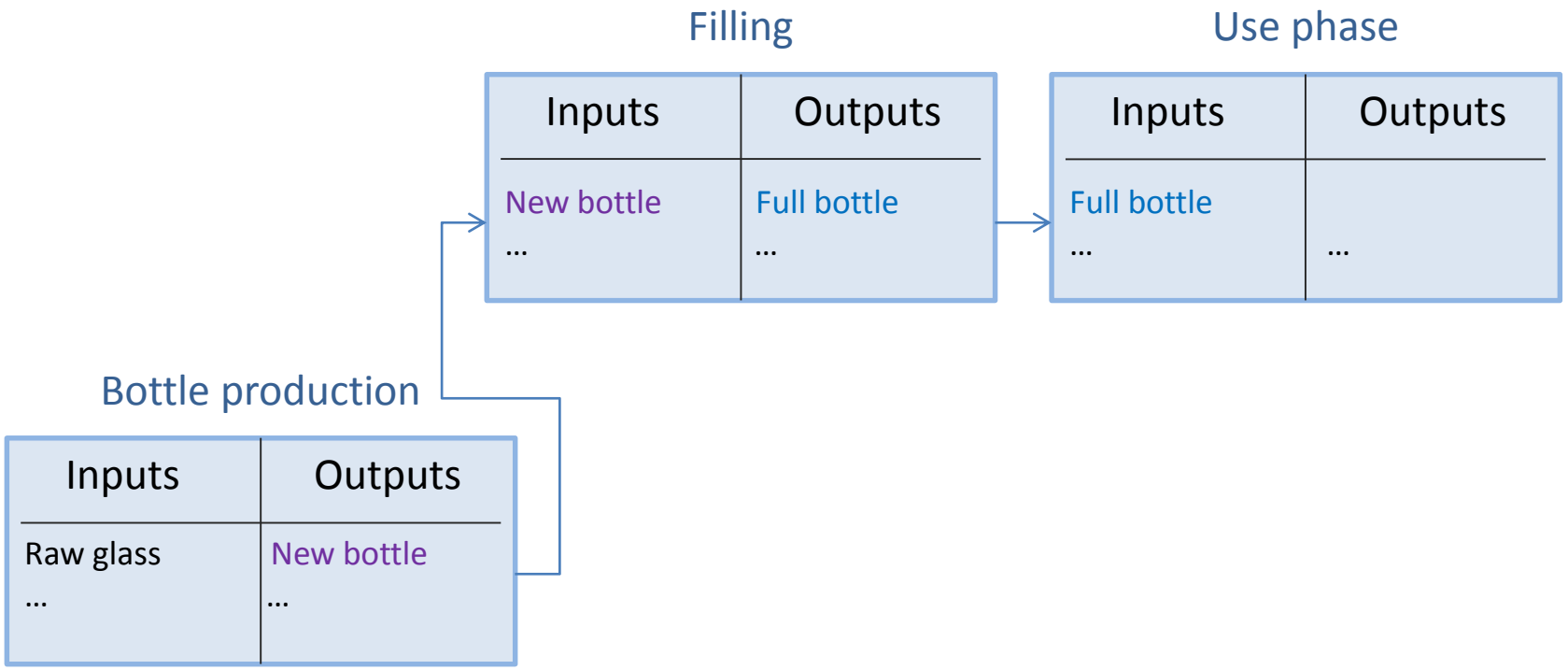
openLCA-data directory

- The openLCA-data folder is automatically created under in your user/Documents folder.
- The directory can be edited in the 'openLCA.ini' file contained in the openLCA folder with a text editor in

```
-clean
-nl
en
-data
@noDefault
-olcaDataDir
HERE THE FULL PATH OF THE NEW DIRECTORY
-olcaVersion
1.4.0
-vmargs
-Xmx4096M
-Dorg.openlca.core.updatesite=http://nexus.openlca.org/updatesite
```

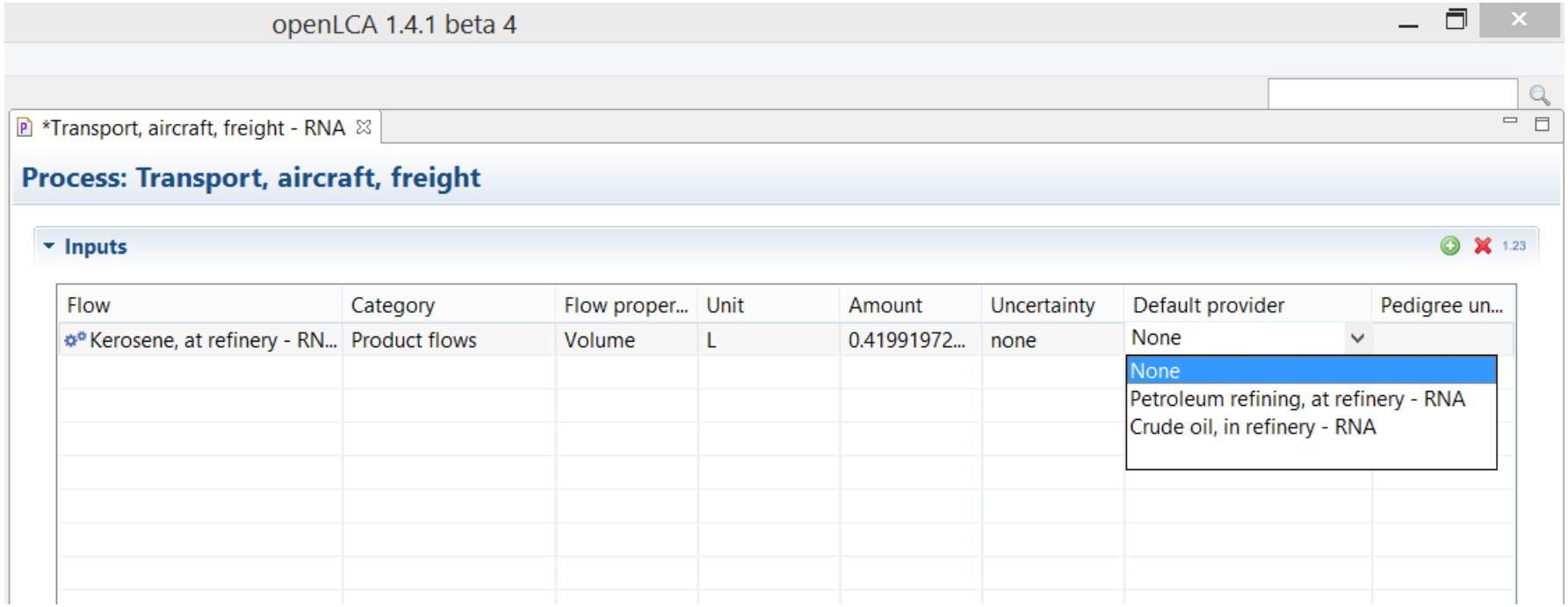
Modelling with product flows

- Use different flow names for one flow that “hikes“ through your product system



Modeling with product flows

- The default provider can be set for each exchange



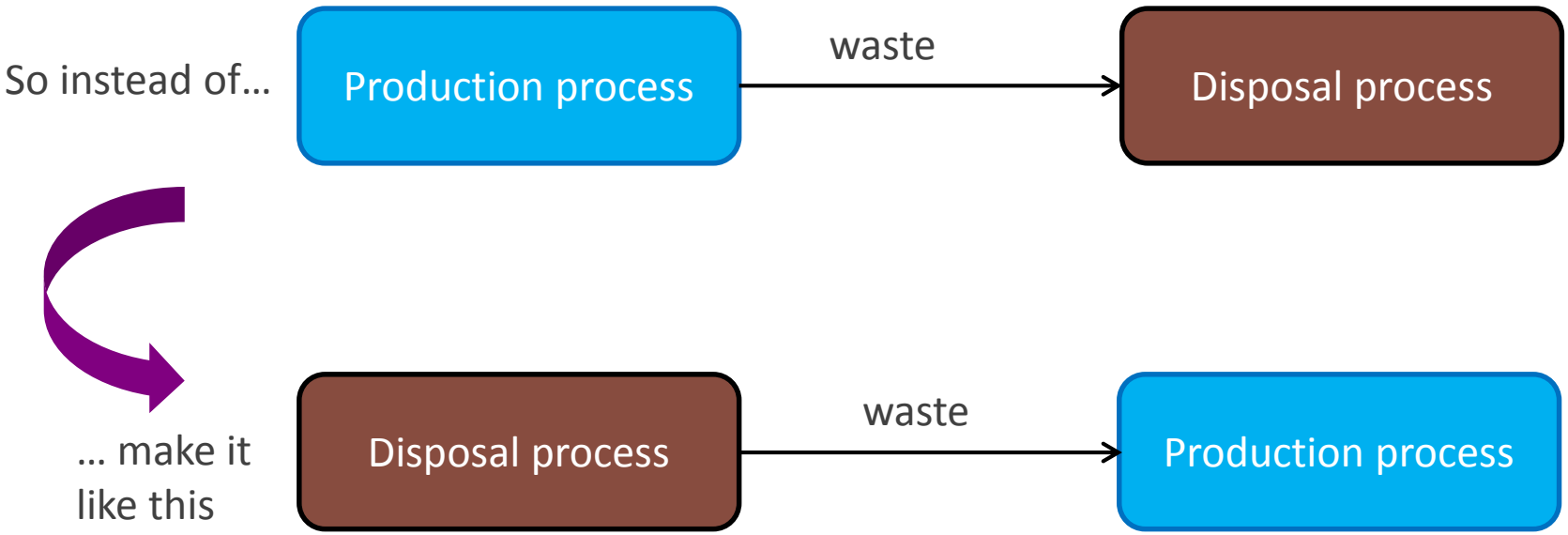
Modelling of waste

- "Reverse direction": Usual (production processes) is that donations to another process are something of value for the receiving process.
- Disposal processes aim to eliminate the receiving flow

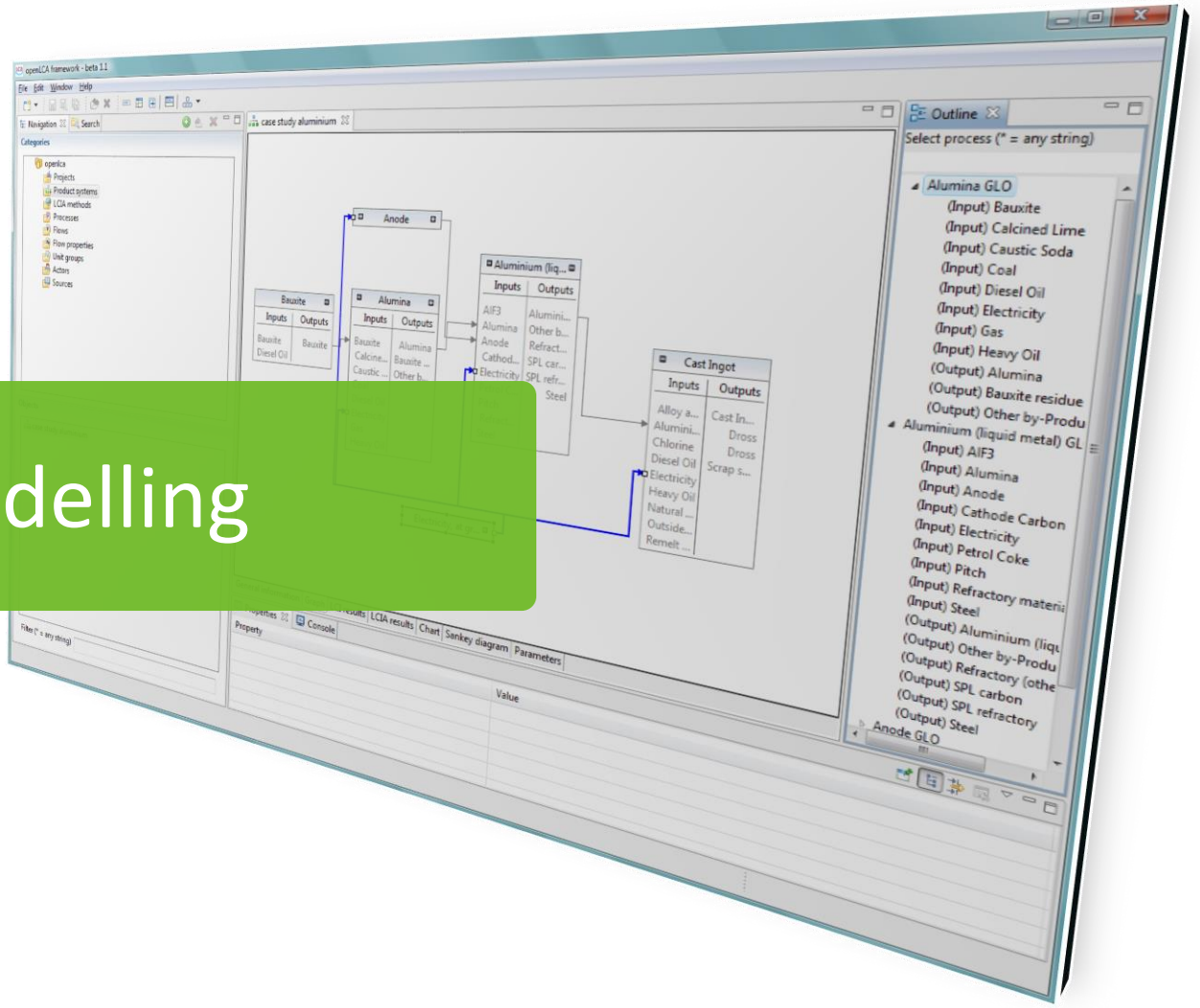
→ Model according to the "value flow direction":

Disposal as a service counter to the direction of material flow

Modelling of waste



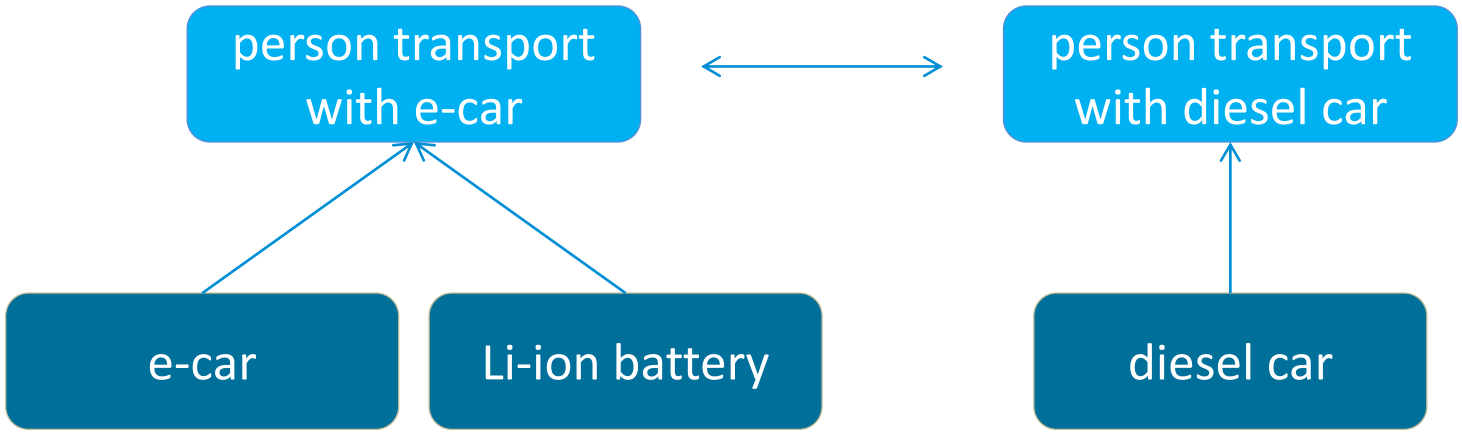
Modelling



GreenDeLTa

Case study: Li-on batteries in e-cars

- FU: 100,000 pkm



Case study: Assumptions

Li-ion battery:

Features battery	scenario 1	scenario 2
Weight	326 kg	250 kg
Amount of cells	192p à 1,45 kg	192p à 1,11 kg
Energy density	70 Wh/kg	180 Wh/kg
Product life	1.500 load cycles	2.500 load cycles
Consumption	17,115 kWh/100km	15,2 kWh/100km
Cruising range	134,12 km/load cycle	296,05 km/load cycle
Total cruising range	200.000 km	740.000 km
Required battery amount for 100,000km	0,5 p	0,135 p

Cars:

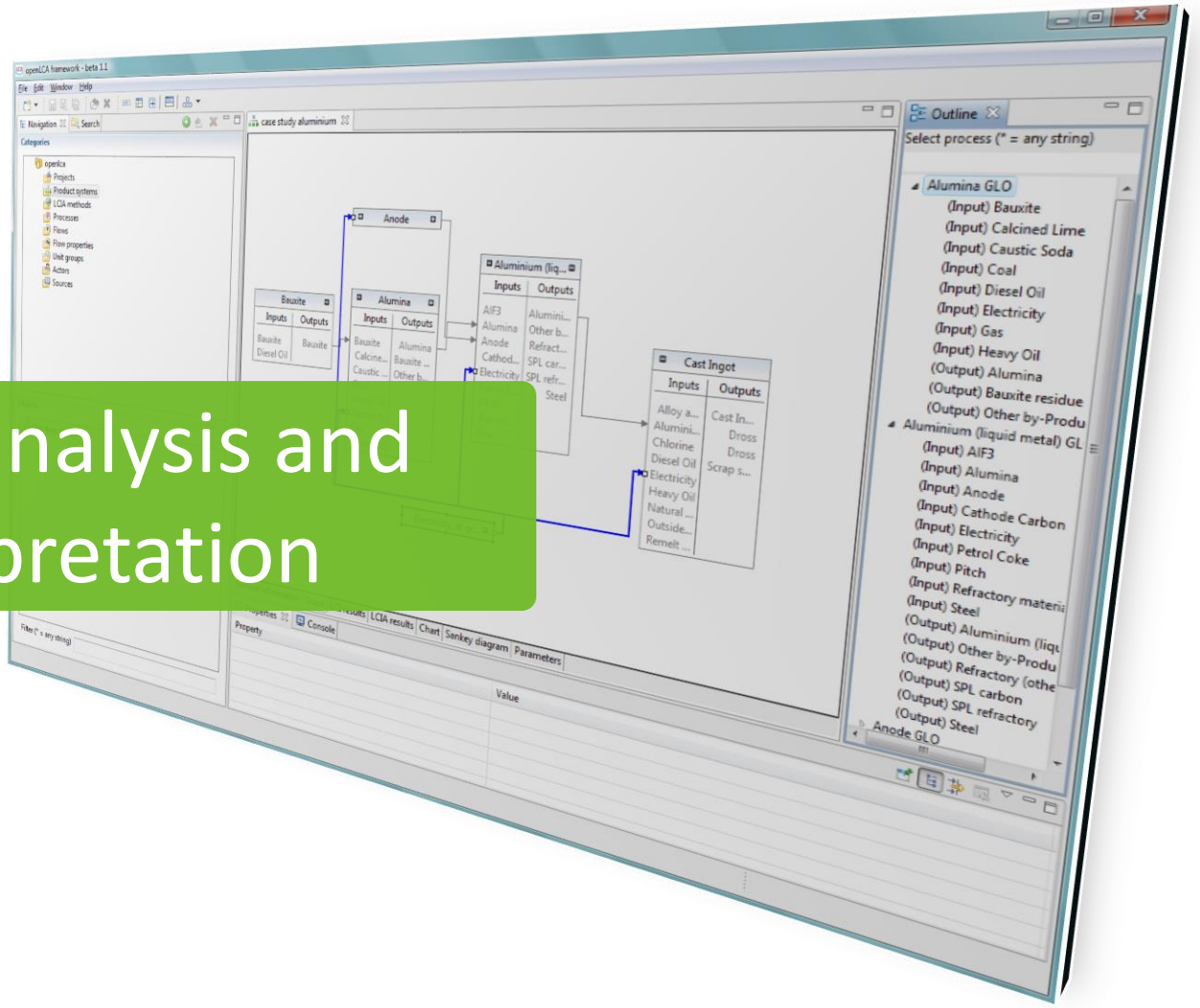
Features car	e-car	diesel car
Weight	1.381 kg (S1) 1.305 kg (S2)	1.384 kg
Product life	400.000 km	400.000 km

Exercise 3: Production phase of the battery

a) Analyze the graph of the product system “Battery production” in the database “openlca4students”. Then calculate the inventory of the product system. Which information can you derive from the inventory?

- Open the product system “Battery production”
- Go to the graph
- Calculate the m  erial balance calculation using the buttons on the left top of the main menu , , quick calculation
- 10 min

Result analysis and interpretation



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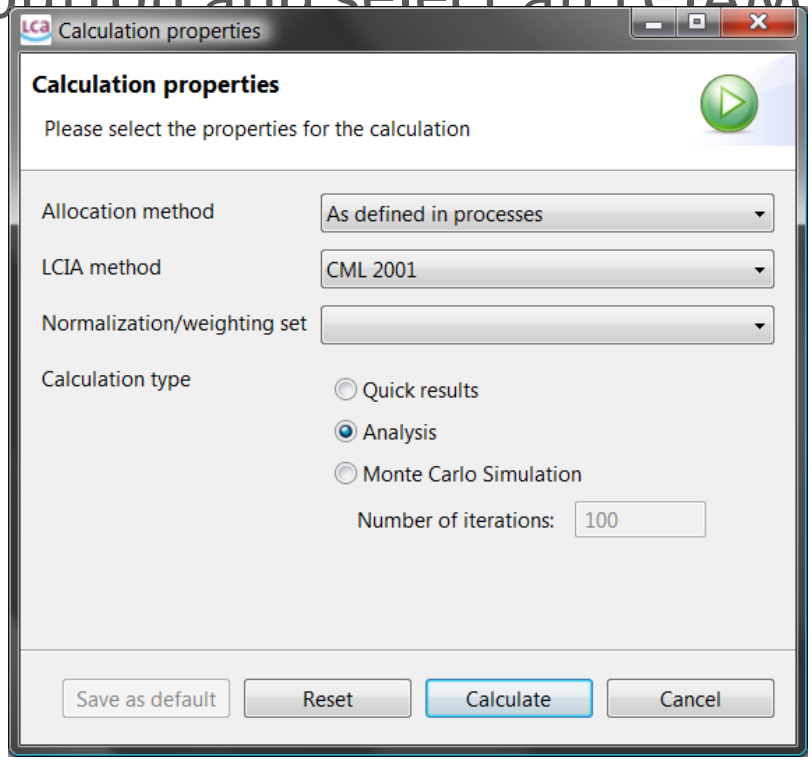
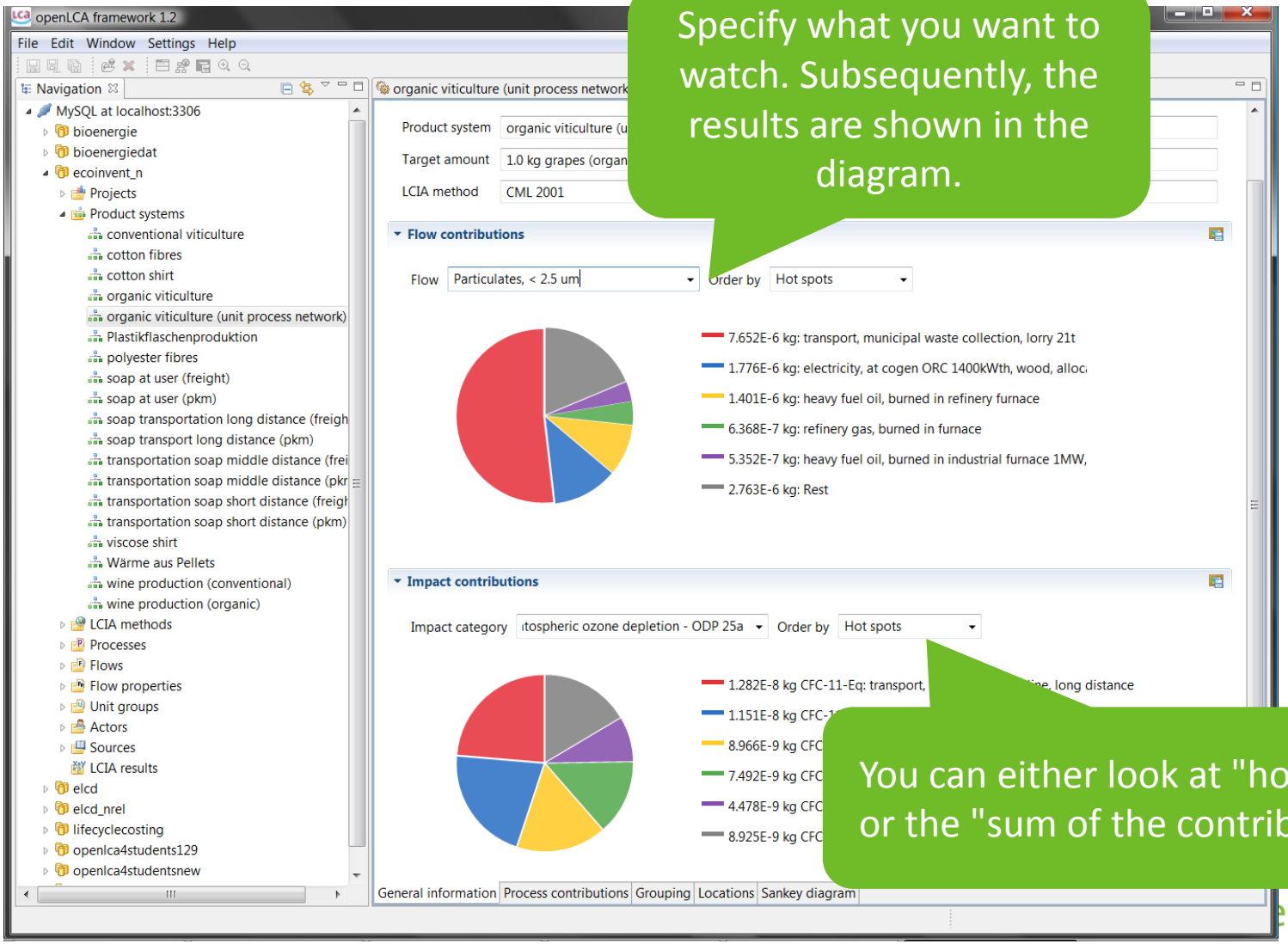
Analysis functions

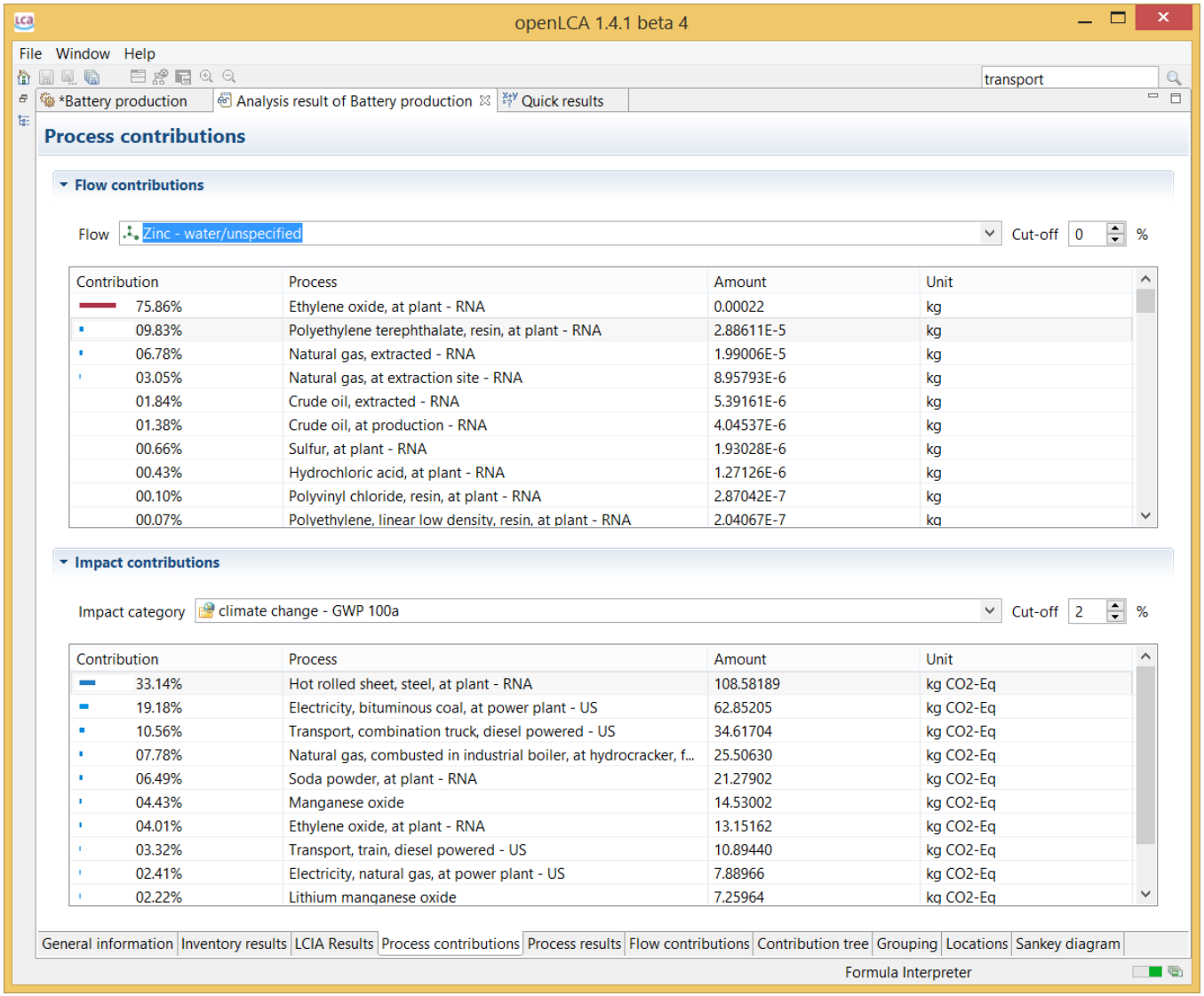
- To run the anaysis functions the product system needs to be recalculated.
- Click the calculation button and select an LCIAM and check „Analysis“



Analysis functions: contribution to the characterization



Analysis functions: process contributions



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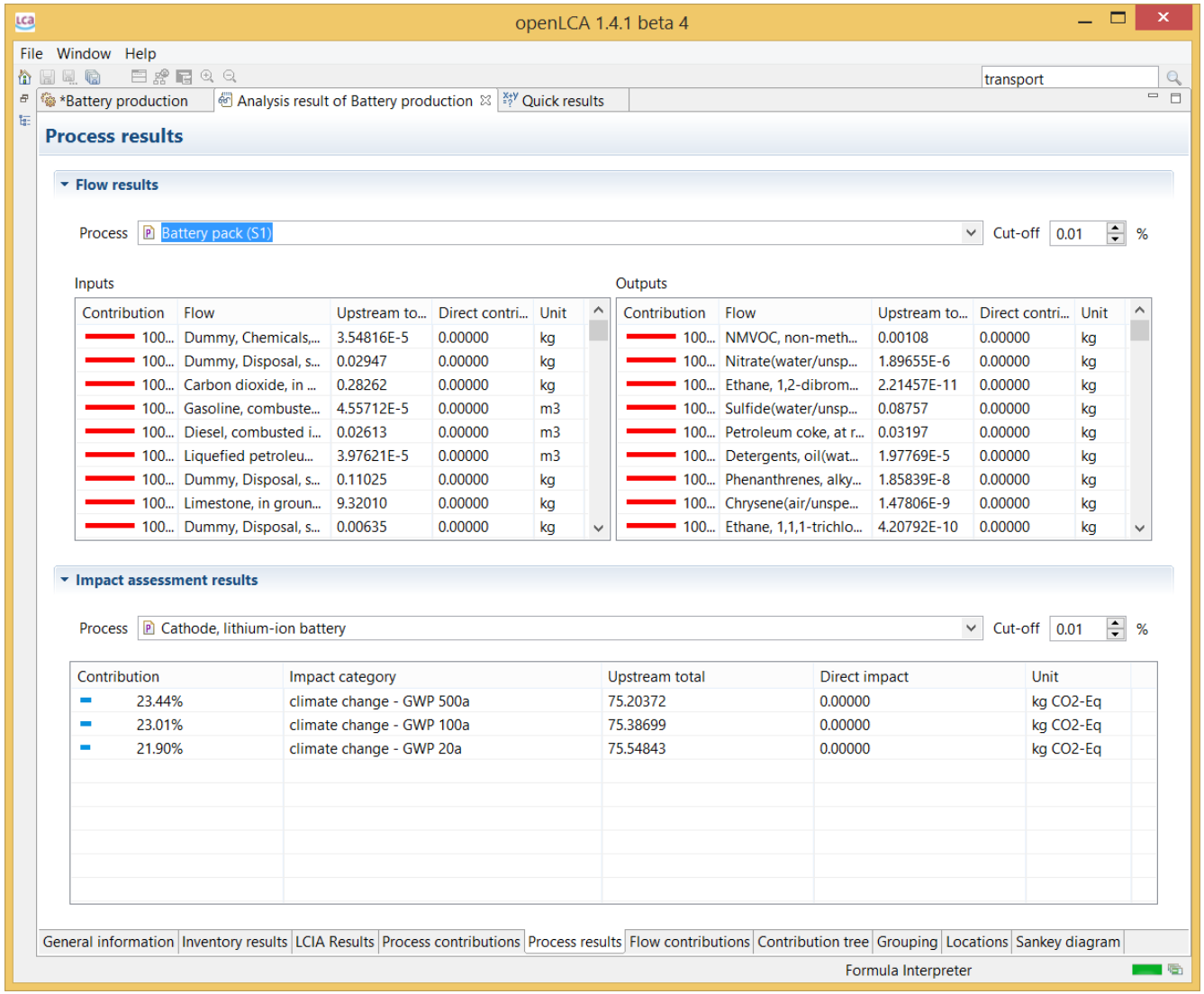
Analysis functions: process results



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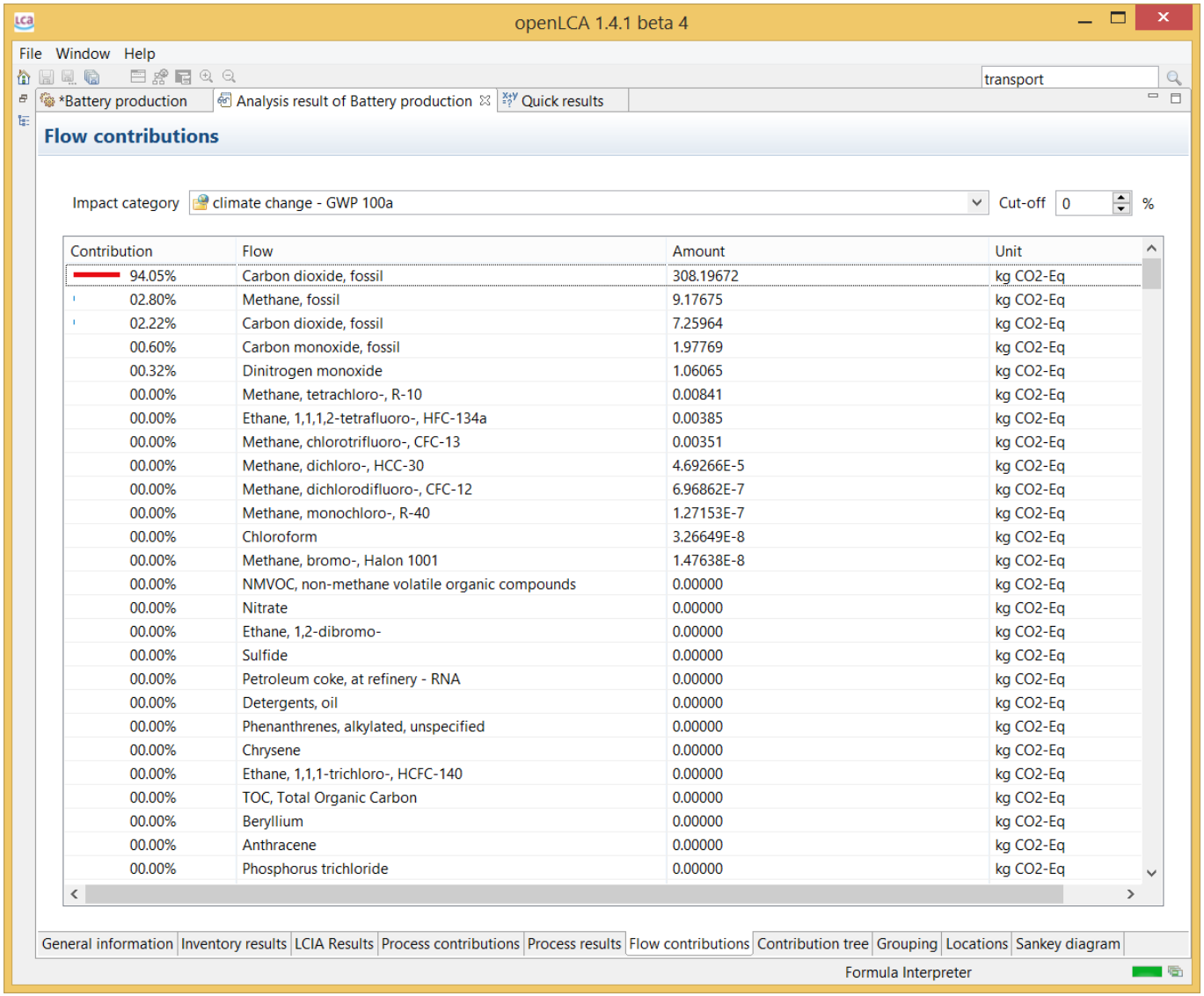
Analysis functions: flow contributions



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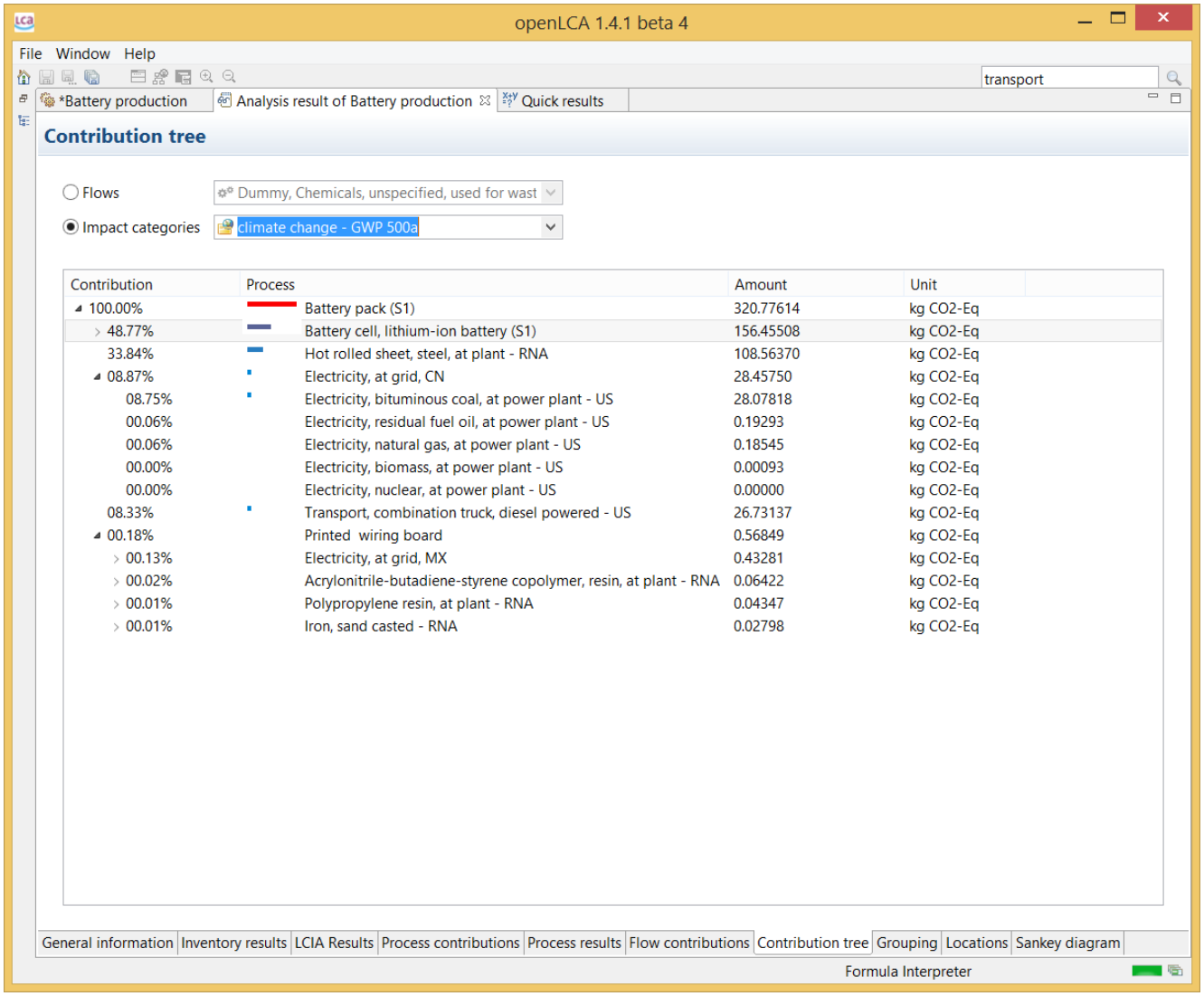
Analysis functions: contribution tree



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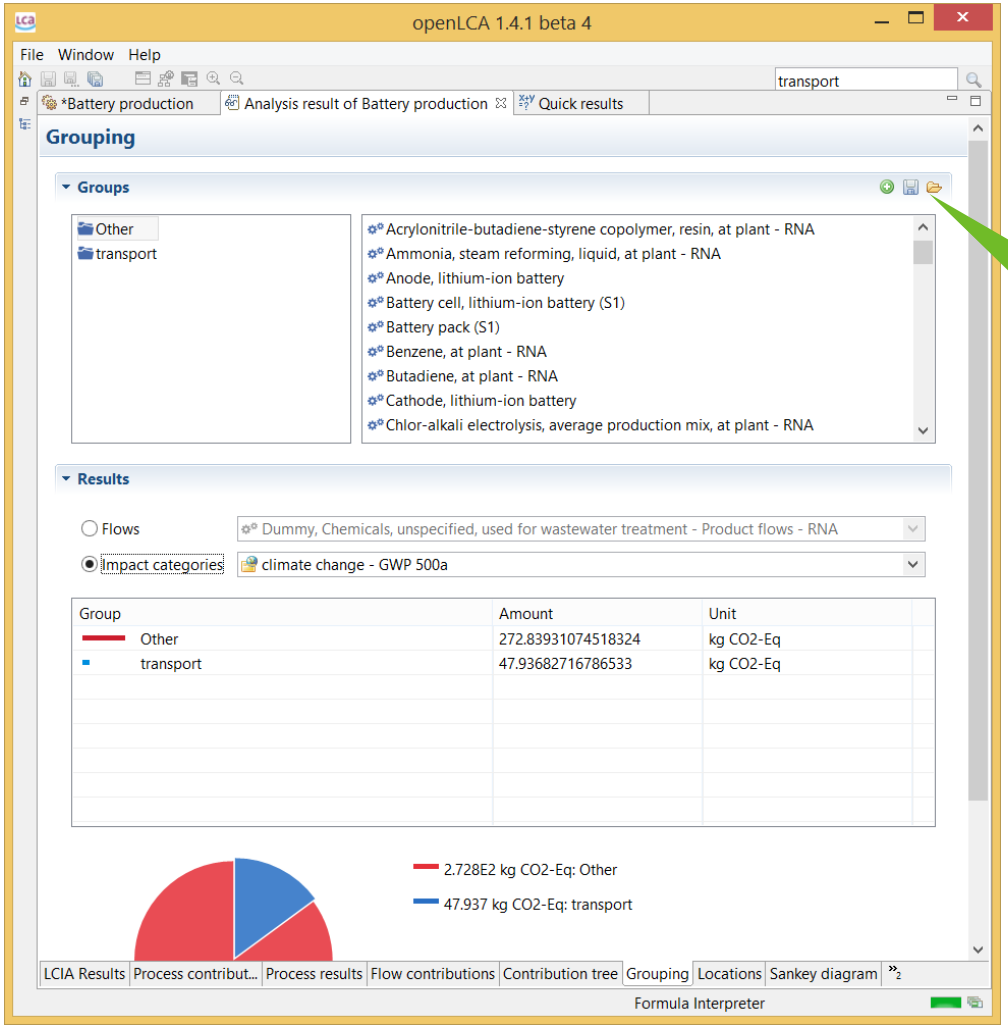
Analysis functions: grouping



Add new groups and move (right click on process name) processes to them

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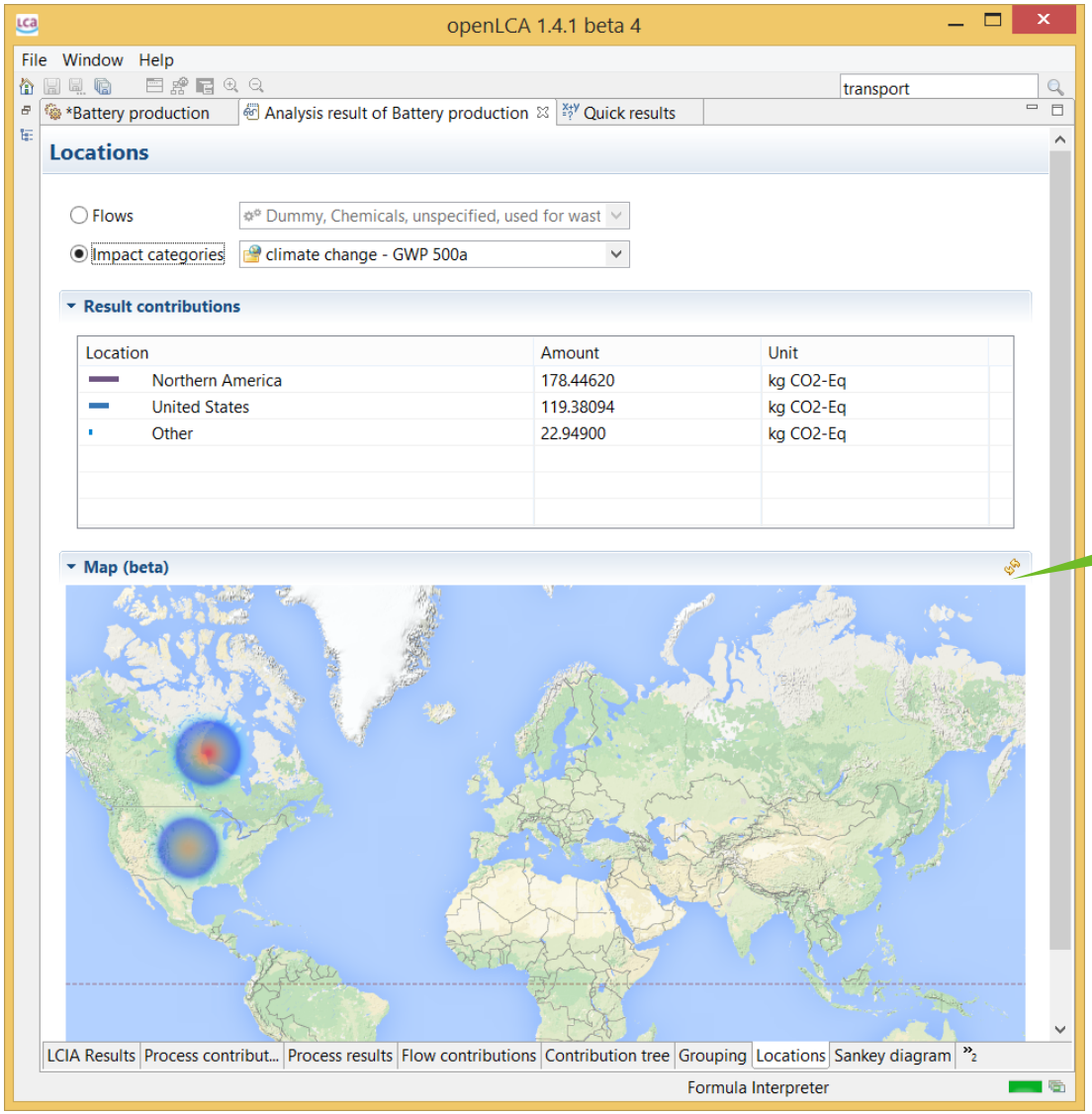
Analysis functions: locations



If you don't see any points in the map, click "reload"

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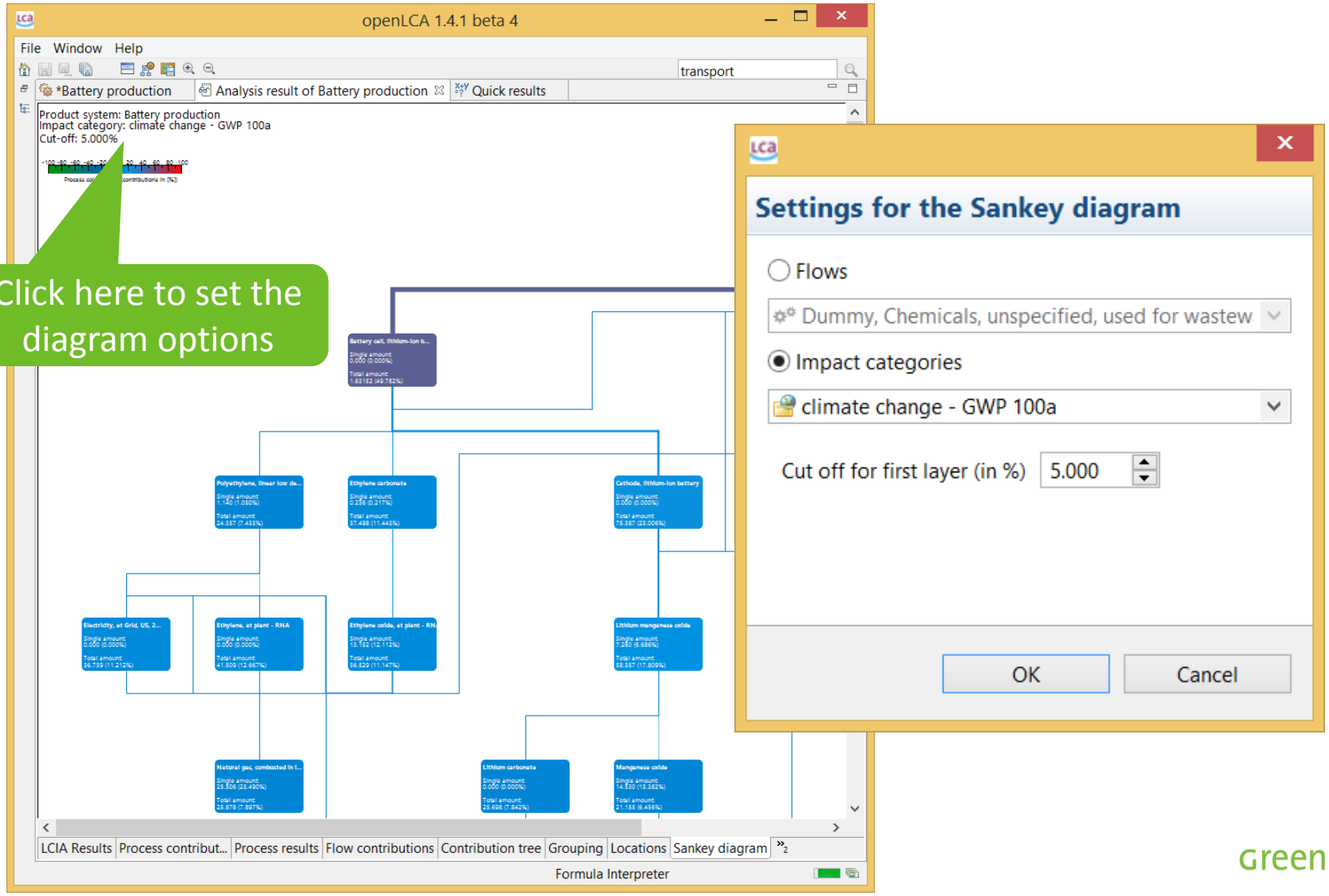
Analysis functions: Sankey diagram



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Exercise 3: Production phase of the battery

b) Calculate the environmental impacts caused by the Li-ion battery with the LCIAM IPCC 2007 and interpret the results. Which processes contribute most to the impact category "climate change – GWP 20a" (without prechain)? How contributes the process "Acetic acid production" to the LCIA category "climate change – GWP 100a?

- Go to the product system "Battery production" in the navigation and click with the right mouse button on "Analysis"
- Select IPCC 2007 as LCIAM
- Switch through the tabs to find the information you need
- 15 min

Exercise 4: Use phase of the battery

a) Create a new process “Transport person e-car (average US) (S1)” with “Person transport” as quantitative reference. Use the following flows and amounts.

Inputs	Amount	Outputs	Amount
Battery pack (S1)	0.5E-5 pieces	Person transport	1 pkm
Car, electrically powered	0.25E-5 pieces		
Electricity, at grid, US 2008	0.17115 kWh		

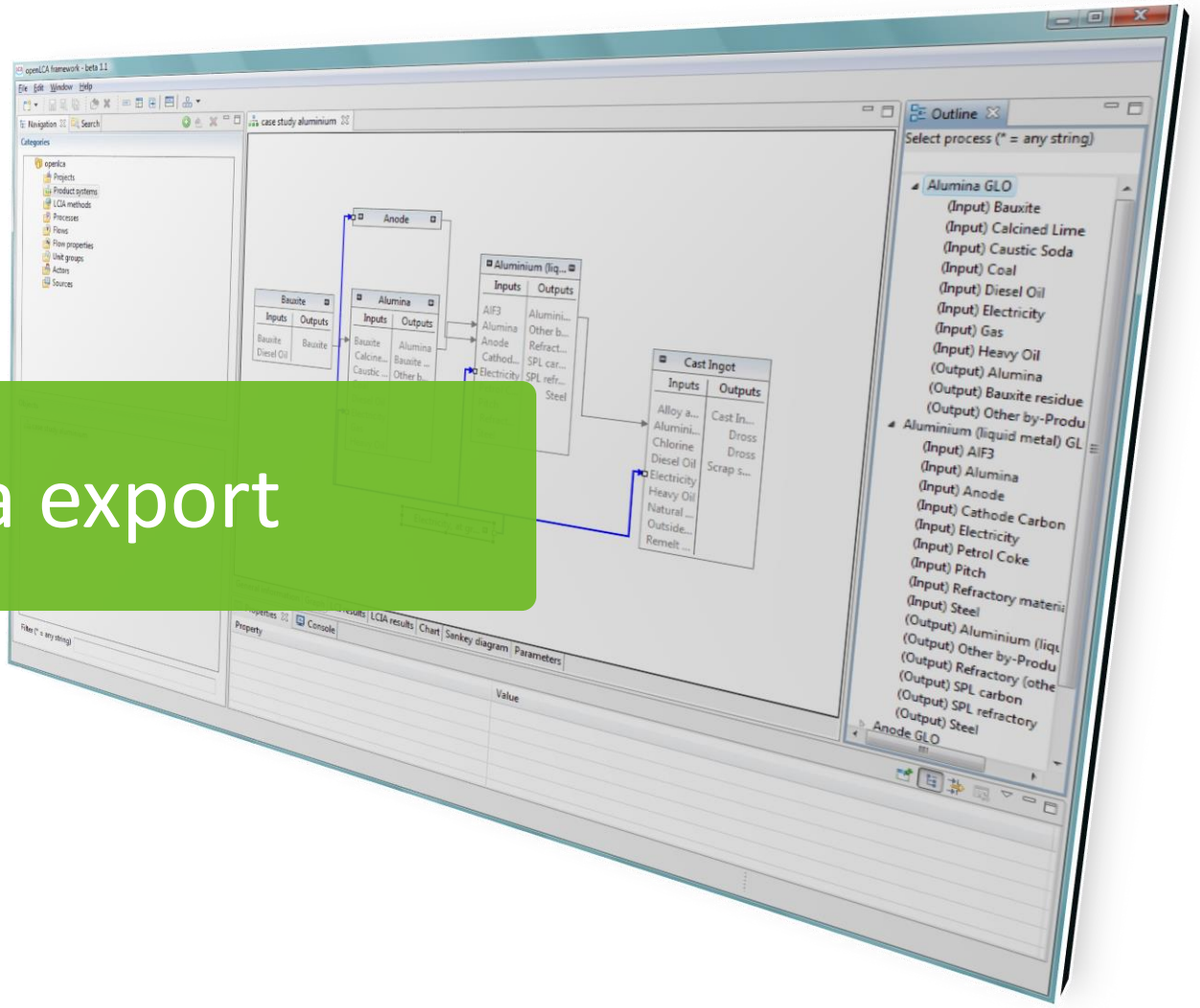
- Create the process in the folder Case study Li-ion battery/scenario 1
- Use the drag and drop function of openLCA
- 10 min

Exercise 4: Use phase of the battery

b) Calculate the environmental impacts of the production and the use phase of the battery with IPCC 2007. Which processes have the main contribution to the environmental load?

- Create a new product system “Transport person e-car (average US) (S1)” and select the same process as a reference.
- Add connected processes automatically.
- Set the target amount in respect to the FU.
- Calculate the inventory and the environmental impacts.
- 10 min

Data export



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EcoSpold export

EcoSpold 1

- Processes
- Impact assessment methods

EcoSpold 2

- Processes

ILCD export

- Actors
- Flow properties
- Flows
- LCIA methods
- Processes
- Product systems
- Sources
- Unit groups

Excel export

- Processes
- Quick results
- Analysis results
- Monte Carlo simulation results
- Product systems:
  - Elementary flows
  - Product flows
  - LCIA factors

Other export formats

CSV-Matrix

- Graph of a product system

Images

- Diagrams

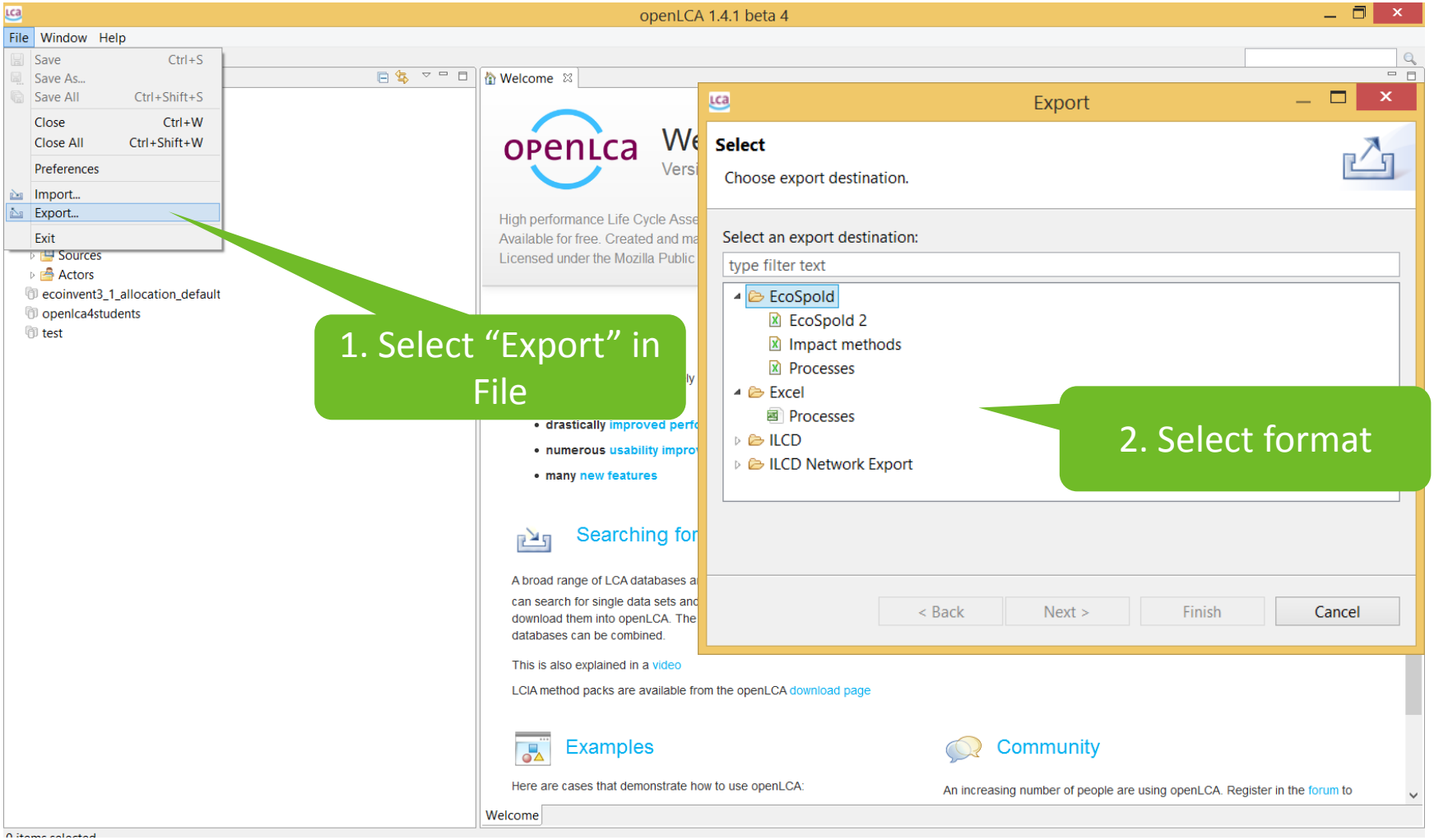
HTML

- Project report

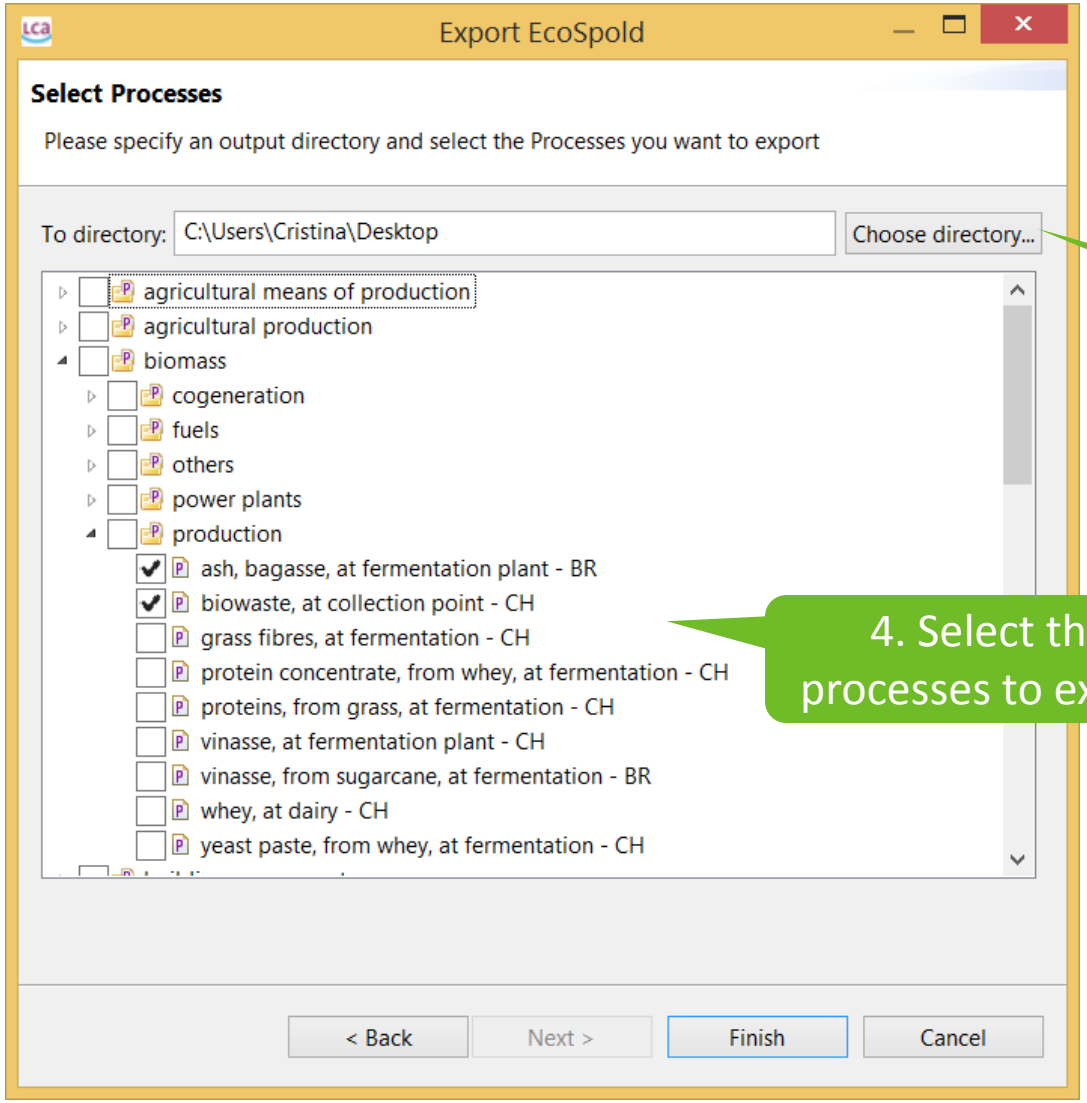
openLCA script (.zolca)

- Complete databases

Example: process export (I)



Example: process export (II)



3. Select the directory where data will be stored

4. Select the processes to export

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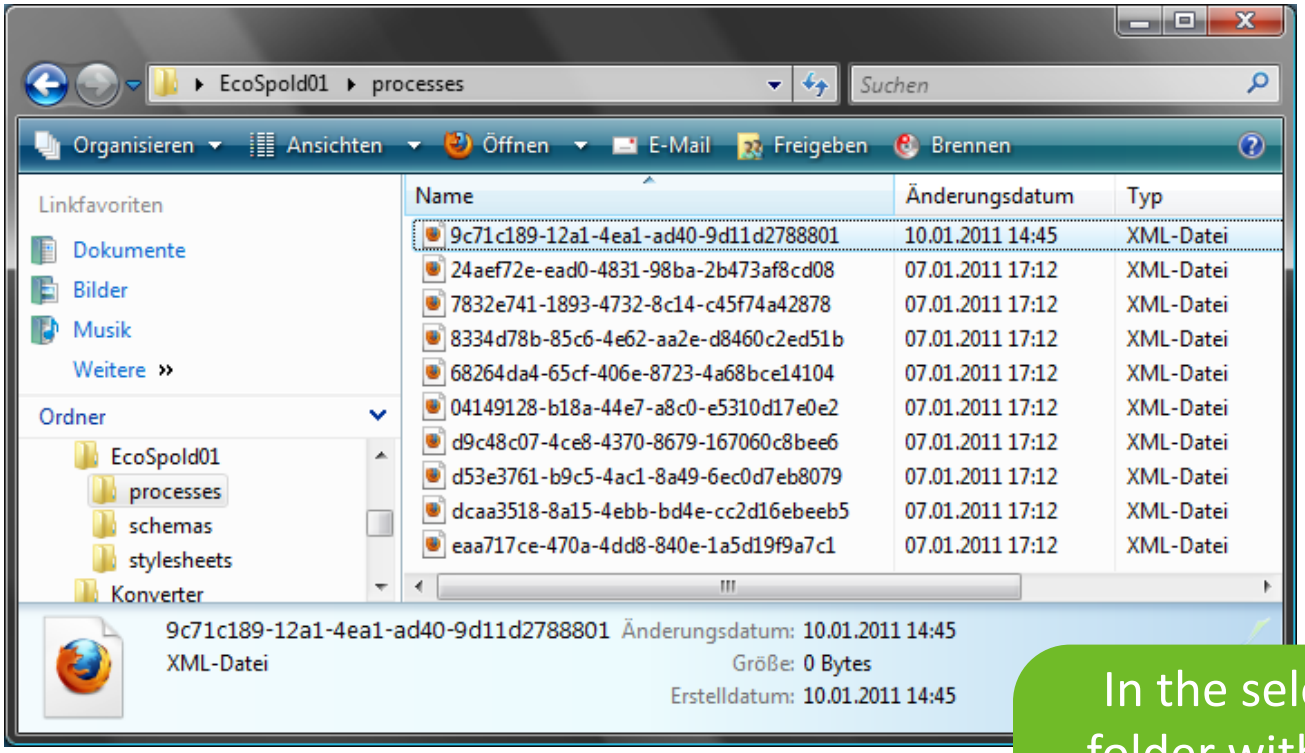
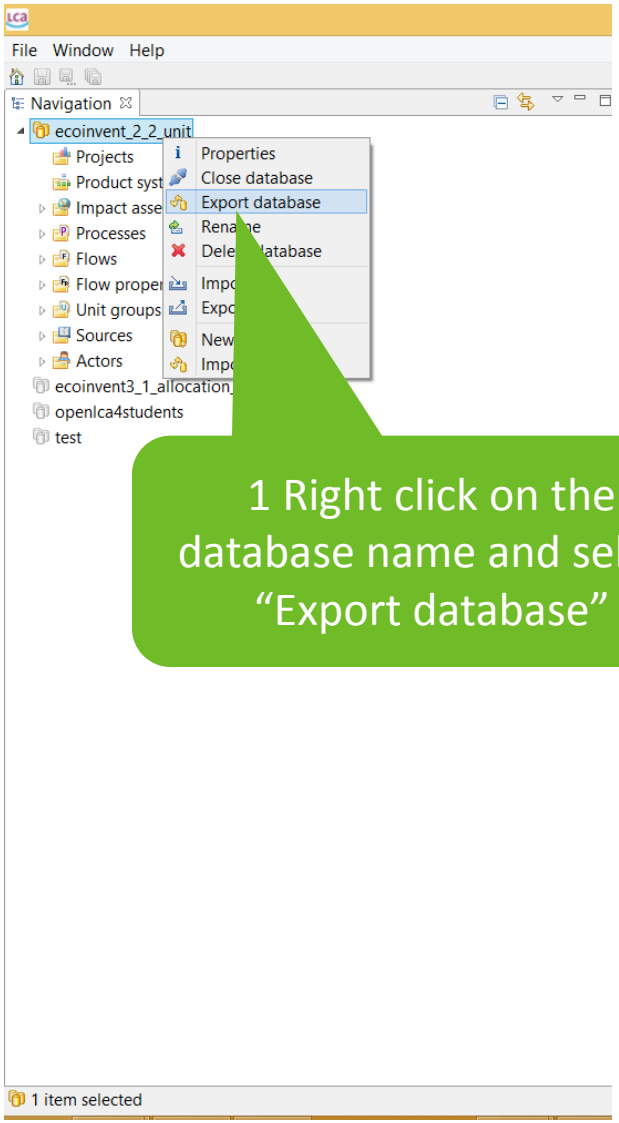
Example: process export (III)

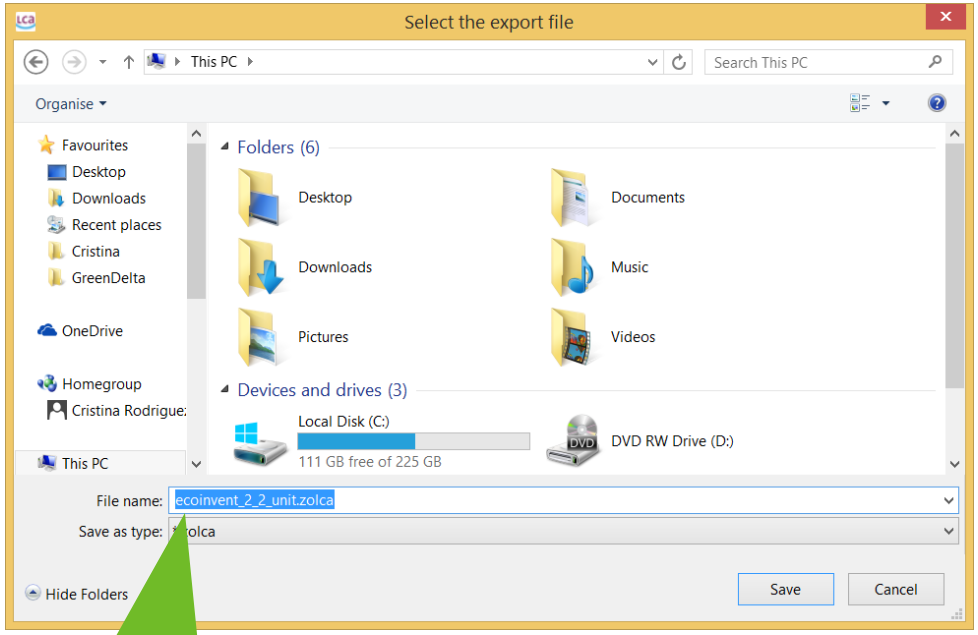


In the selected directory a folder with the name of the export format is created. For instance, Desktop\ EcoSpold01\ processes

Export of openLCA database



1 Right click on the database name and select "Export database"



2. Select the directory and name for the .zolca file

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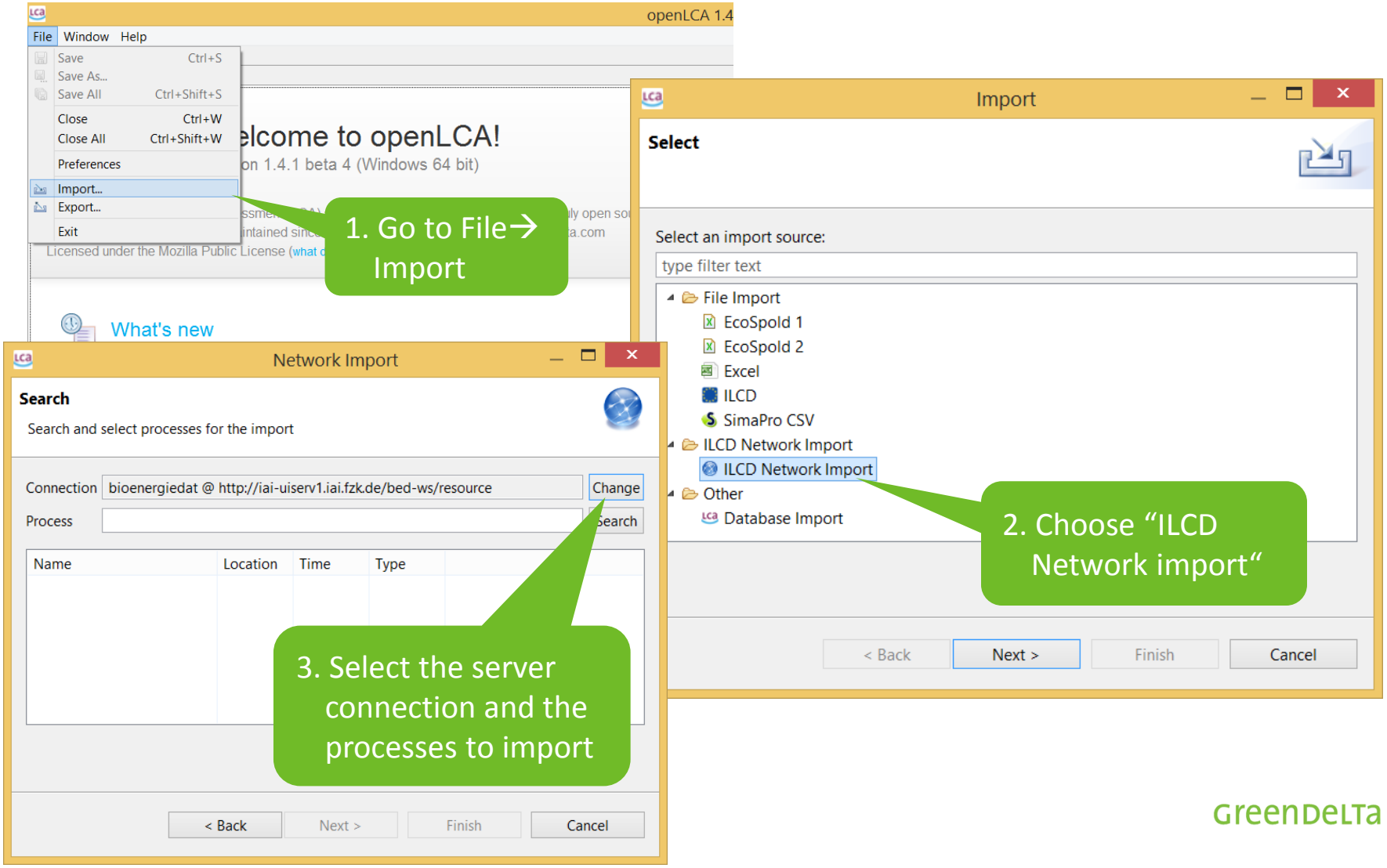
Using an ILCD network database

- Useful, if more than one person is working on one study.
- Data are uploaded into a database on a server and can be downloaded from each user with access to the server.

ILCD network database: import



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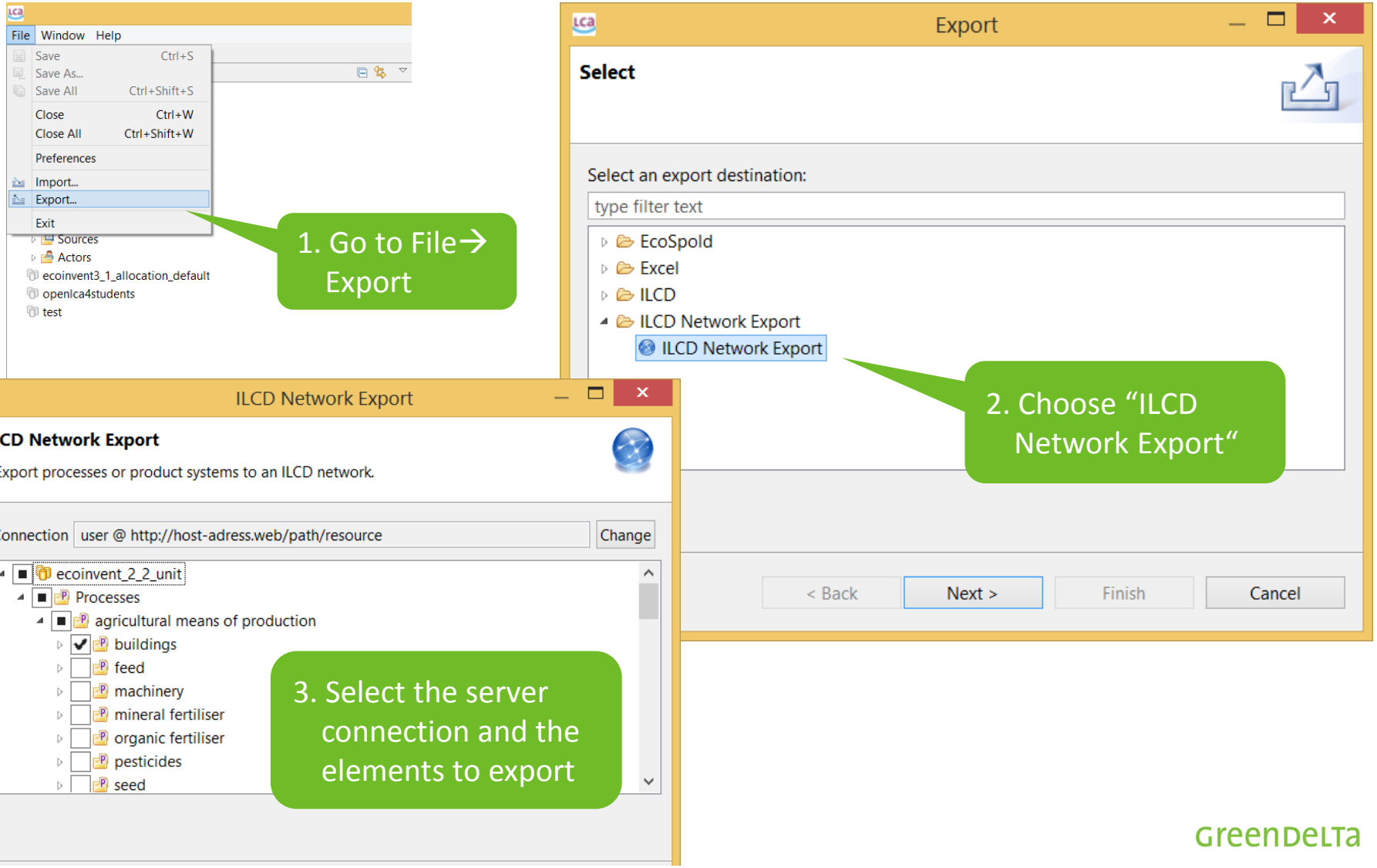
ILCD network database: export



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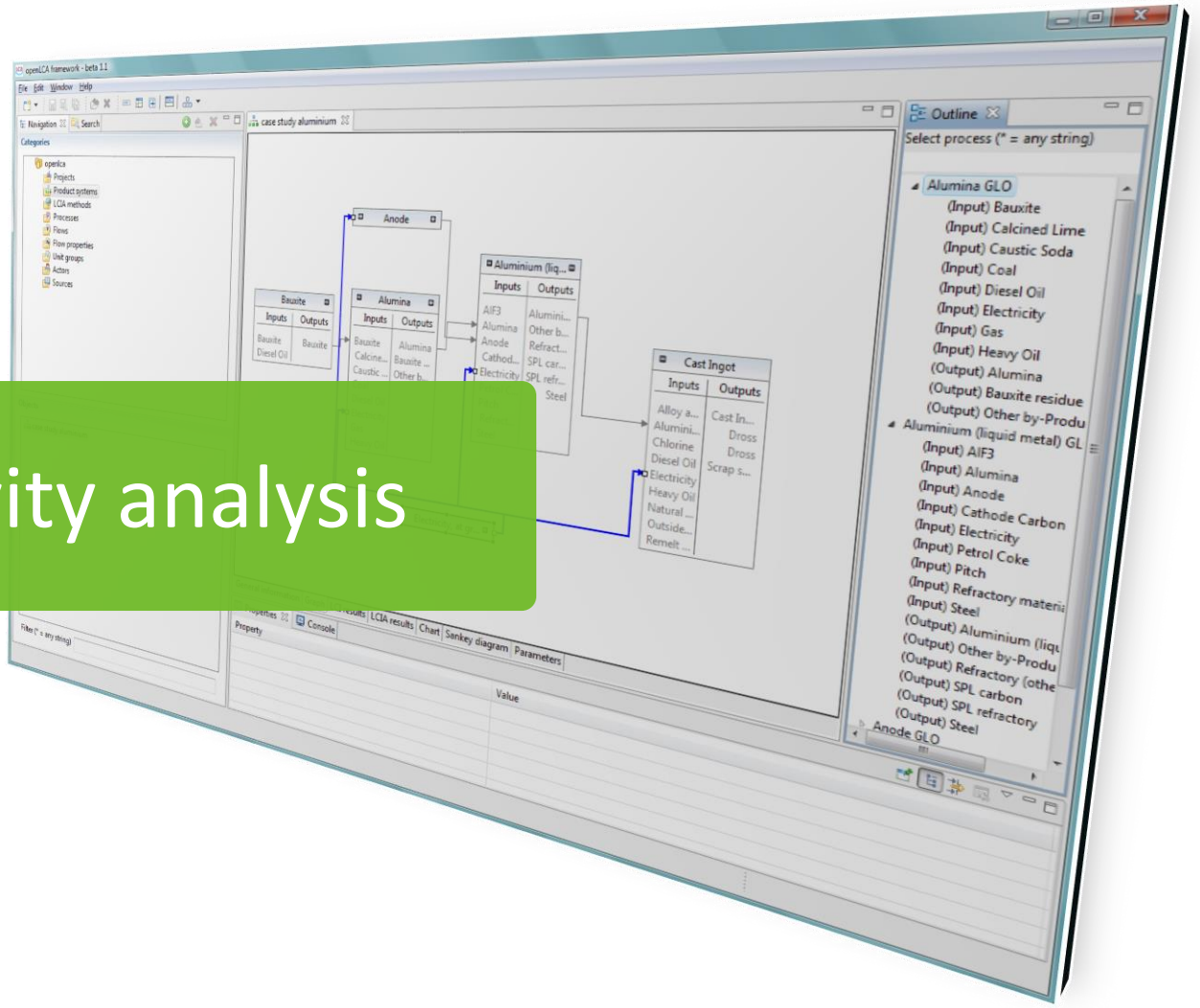
Sensitivity analysis



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Sensitivity analysis

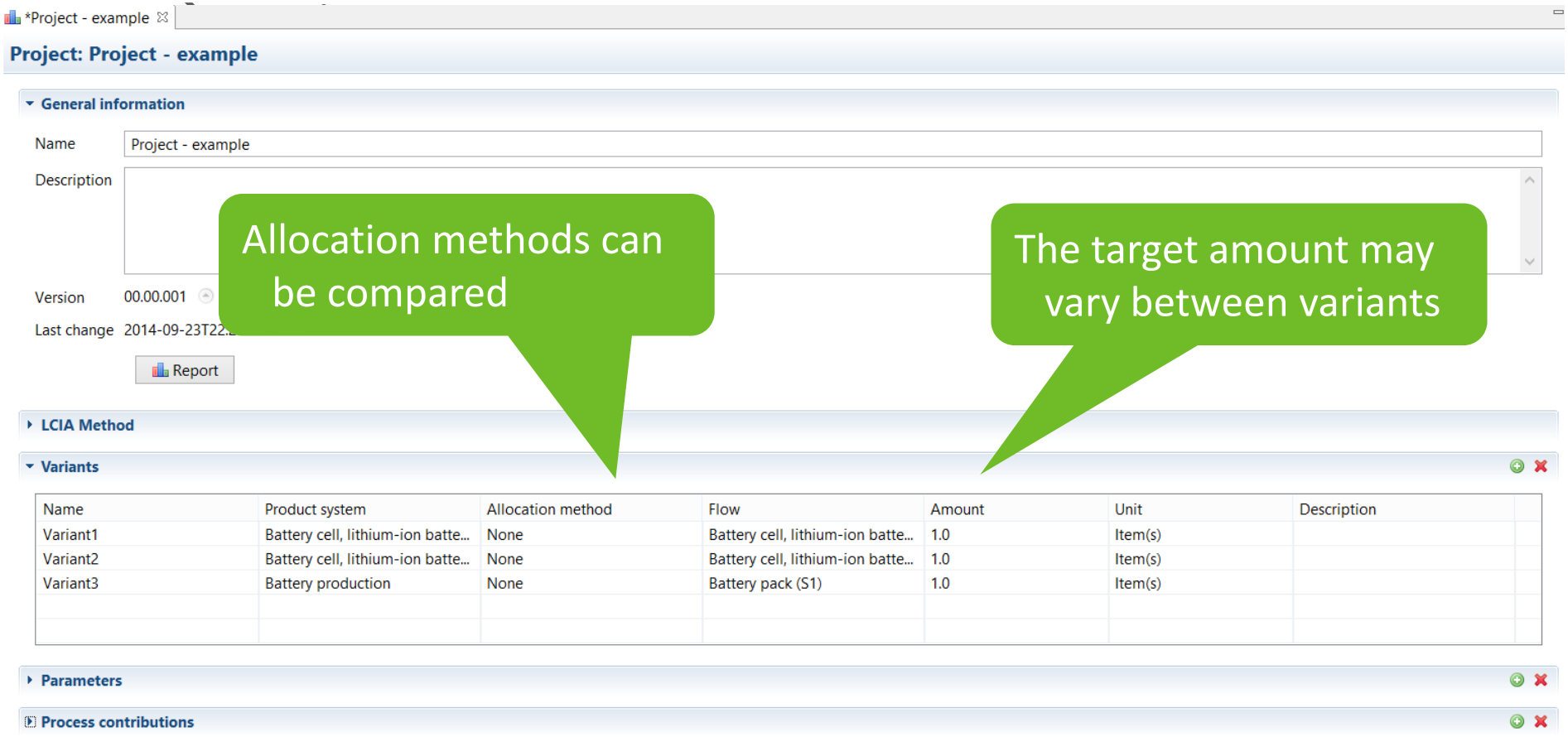
"systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study"

(ISO 14040)

- Are results stable if you change specific aspects?
  - What happens if you expand your system boundaries?
  - What happens if you use other allocation methods?
  - What happens if you change your assumptions?
  -

Comparative assessments in openLCA: Projects

- Same or different product systems can be compared



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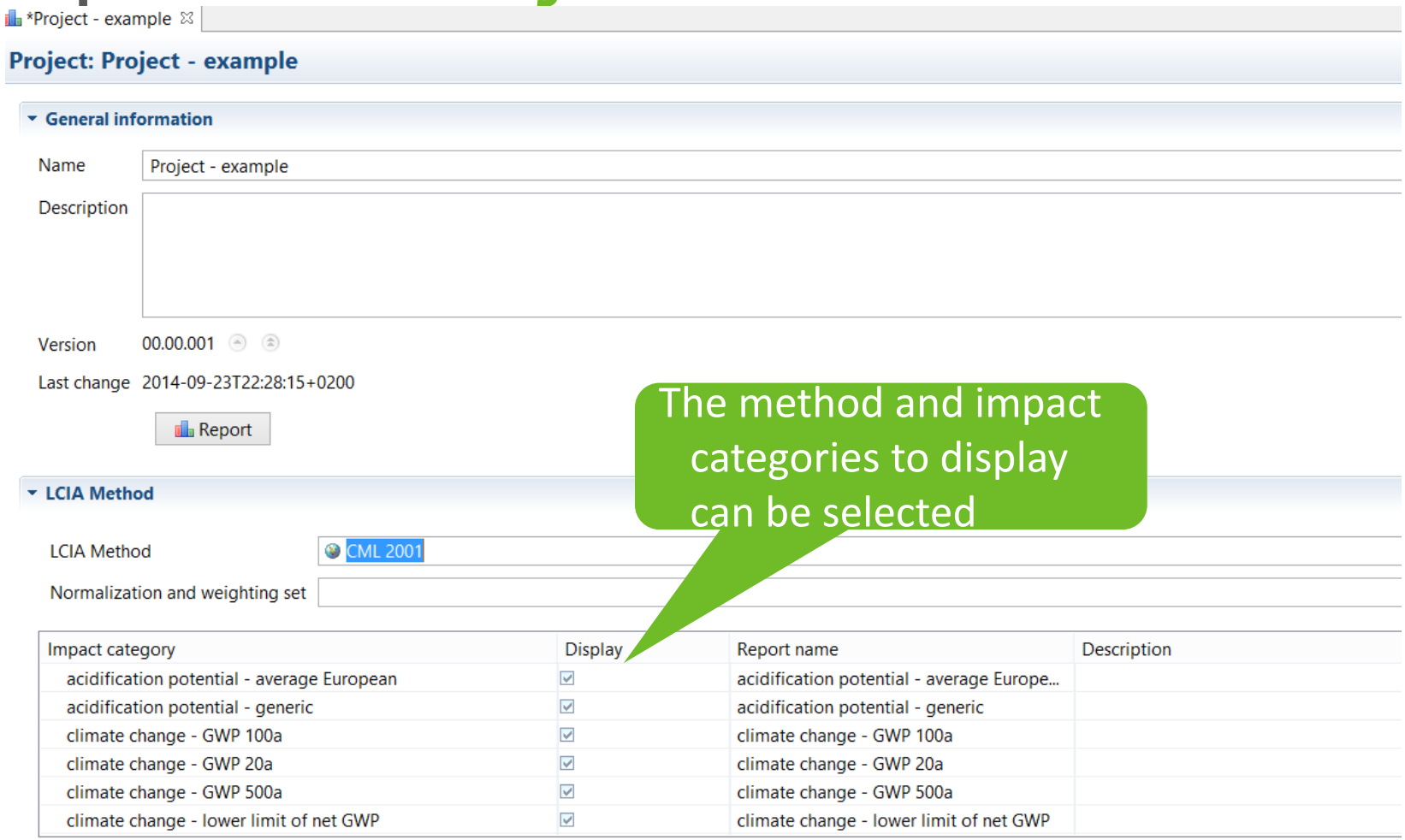
Comparative assessments in openLCA: Projects



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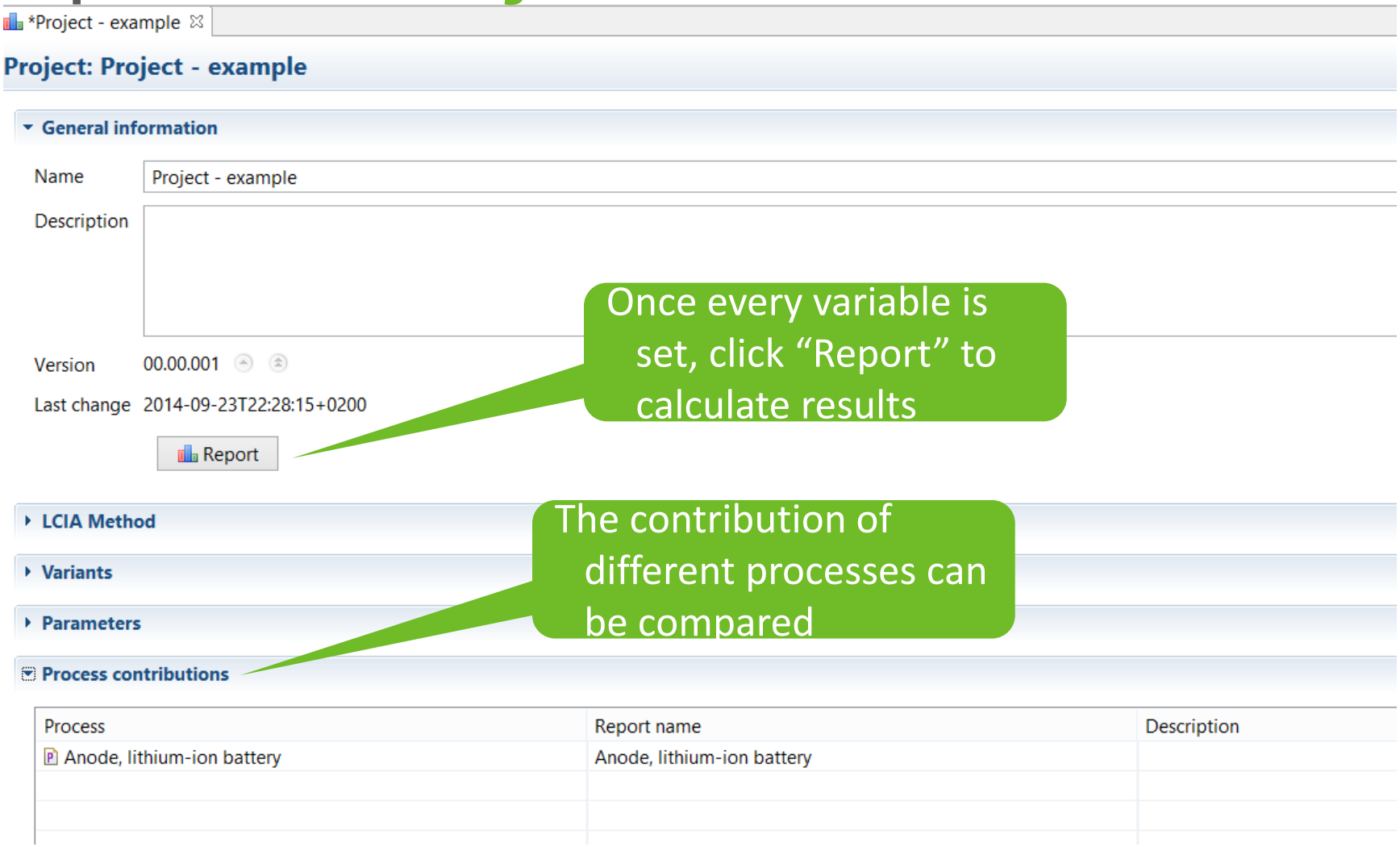
Comparative assessments in openLCA: Projects



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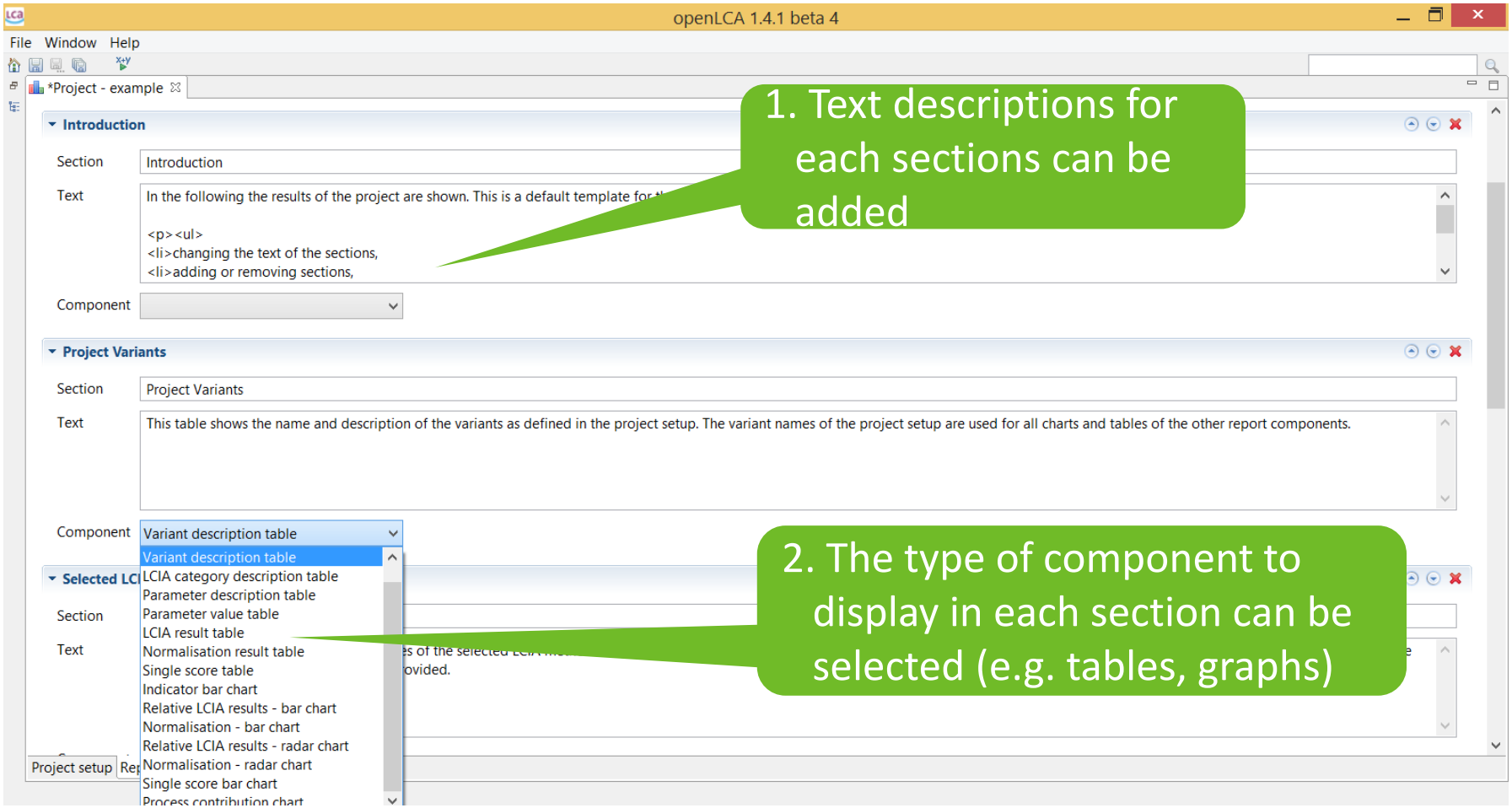
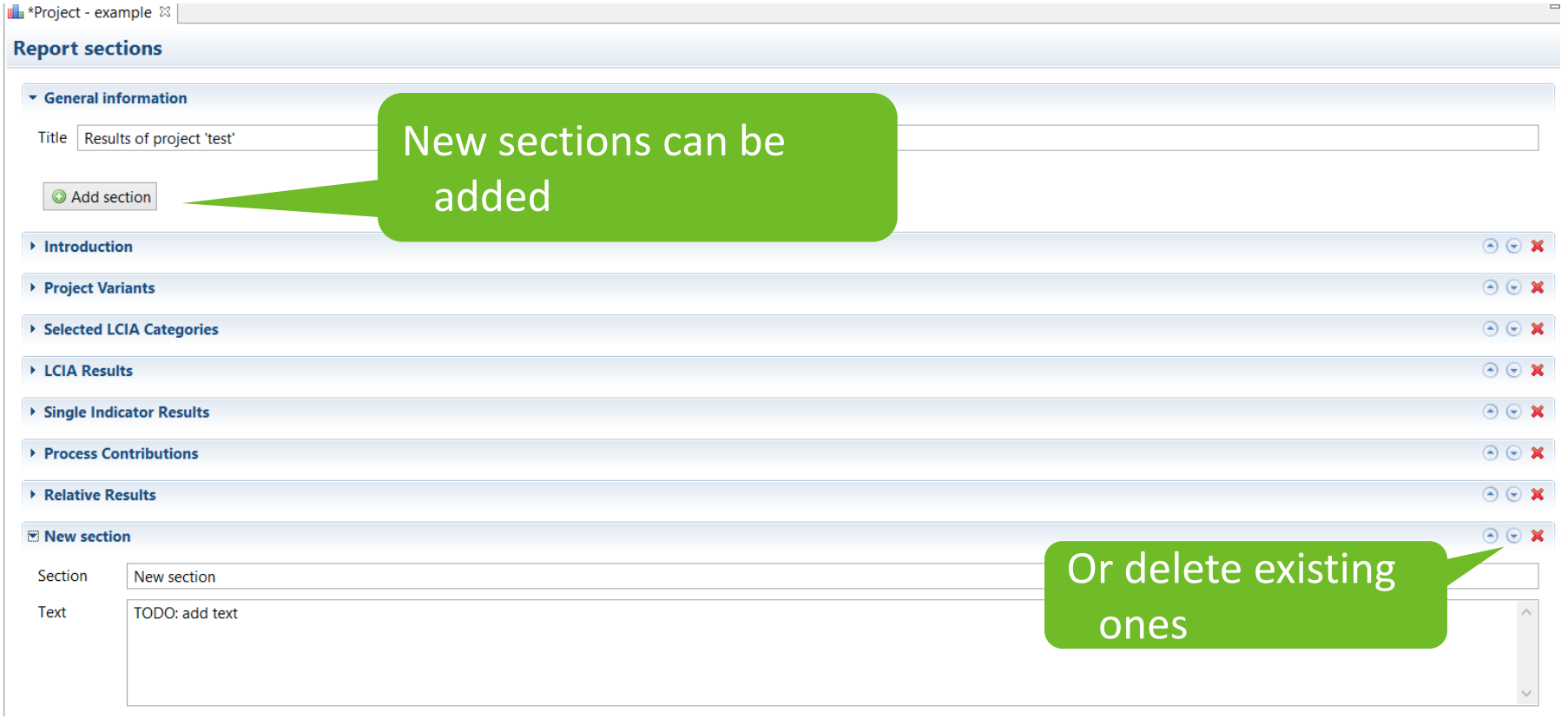
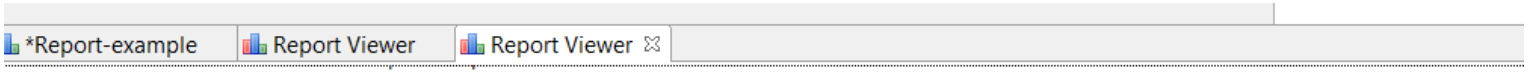
Project: Report



Project: Report sections



Example: Project report



Variant	Description
Variant1	
Variant2	

Selected LCIA Categories

The table below shows the LCIA categories of the selected LCIA method of the project. Only the LCIA categories that are selected to be displayed are shown in the report. Additionally, a user friendly name and a description for the report can be provided.

LCIA category	Unit	Description
climate change - GWP 100a	kg CO2-Eq	
climate change - GWP 20a	kg CO2-Eq	
climate change - GWP 500a	kg CO2-Eq	

LCIA Results

This table shows the LCIA results of the project variants. Each selected LCIA category is displayed in the rows and the project variants in the columns. The unit is the unit of the LCIA category as defined in the LCIA method.

LCIA category	Variant1	Variant2	Unit
climate change - GWP 100a	-1.35354e+2	-9.02359e+1	kg CO2-Eq
climate change - GWP 20a	-1.38358e+2	-9.22388e+1	kg CO2-Eq
climate change - GWP 500a	-1.33922e+2	-8.92811e+1	kg CO2-Eq

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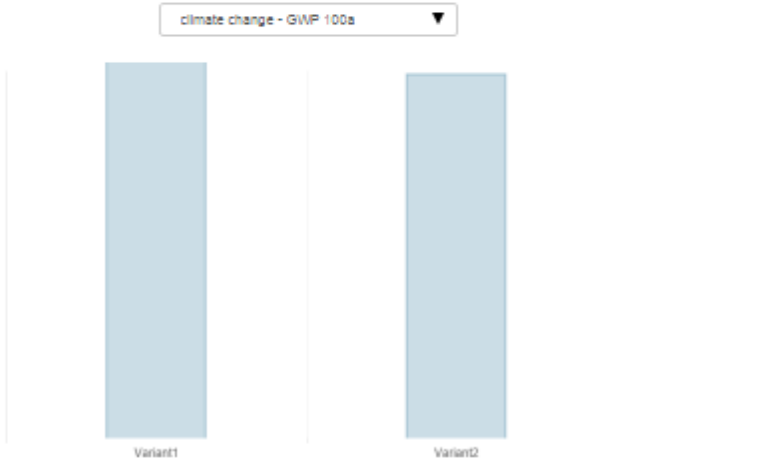
Example: Project report

Single Indicator Results

The following chart shows the single results of each project variant for the selected indicator. You can change the selection and the chart is dynamically updated.



Process Contributions

This chart shows the contributions of the selected processes in the project setup to the variant results of the selected LCIA category. As for the single indicator results, you can change the selection and the chart is dynamically updated.

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Exercise 5: e-car vs. diesel powered car

a) Compare the environmental effects caused by the person transport of 100,000 pkm in an e-car with those caused by the person transport of 100,000 pkm in a diesel car. Use first the impact assessment method IPCC 2007, then USEtox. Which kind of transport is eco-friendlier?

- Create a new project and add the product systems “Transport person e-car (average US) (S1)” and “Transport person diesel car”
- Select the LCIAMs, first IPCC 2007, then USEtox and analyse the results
- 10 min

Exercise 5: e-car vs. diesel powered car

b) Compare the environmental effects of the use of the e-car in different regions (average US, Chile, Mexico, and Norway). What happens?

- Select first IPCC 2007, then USEtox as LCIAM's
- 15 min

Modelling with parameters

- Useful for sensitivity analyses → What impact is the change in one aspect of my earnings?
- Useful for preliminary data: data can be changed easily at the end of your study.
- With different input values can create different versions of the life cycle.
- Reduces the likelihood of calculation errors.

Modelling with parameters

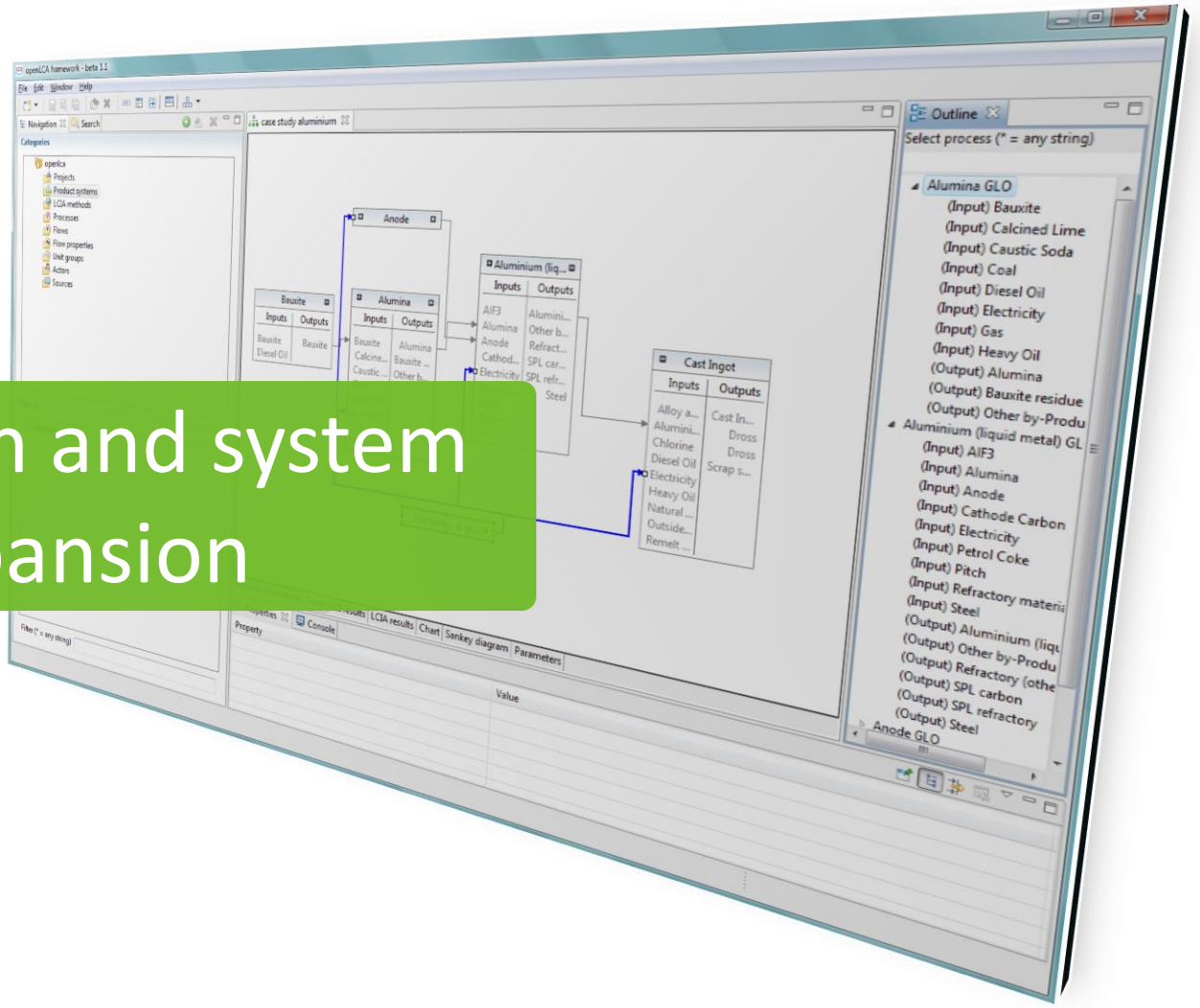
- Entry of calculation rules instead of concrete values → more flexibility
- Available on process, product system, LCIA method, project and database level
- Local and global parameters → parameters can overwrite each other!
- Parameters can be linked to other parameters (i.e. dependent parameters) → Loops are not allowed

Exercise 6: sensitivity analysis with parameters

The diesel car in our case study consumes 8l/100km. What happens, if it consumes 6l/100km and 10l/100km respectively?

- Create a parameter for the fuel consumption of the diesel car.
- The CO_2 emissions depend on the fuel consumption. 1l diesel causes around 2.26kg of CO_2 and 170mg particulates.
- 10 min

Allocation and system expansion



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Multi-output processes

- Often multi-output processes
  - cow (milk, leather, meat)
  - Co-generation (heat, power)
  - Chloralkali elektrolysis (natriumhydroxide, chloric gas, hydrogen)
- Usually you need for LCAs only processes with one output
- Two strategies:
  - Avoiding Allocation: System expansion
  - Elementary flows and products from multi-output processes mathematically divided into multiple processes (= allocation)

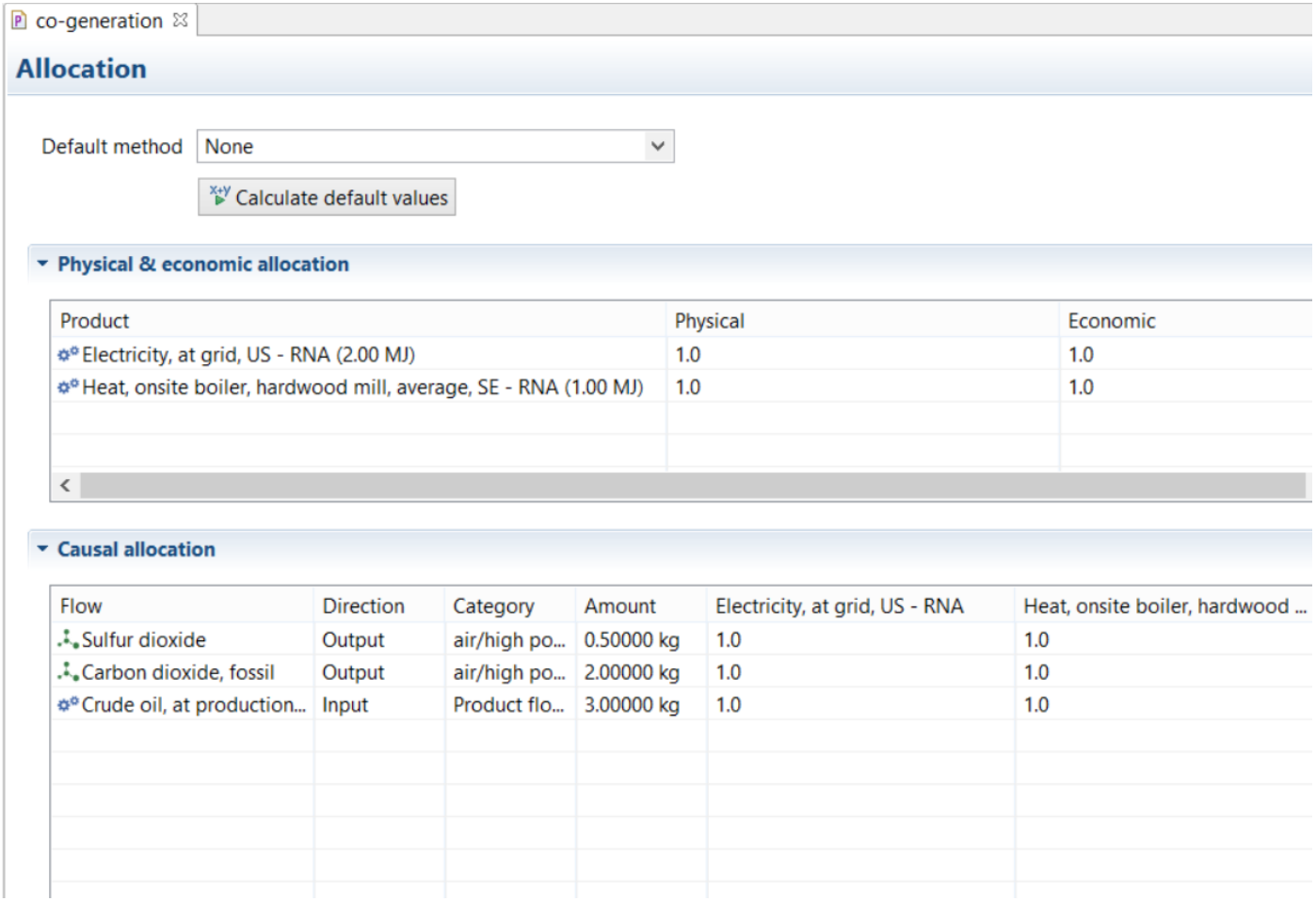
Allocation

"partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems"

(ISO 14040)

- Which allocation methods are possible?
- Allocation methods in openLCA:
  - physical allocation
  - causal allocation
  - economic allocation

Example: co-generation



Product	Physical	Economic
Electricity, at grid, US - RNA (2.00 MJ)	1.0	1.0
Heat, onsite boiler, hardwood mill, average, SE - RNA (1.00 MJ)	1.0	1.0

Flow	Direction	Category	Amount	Electricity, at grid, US - RNA	Heat, onsite boiler, hardwood ...
Sulfur dioxide	Output	air/high po...	0.50000 kg	1.0	1.0
Carbon dioxide, fossil	Output	air/high po...	2.00000 kg	1.0	1.0
Crude oil, at production...	Input	Product flo...	3.00000 kg	1.0	1.0

Exercise 7: Causal allocation

a) Open the process „co-generation unit“ and apply causal allocation.

- If you cannot find the process in the navigation use the search function.
- Assumptions:
  - 60% of the emissions are caused by power production
  - 40% are caused by heat production
- 5 min

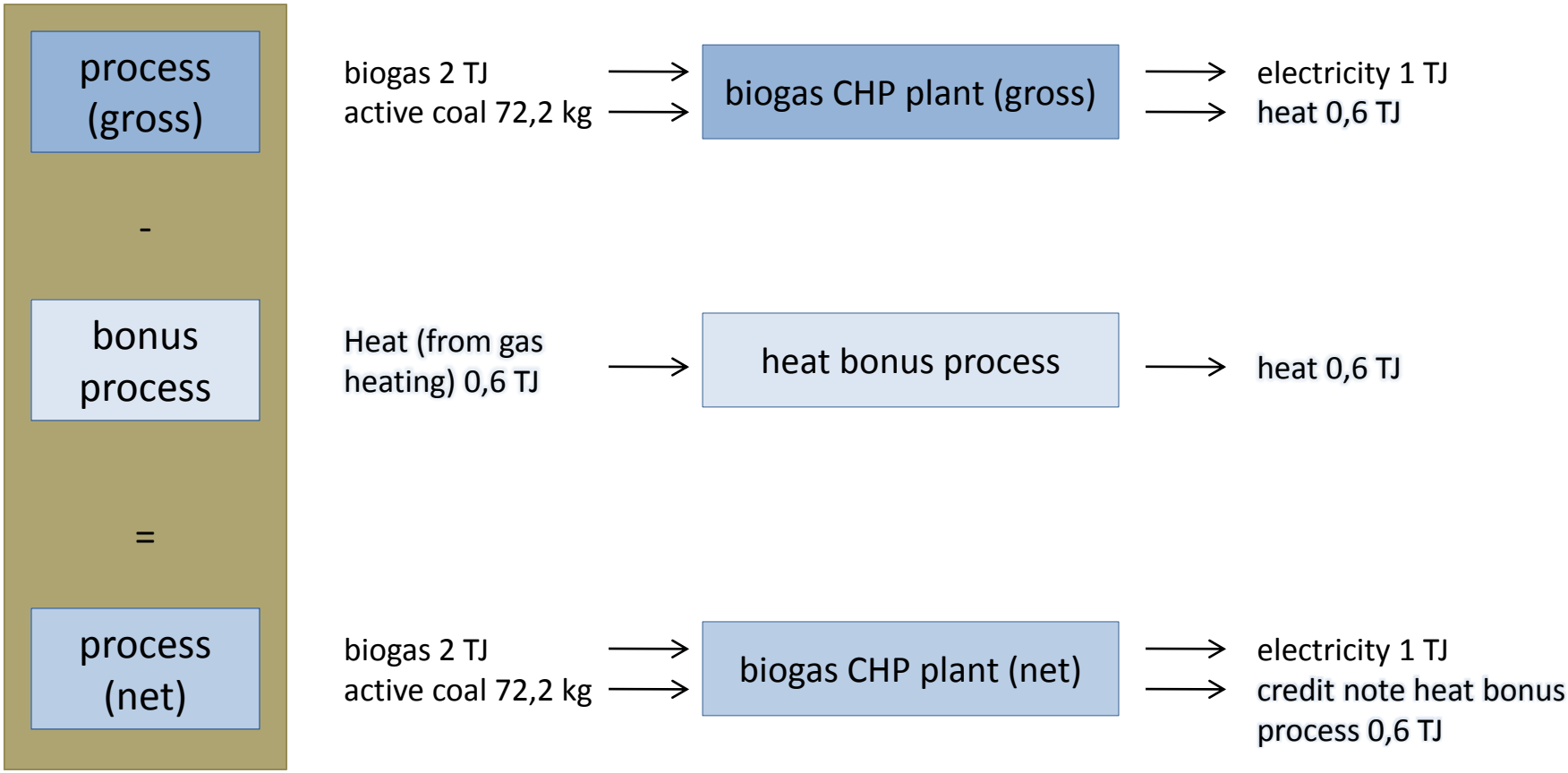
Exercise 7: Economic/physical allocation

b) Apply for the same process „co-generation unit“ now economical allocation.

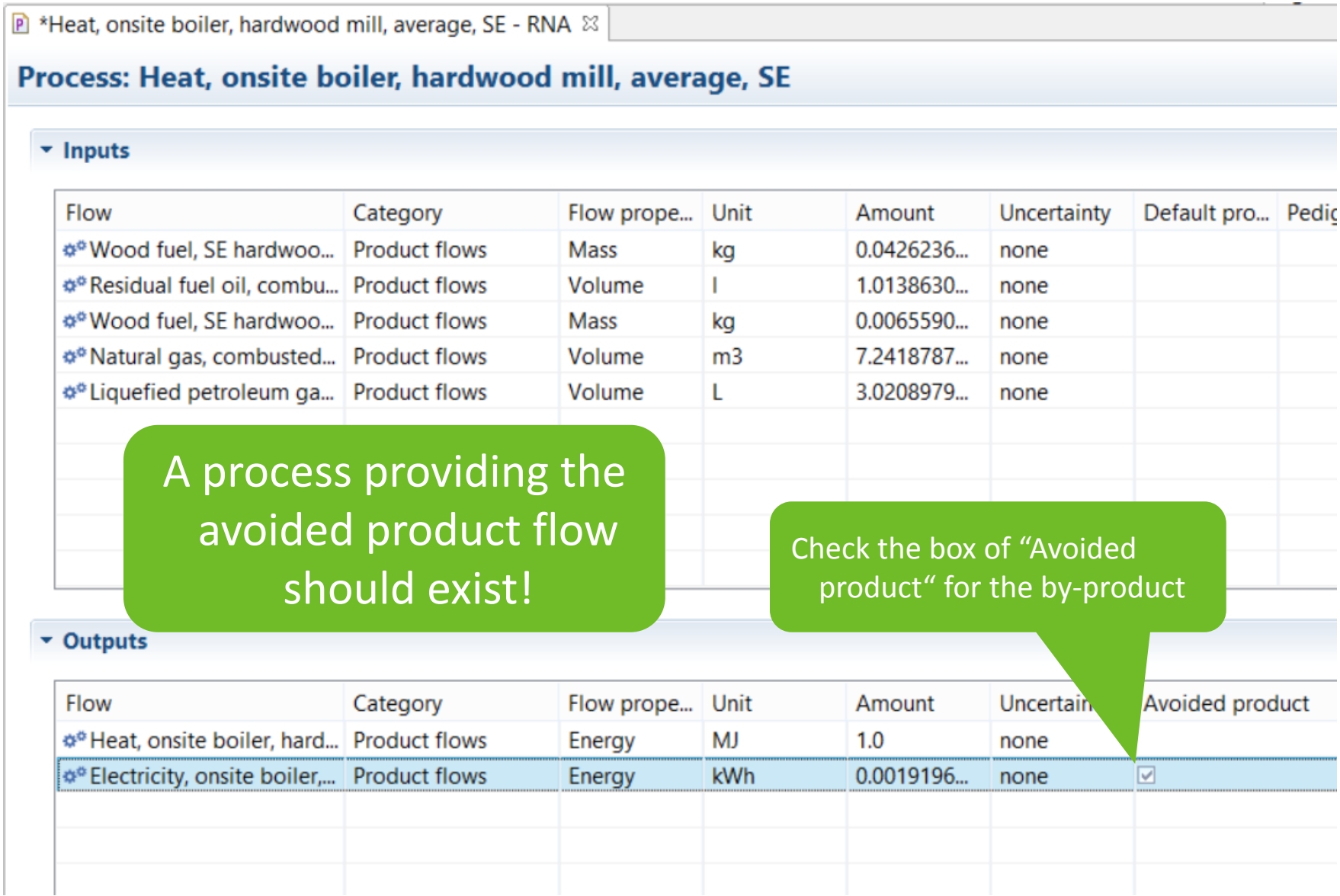
- Assumptions:
  - Market value for electricity: 0.79 €/MJ
  - Market value for heat: 0.36 €/MJ
- 10 min

c) Apply now physical allocation.

System expansion



System expansion in openLCA



Exercise 8: System expansion

- Apply for the process „co-generation unit“ system expansion.
  - Create a new process that creates only heat. Use

Inputs	Amount	Outputs	Amount
Natural gas, at extraction site	0.45 m^3	Heat, gas heating	1 MJ
		Carbon dioxide, fossil	73.8 kg
		Nitrogen oxides	0.0578 kg
		Sulfur dioxide	0.004 kg

- Create a new product system and have a look at the graph.
- 10 min

Free task: Life Cycle Assessment of a disposable shaver

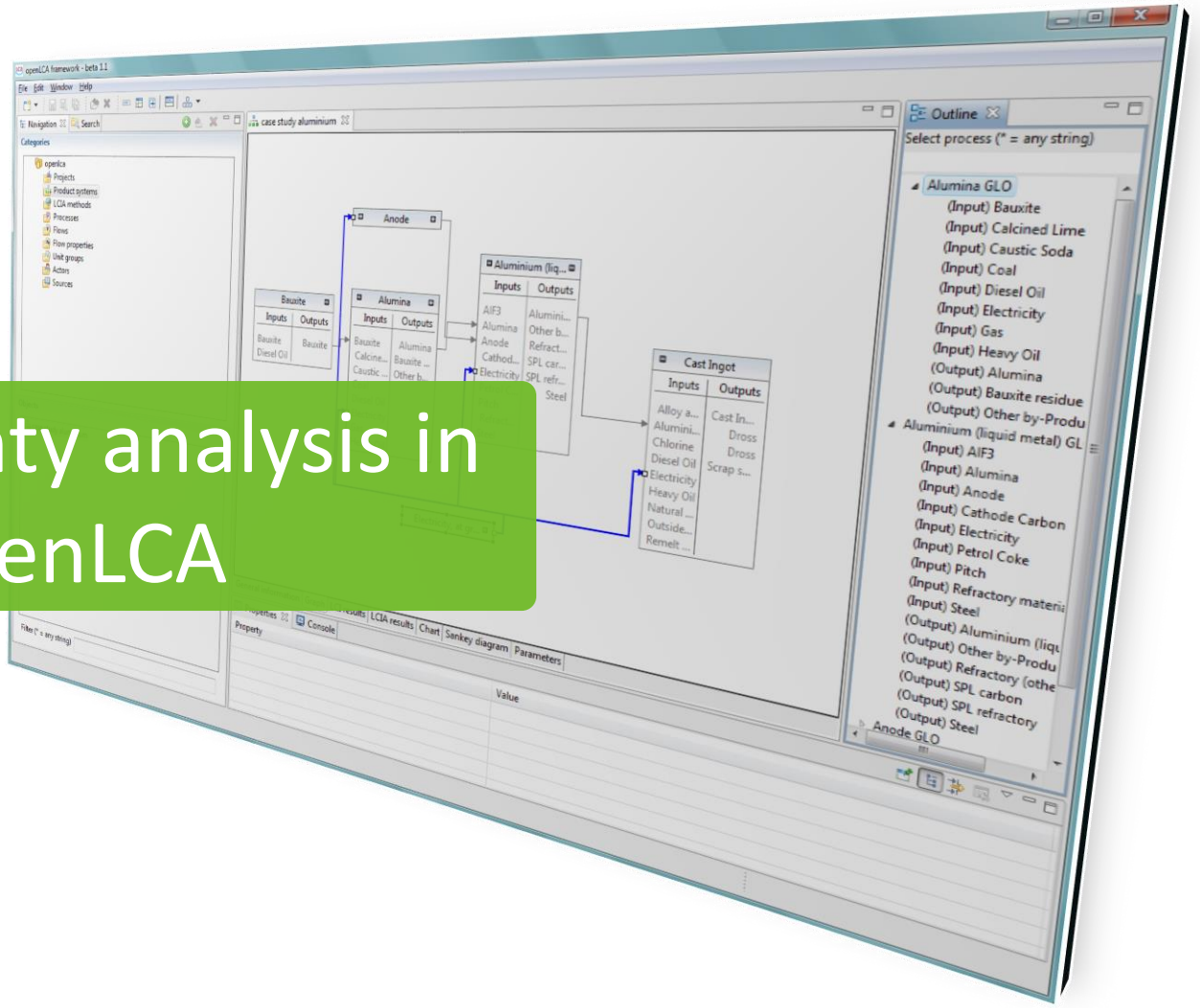
a) Create an LCA of a disposable shaver is produced in China and used in the United States.
   - Some facts:
     - Shaver: head with 2 steel blades weighs 20g; handle is made of 200g ABS (Acrylonitrile-butadiene-styrene copolymer)
     - packing: 55g PET, 10 shaver in one package
     - The shaver can get used for 0.25m∞ skin, then they are dull
     - the shaver will get incinerated, not recycled
- Grouping your model in production, use and disposal phases.
- Describe your approach.
- 30 min

Free task: Life Cycle Assessment of a disposable shaver

b) Create your shaver environmentally friendly!

- Apply common eco-design rules and produce a more environmentally friendly shaver.
- Explain your approach and your results.
- 30 min

Uncertainty analysis in openLCA



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Types of uncertainty

- Data uncertainties
  - Uncertainties through measurements and estimations
  - Uncertainties through the use of non-ideal data sets (region, technology, time period)
  - Uncertainties of consumer behaviour regarding use and disposal of products
  - …
- Uncertainties in LCIAM due to lack of scientific knowledge
- …

Data uncertainty: basics

- It is basically not possible to measure error-free.
- But: Data uncertainty is in contrast to other uncertainties quite easy to handle with statistical methods (e.g. Monte Carlo simulation, Pedigree approach, interval calculations, with fuzzy logic approach or the Gaussian error propagation formulas)

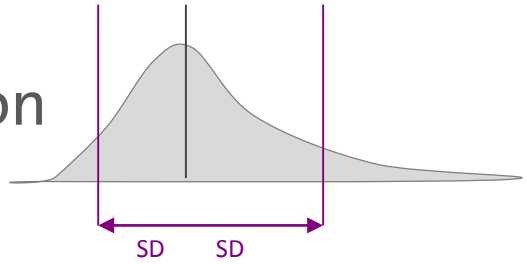
→ Measurements have a distribution; the scope is defined as standard deviation.

→ Results have also a standard deviation and a mean as well as an average:

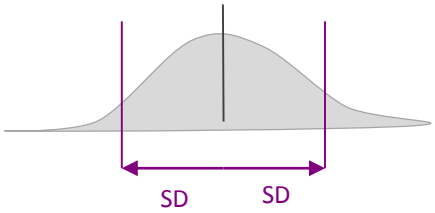
- The median is the mean value (for 100 samples the 50th sample is the median).

Uncertainty distribution

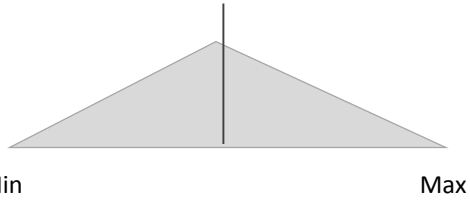
- Log-normal distribution



- Normal distribution



- Triangle distribution



- Uniform distribution

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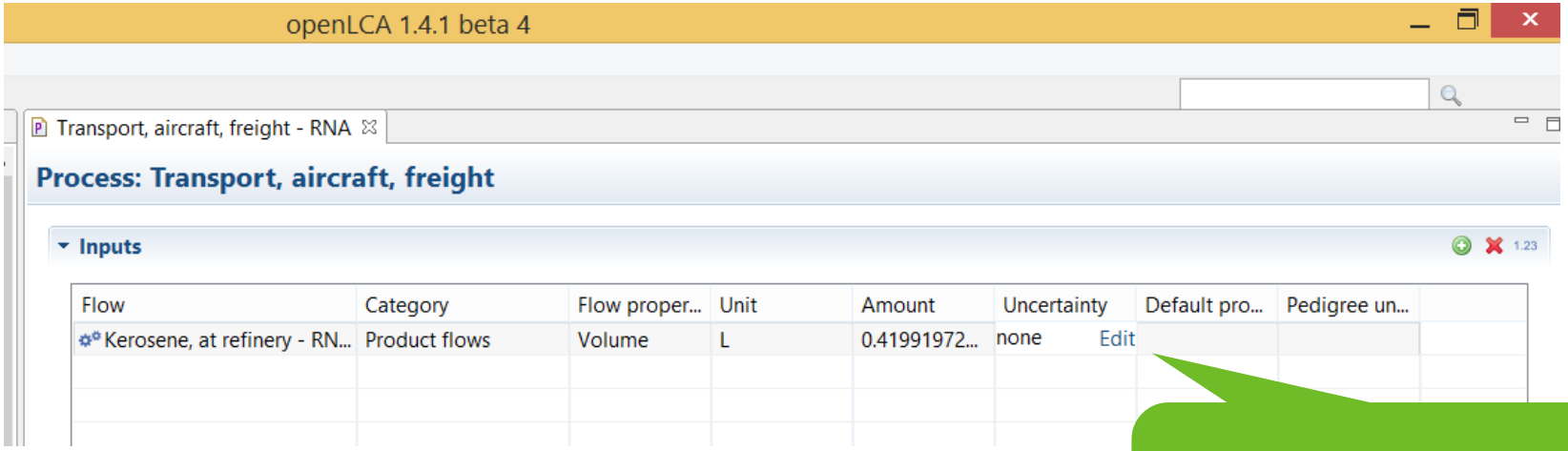
The Monte Carlo simulation

- Simulation varies entry data of the model calculation randomly according to the uncertainty distribution.
- An uncertainty distribution for the calculation result is provided.
- By a breakdown of the value ranges in individual intervals and the alternate drawing from different intervals, a more uniform distribution of the results is achieved, thereby reducing the number of iterations required.

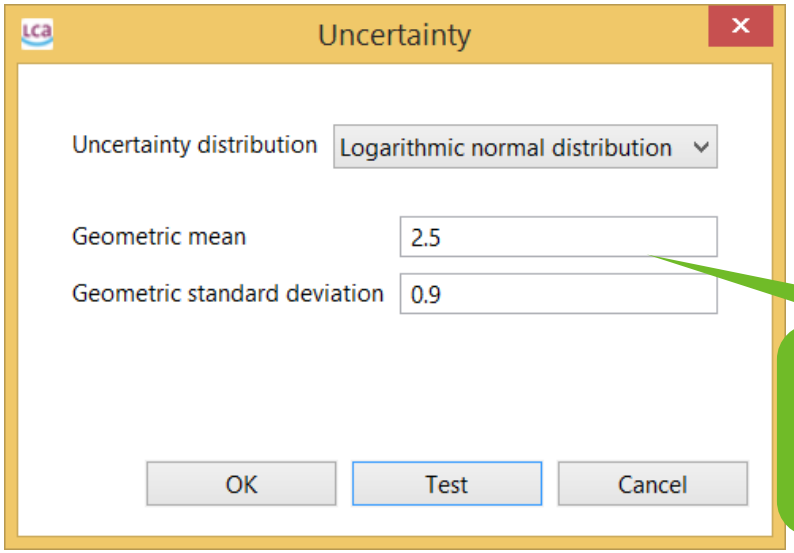
The Monte Carlo simulation

- First, uncertainty data are added to all flows in the processes (Distribution, standard deviation, min / max, etc.); only for the reference output no uncertainty distribution is assumed.
  - Uncertainty data can be defined also for parameters and LCIA characterisation factors
- Then, in the calculation window the Monte Carlo simulation can be selected and the number of simulations can be entered.
- Uncertainties are calculated for each flow or impact

Adding uncertainty information

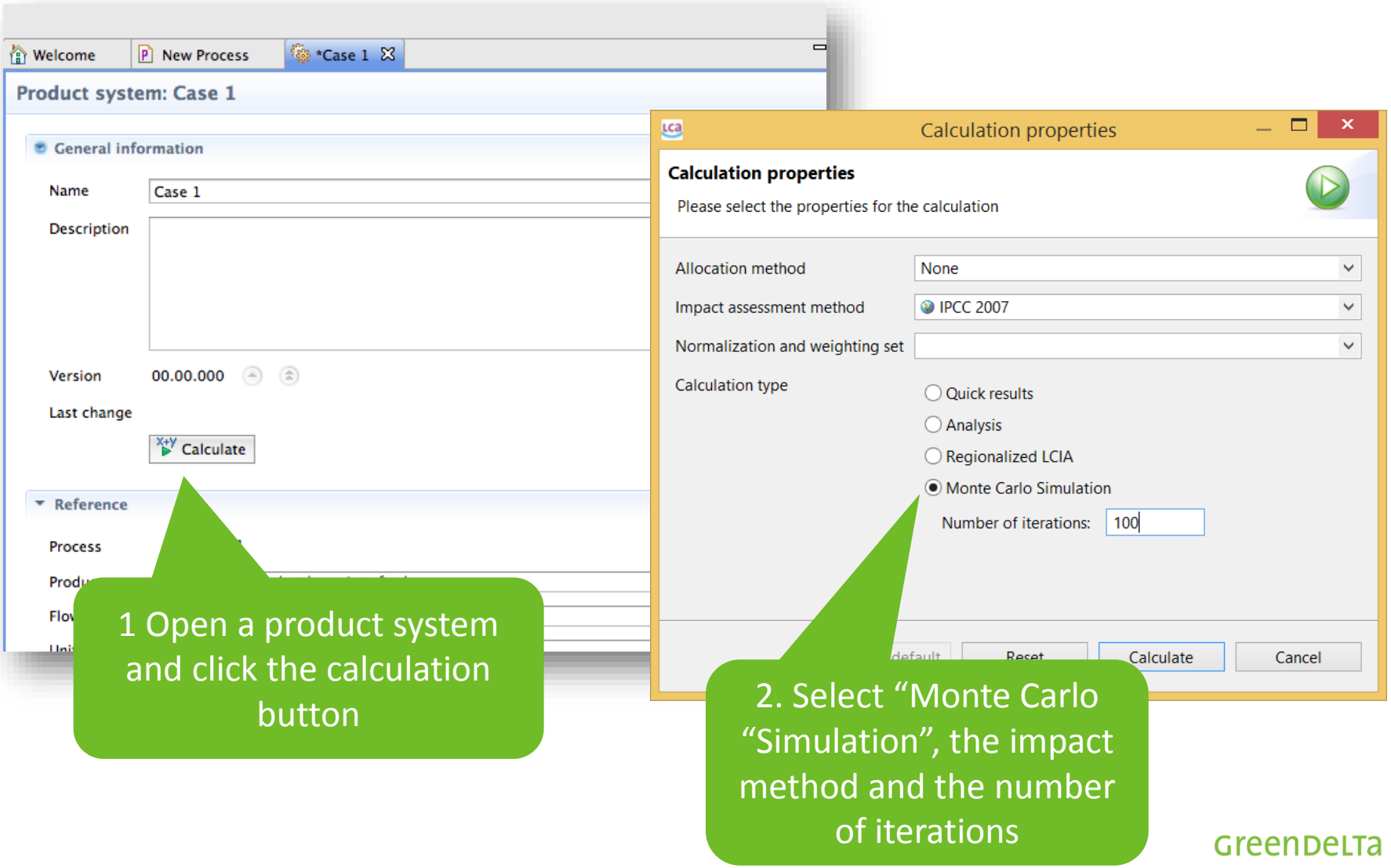


1 Select “Edit” in the uncertainty field



2. Define the values of the distribution

Starting the Monte Carlo simulation



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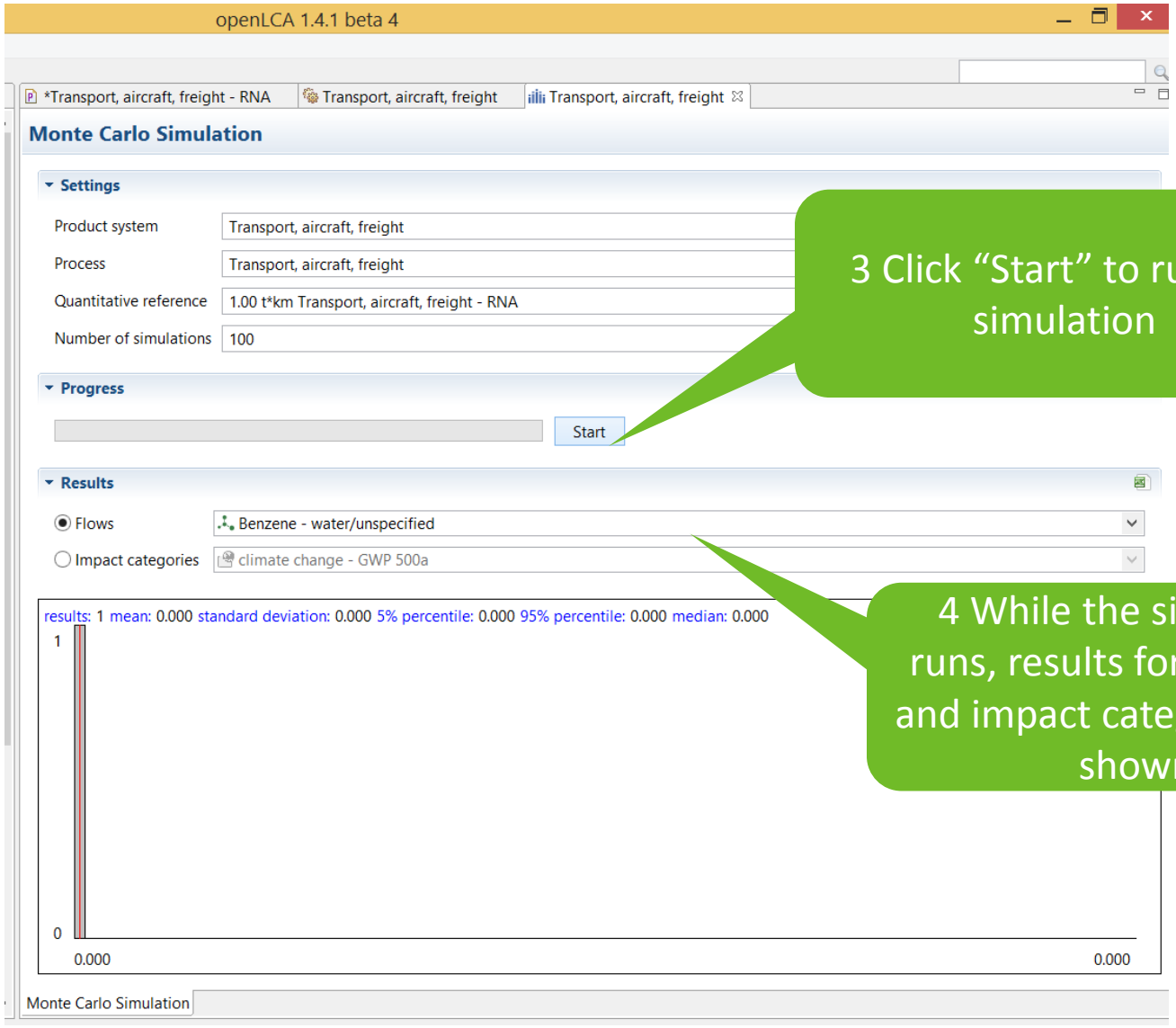
Starting the Monte Carlo simulation



3 Click “Start” to run the simulation

4 While the simulation runs, results for each flow and impact category can be shown

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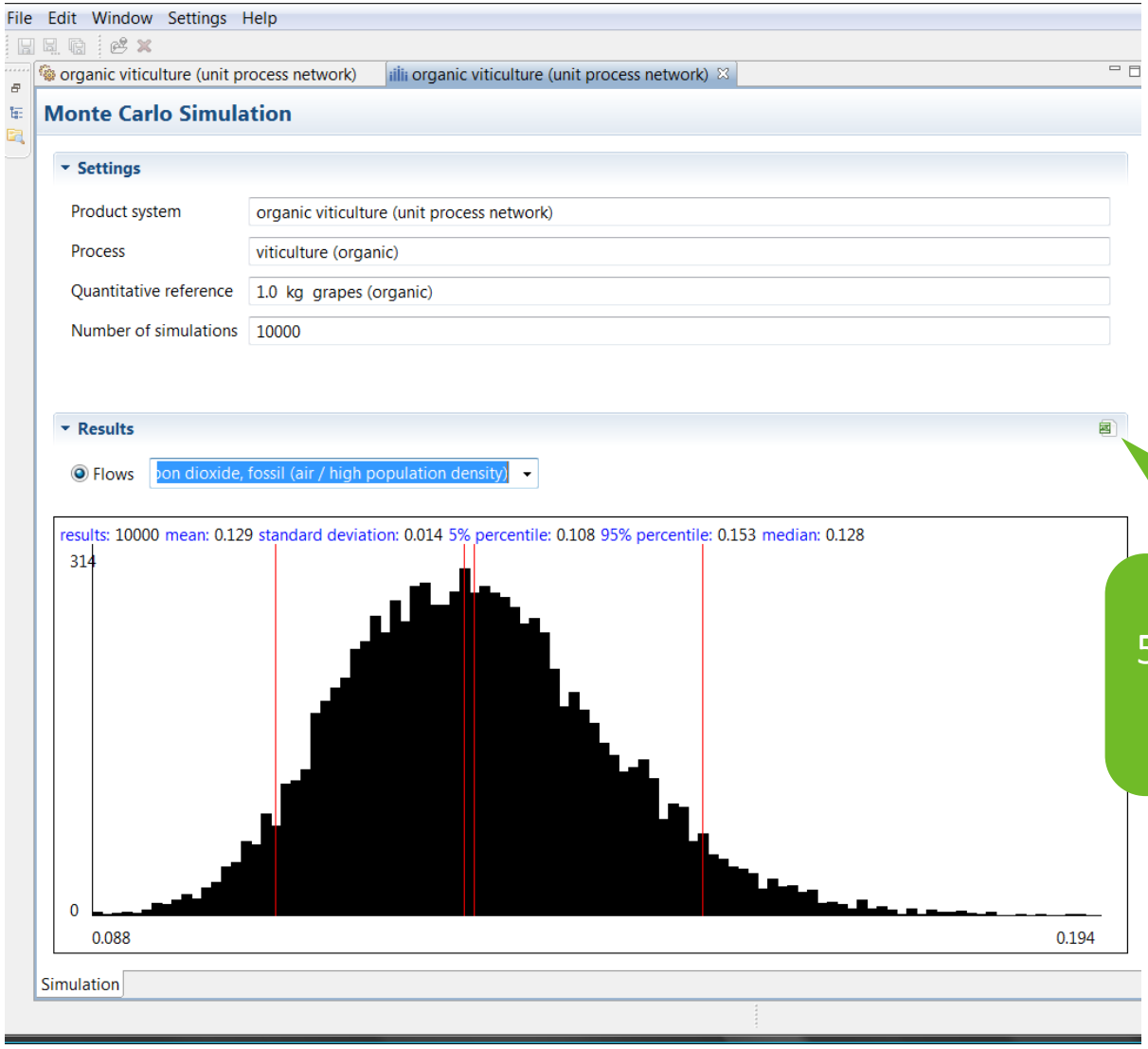
Results of the Monte Carlo simulation



5 Results can be exported as Excel

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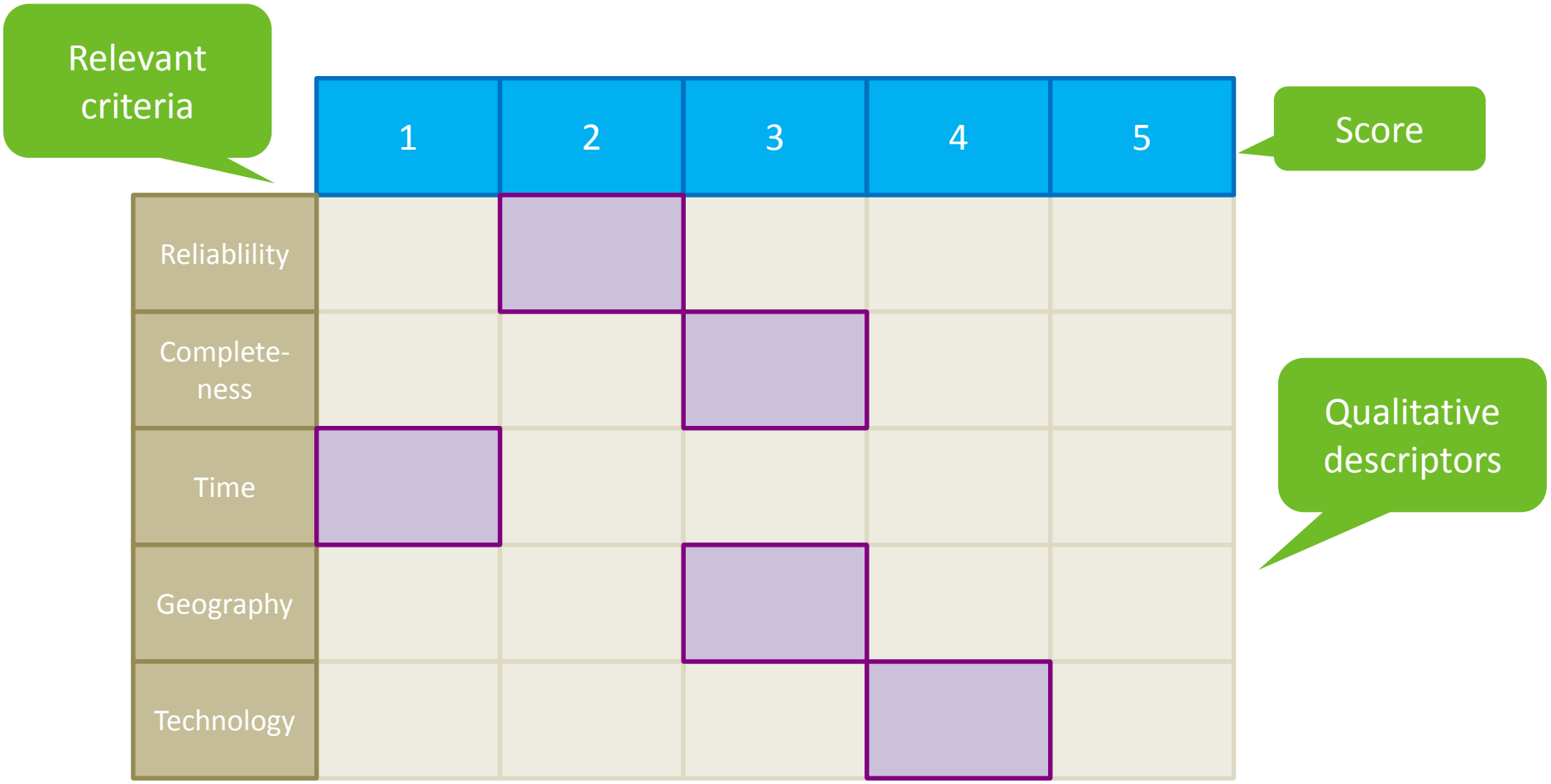
The Pedigree approach in ecoinvent

- Developed by Weidema and Wesnaes in 1996 as part of their NUSAP scheme to estimate all kinds of uncertainty
- A pedigree illustrates key aspects in a matrix:
  - Columns represent pedigree criteria
  - Lines represent qualitative characterisations of each criteria by expressing different levels of data quality or uncertainty
- Quantitative scores are assigned to each qualitative description
- The pedigree matrix was transferred in 1996 by

The Pedigree approach in ecoinvent

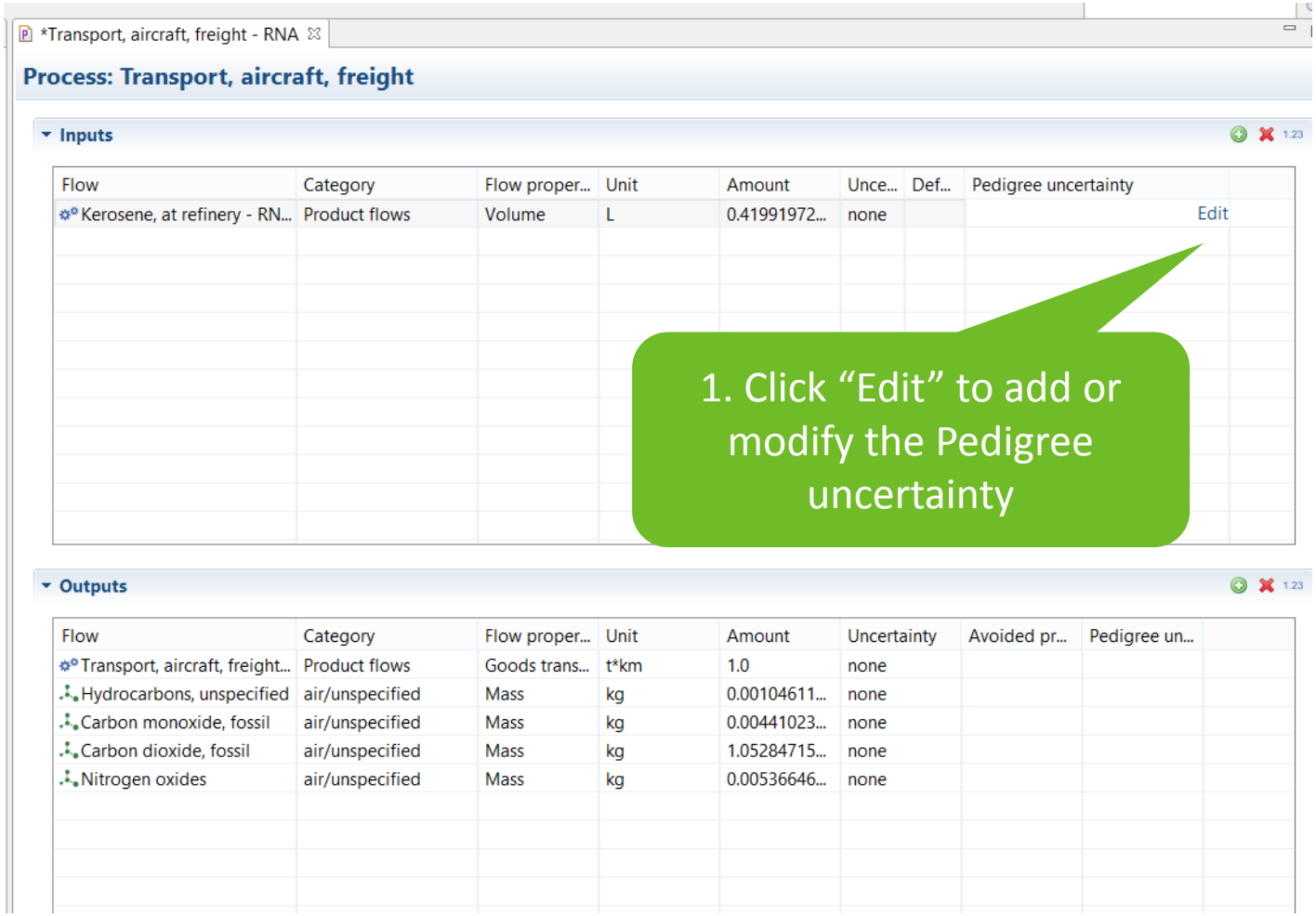


The Pedigree approach in ecoinvent

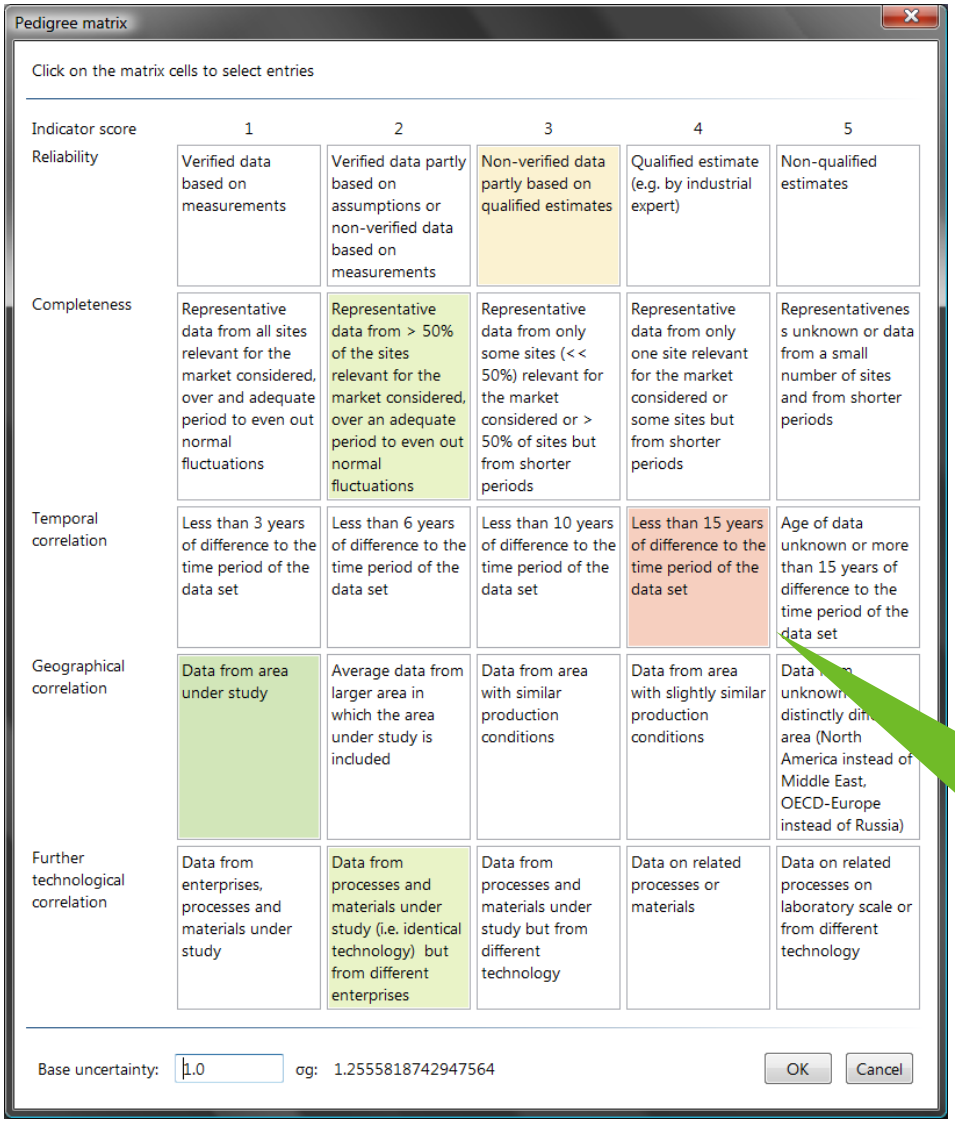
	1	2	3	4	5
Reliability	1.00	1.05	1.10	1.20	1.50
Complete-ness	1.00	1.02	1.05	1.10	1.20
Time	1.00	1.03	1.2	1.20	1.50
Geography	1.00	1.01			1.10
Technology	1.00		1.50	1.50	2.00

Default uncertainty factors

The Pedigree matrix in openLCA



The Pedigree matrix in openLCA



2. Click in the different fields to rate the data quality, add a basic uncertainty and click „OK“.

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Basic uncertainty

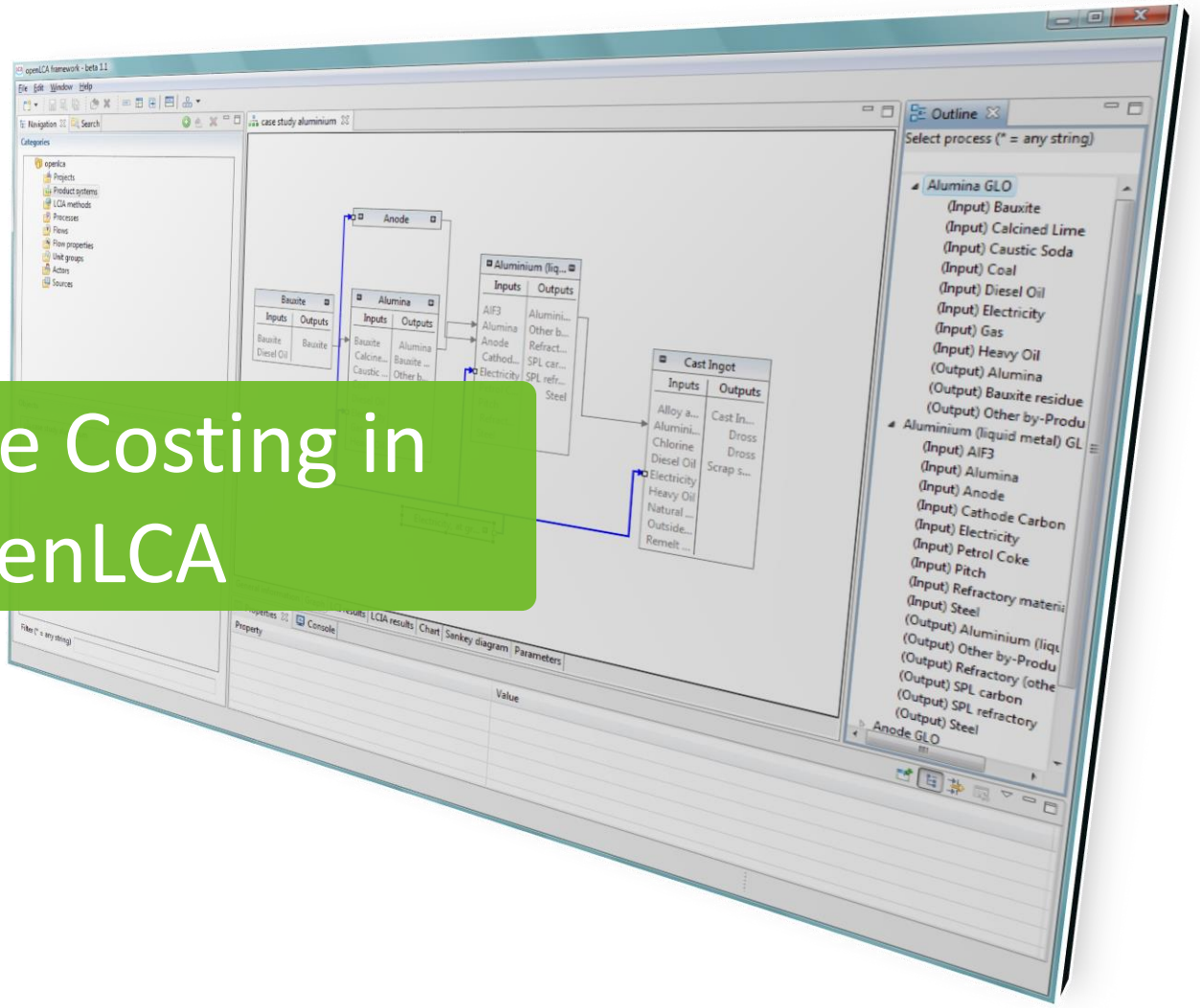
- Developed by the ecoinvent centre:

Basic uncertainty	Value
Energy requirement	1.05
Transportation services	2.00
Infrastrukture	3.00
CO2 in air	1.05
PM2.5 of combustion	3.00
Heavy metal in water	5.00
Radionuclides in water	3.00

Calculation of the Pedigree uncertainty

- So far the pedigree matrix is only used for documentation purposes!
- In later openLCA versions the pedigree values will be used to determine all uncertainty parameters to run a Monte Carlo simulation (Distribution, standard deviation, min / max, etc.)
- Derived uncertainties can then be calculated using the Monte Carlo simulation.

Life Cycle Costing in openLCA



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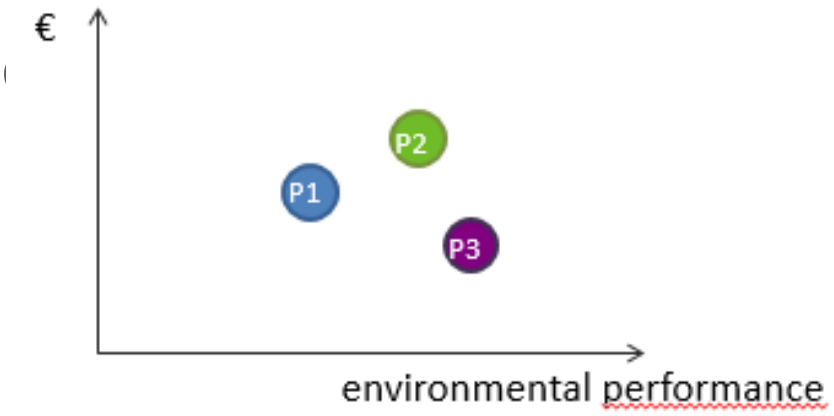
Motivation of LCC

- LCC gives an overview over all costs that arise through the entire life cycle of a product.
- 2 perspectives: manufacturer and consumer
- Important for goods that entail high costs through maintenance (e.g. car or train) or for the comparison of different products
- lation of eco-



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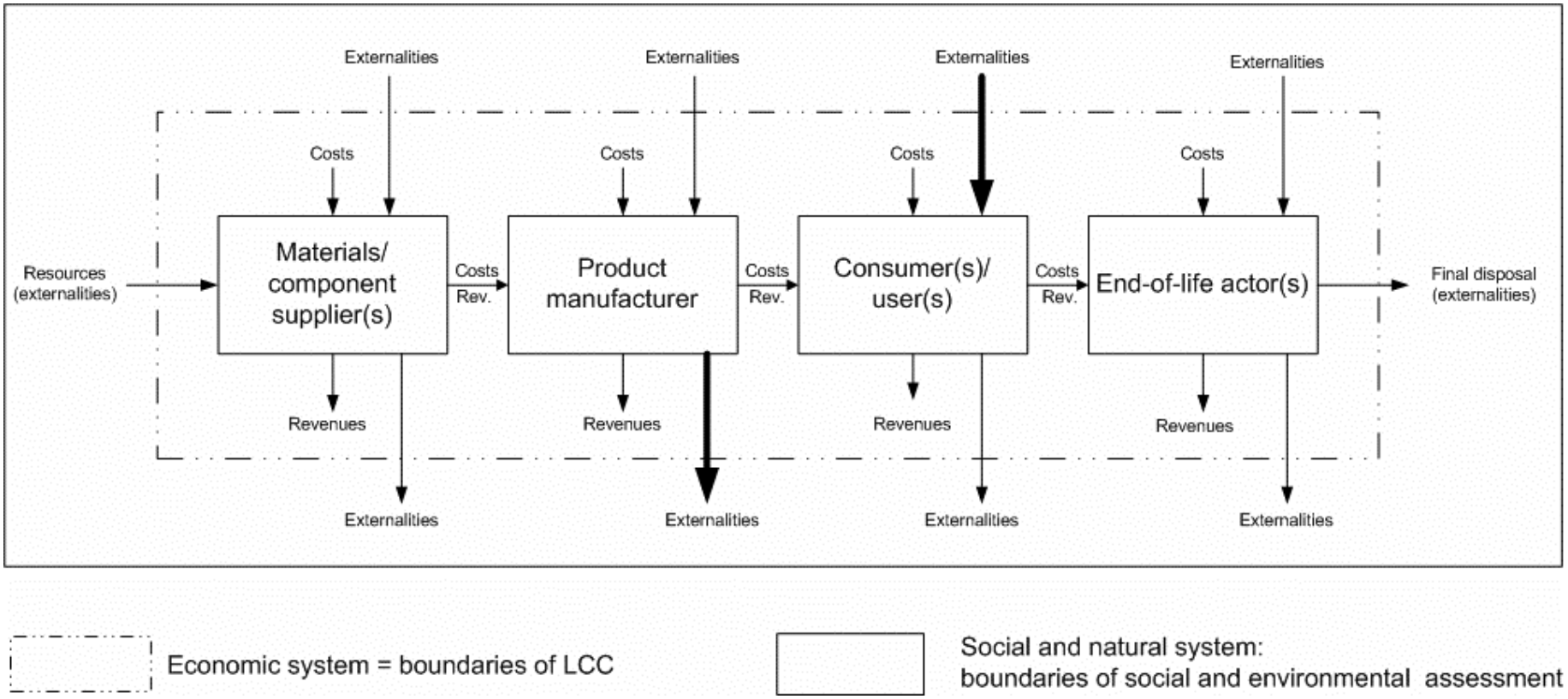
Example: The consumer perspective

	Opel Corsa	Fiat Punto	Citroen Advance
Purchase price	10,945 €	10,890 €	10,9990 €
Costs per year			
Buy price	1,977 €	2,164 €	1,936 €
Taxes, insurance, etc.	1,753 €	1,911 €	1,527 €
Operating costs	909 €	964 €	998 €
Repair costs	352 €	490 €	318 €
Total yearly costs	**4,991 €**	**5,529 €**	**4,779 €**

Scope of LCC



(Rebitzer G., Hunkeler D. (2003): Life Cycle Costing in LCM: Ambitions, opportunities, and limitations, Discussing a framework. In: Int J LCA 8 (5), pp. 253-256)

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LCC in openLCA

- Two possibilities:
  - Costs are treated as environmental impacts (costs are emissions)
    - Costs are considered as elementary flows
  - Use of the costs tab in the process editor
    - Only cost categories can be considered

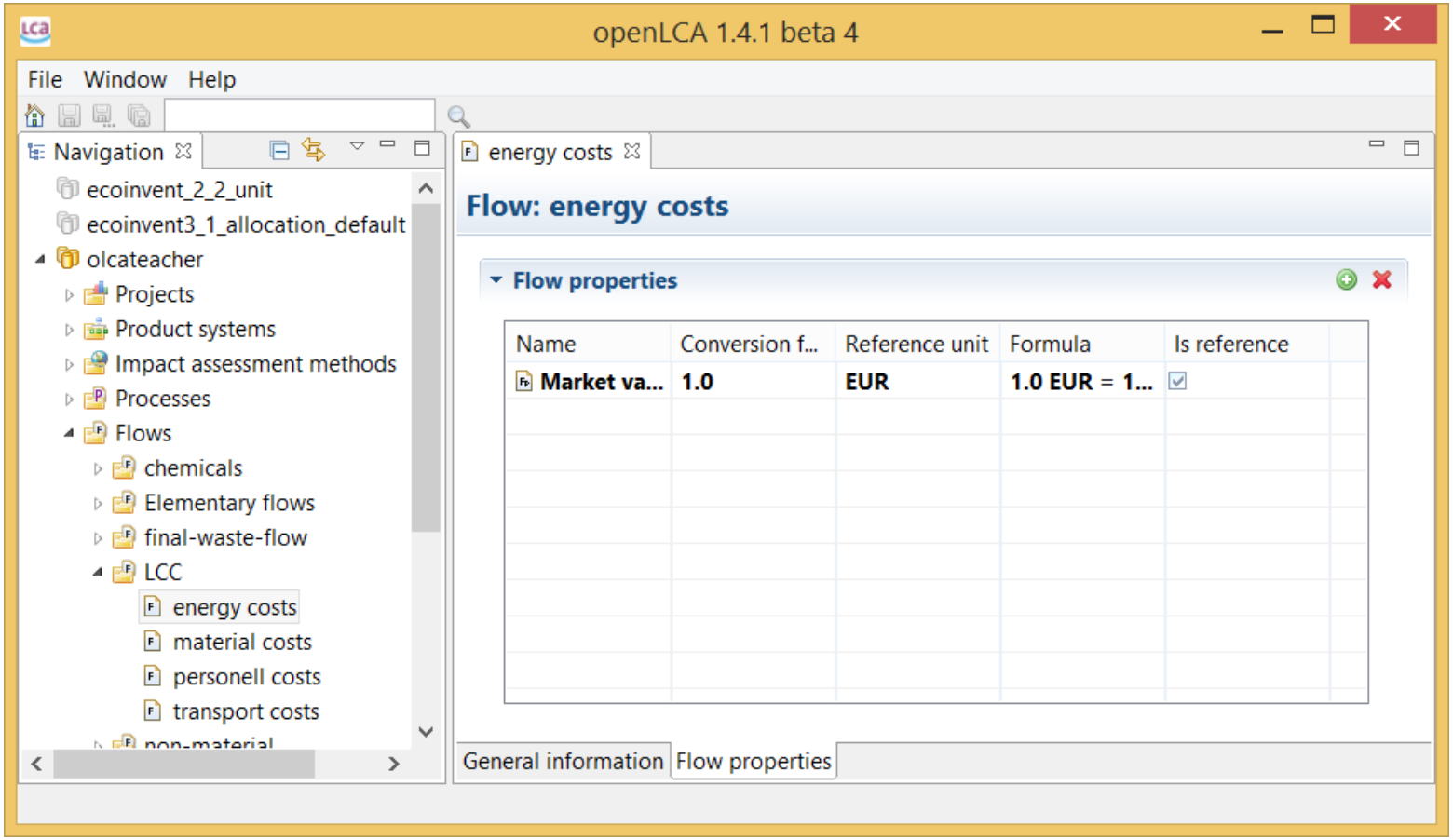
The costs tab option is currently only included process documentation purposes → No calculation is available!

Option 1: Costs as elementary flows

- In a first step, specific or general cost flows are defined (e.g. [(material costs) for PET], [(labour costs) for engineers], [(transport costs) for road transportation], etc.).
- These cost flows are assigned to processes (treated as emissions).
- It is recommended to create a new impact assessment method which adds up the cost flows. Different cost categories (→ impact categories) can be defined (e.g. manufacturing costs, transport costs, disposal costs, ...)

Option 1: Procedure in openLCA (I)

- Creation of costs flows as elementary flows



Option 1: Procedure in openLCA (II)

- Adding costs flows to processes (outputs)

Process: Blade, steel LCC

Inputs

Flow	Category	Flow proper...	Unit	Amount	Uncertainty	Defaul
Steel, billets, at plant - US	Product flows	Mass	g	2	none	
Electricity, at grid, CN	Product flows	Energy	kWh	0.05	none	

Outputs

Flow	Category	Flow proper...	Unit	Amount	Uncertainty	Avoide
Blade, steel_LCC	Product flows	Number of ...	Item(s)	1	none	
energy costs	LCC	Market valu...	EUR	0.2*0.05	none	
personell costs	LCC	Market valu...	EUR	0.004	none	
material costs	LCC	Market valu...	EUR	0.02*0.90	none	

Option 1: Procedure in openLCA (III)

- Creation of an impact assessment method

Impact categories

Name	Description	Reference unit
Energy costs		EUR
Material costs		EUR
Personnel costs		EUR
Transport costs		EUR

Impact assessment method: LCC

Impact factors

Impact category: Energy costs

Flow	Category	Flow property	Unit	Factor	Uncertainty
energy costs	LCC	Market value US 2000, bulk prices	EUR/EUR	1.0	none

Option 1: Procedure in openLCA (IV)

- Calculate the product system costs results with the

LCIA Results

LCIA Results

Impact category	Result	Reference unit
Material costs	0.21268	EUR
Transport costs	0.05000	EUR
Personnel costs	0.10050	EUR
Energy costs	0.06646	EUR

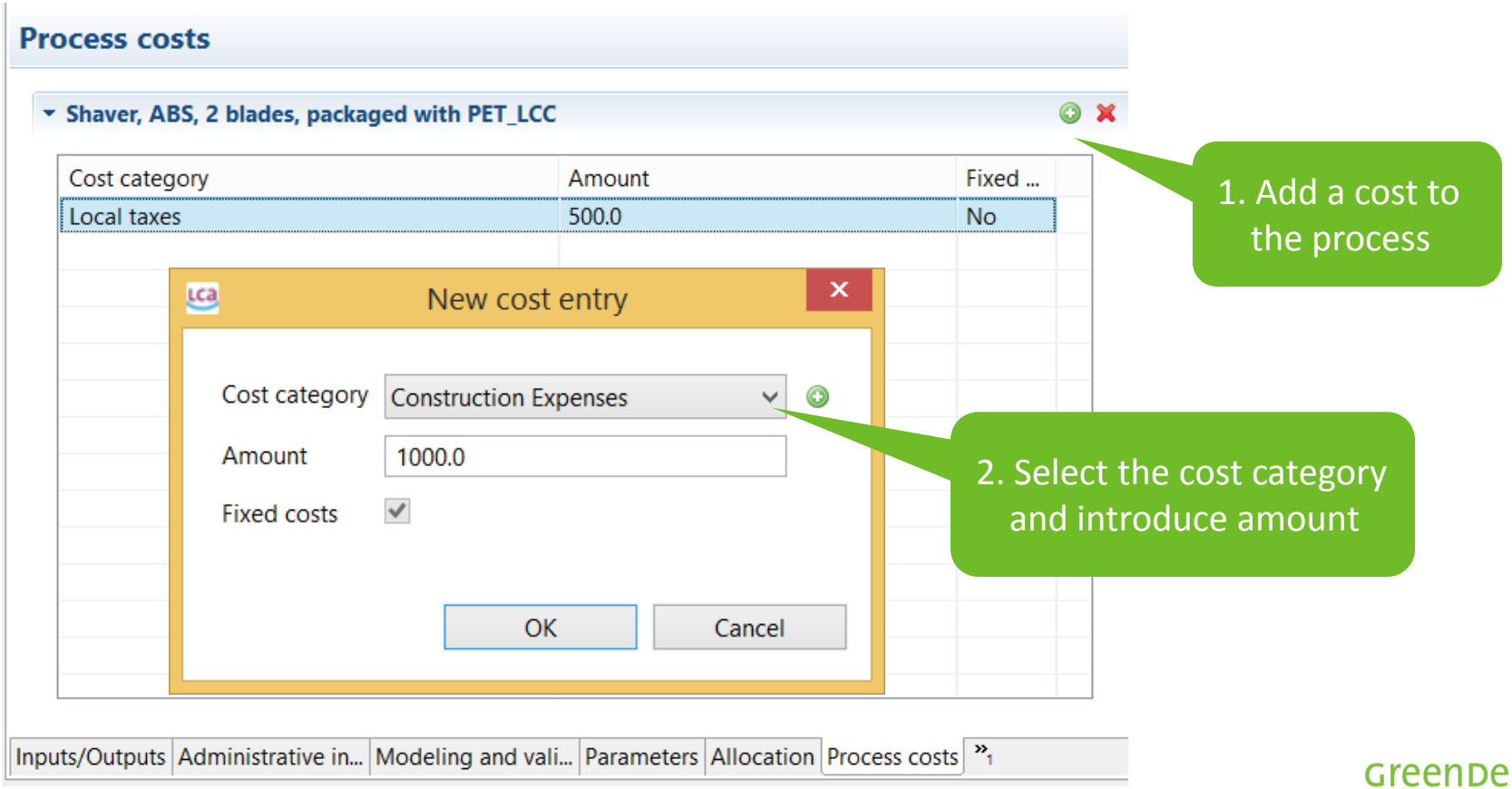
Impact contributions

Impact category: Material costs

Contribution	Process	Amount	Unit
74.99%	Use phase shaver, ABS, 2 blades LCC - US	0.15950	EUR
16.93%	Blade, steel LCC - GLO	0.03600	EUR
07.50%	Shaver handle, ABS LCC - GLO	0.01595	EUR

Option 2: Costs tab in the process editor

- Cost categories are defined on the process level. Values are assigned to these cost categories.



Free exercise: LCC of a shaver

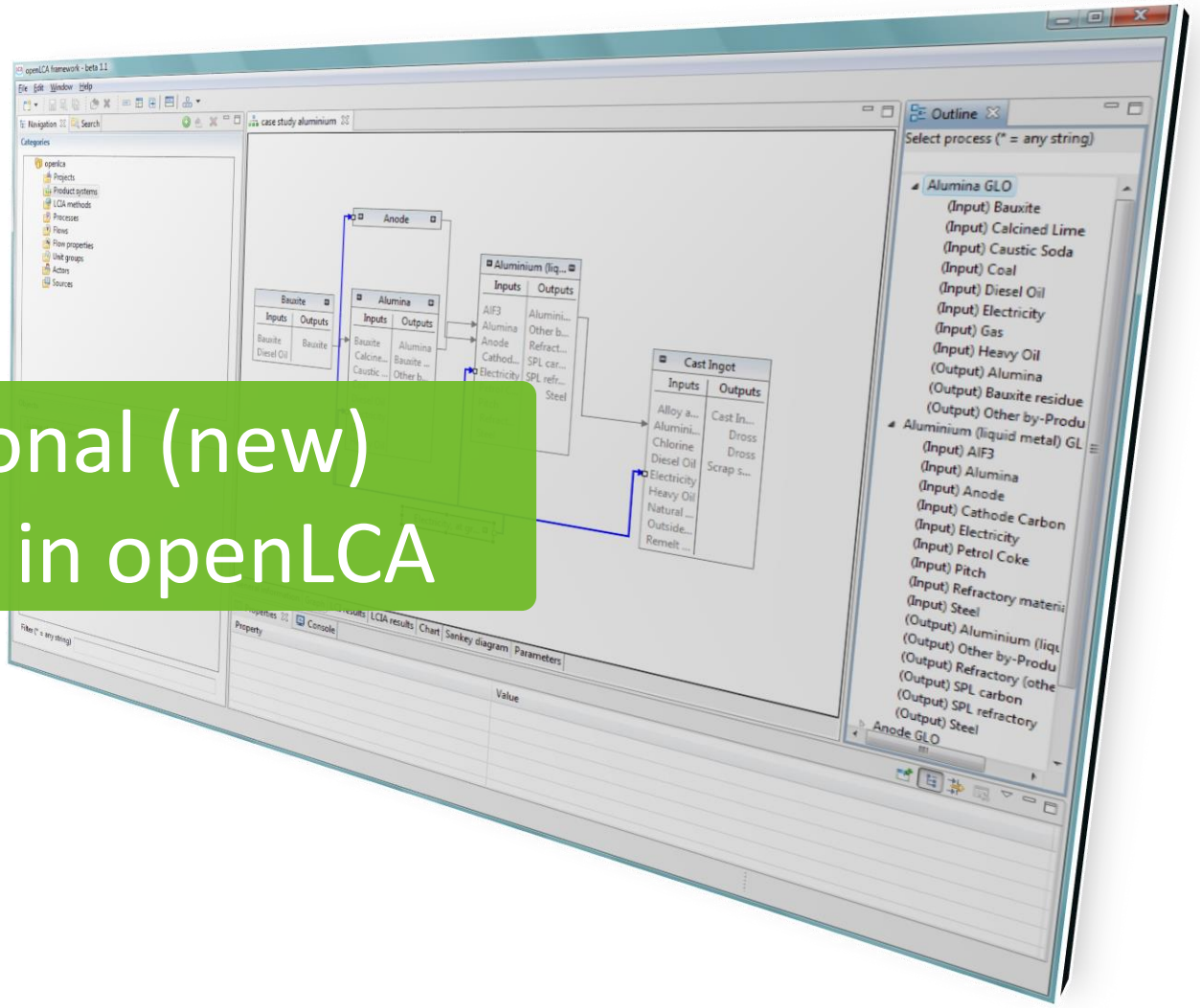
Create for your shaver models a comparative cost analysis from a consumer perspective.

- A few prices:

Product	Price
disposable shaver, 2 blades	0.89 EUR for 5 pieces
tap water, incl. waste water treatment	5EUR/m3 (=> 0.005 EUR/kg)
shaving foam	2.69 EUR for 200ml

- Describe your procedure.
- 15 min

Additional (new) features in openLCA



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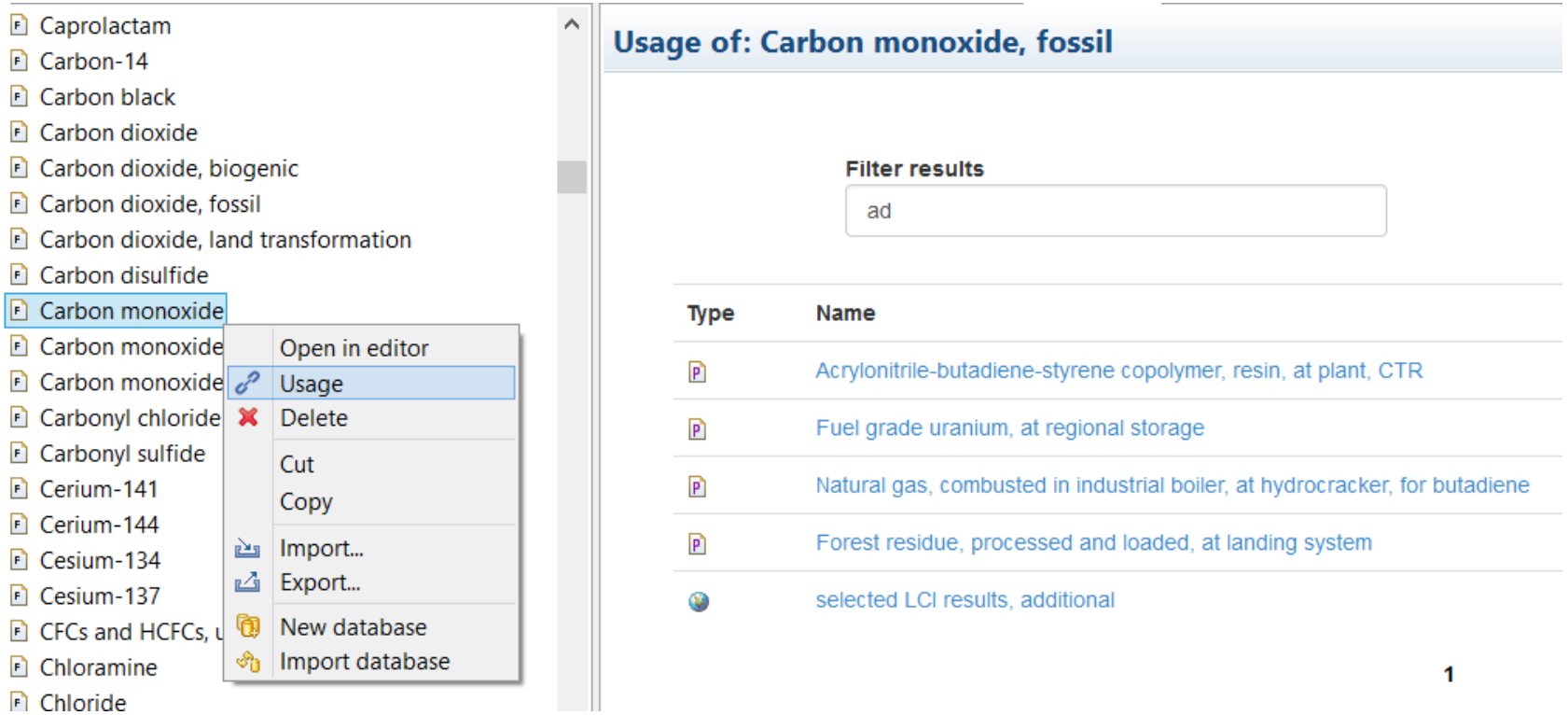
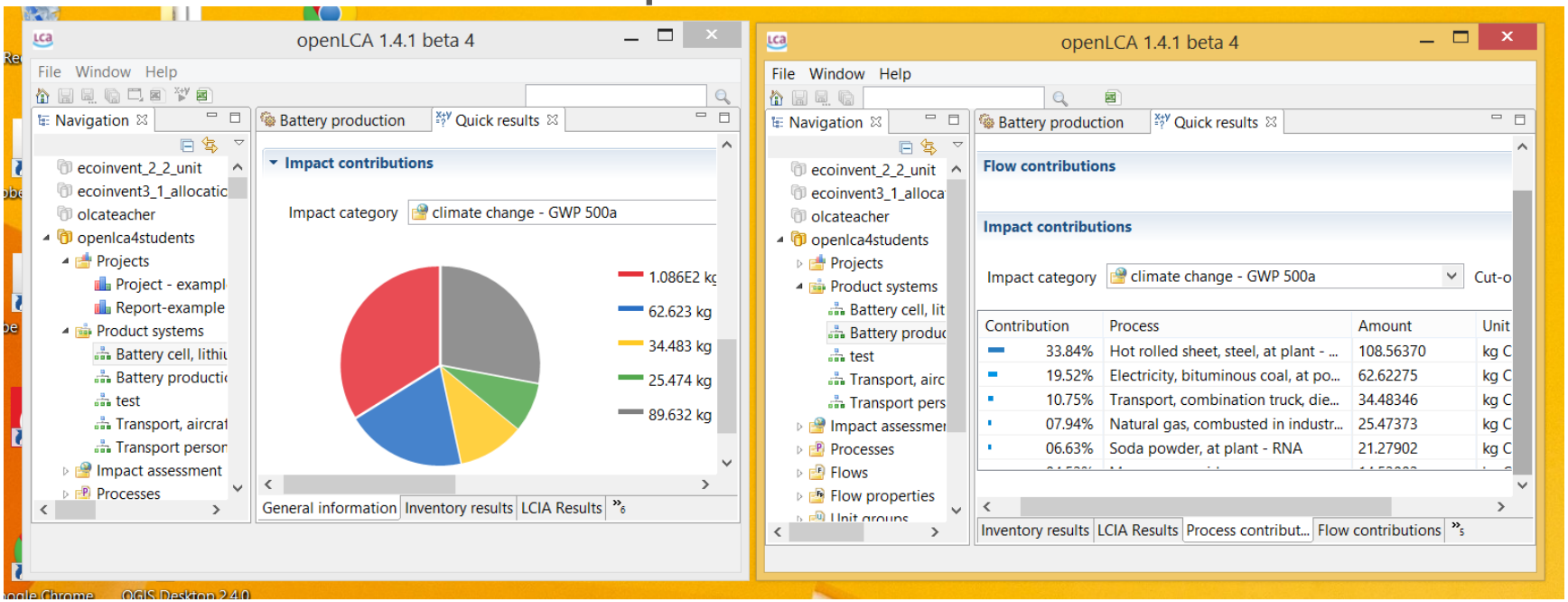
Elements usage

- Available for any element of the database.
- Results can be filtered.



Multiple windows view

- Select Window/Open in New Window to open a new openLCA window
- It can be worked in parallel within the same database



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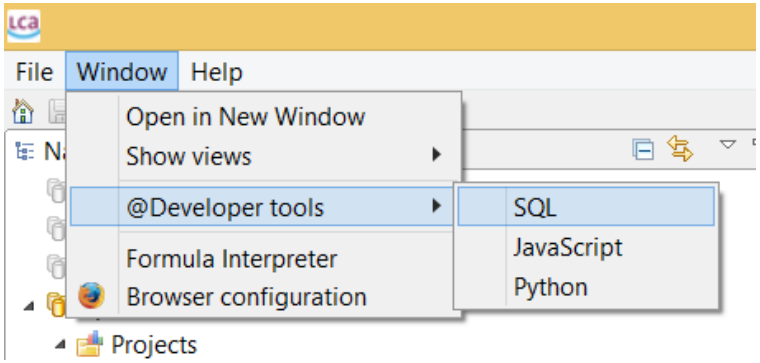
Developer tools

- SQL Query Browser, JavaScript and Python editors.



SQL Query Browser

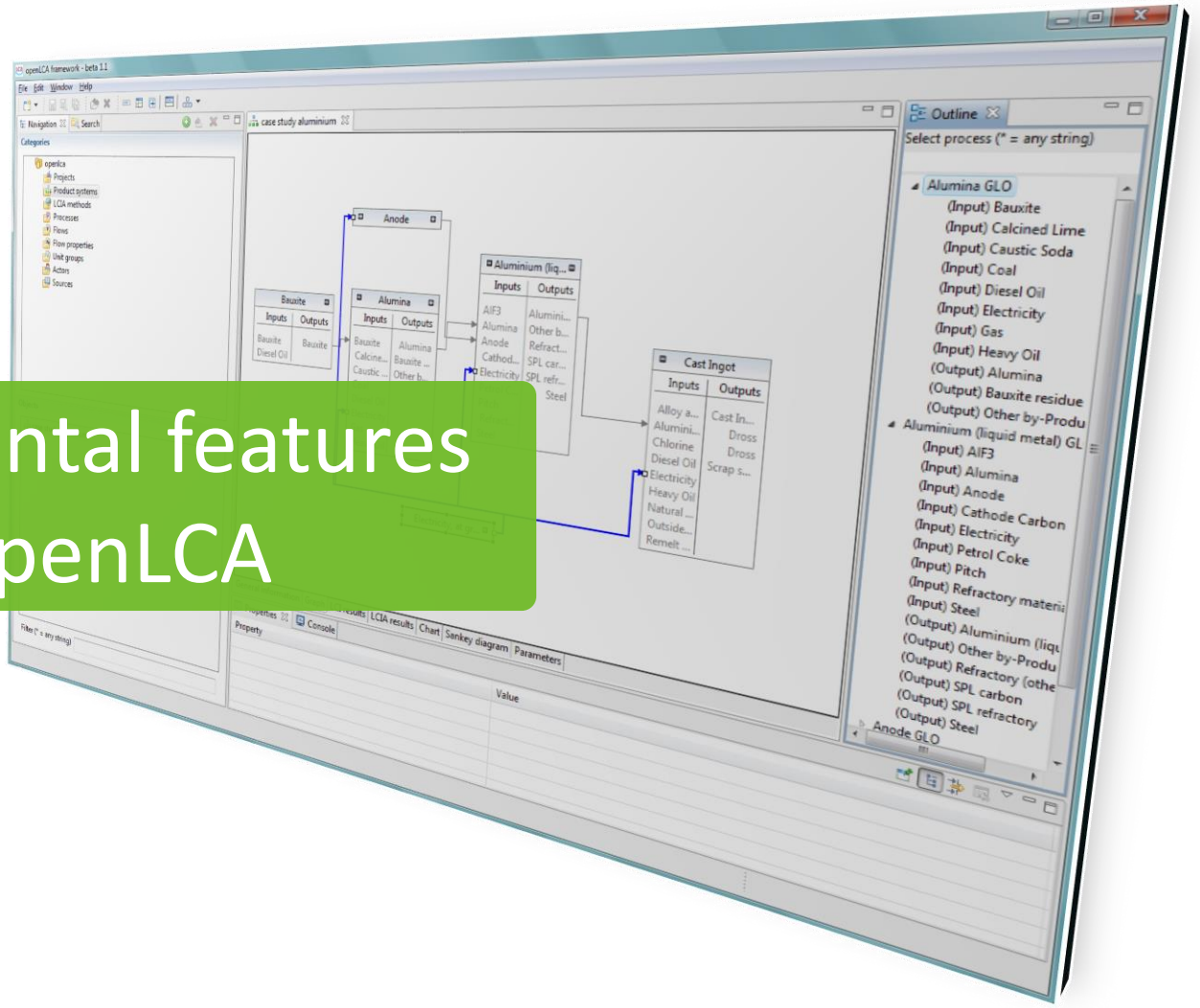
SQL Statement

```
select name, cas_number,formula from tbl_flows
```

Results

NAME	CAS_NUMBER	FORMULA
Ethene, tetrachloro-	000127-18-4	C2Cl4
Florasulam	145701-23-1	C12H8F3N5O3S
Nitrite	014797-65-0	NO2 -
Xenon-137	014835-21-3	Xe-137
Ethyl cellulose	009004-57-3	NULL
Sulfate	014808-79-8	SO4--
Aniline	000062-53-3	C6H7N
Transformation, from traffic area, road network	NULL	CORINE 122a
Cesium-137	010045-97-3	Cs-137
Chlorosulfonic acid	007790-94-5	HSO3Cl
Manganese	007439-96-5	Mn

Experimental features in openLCA



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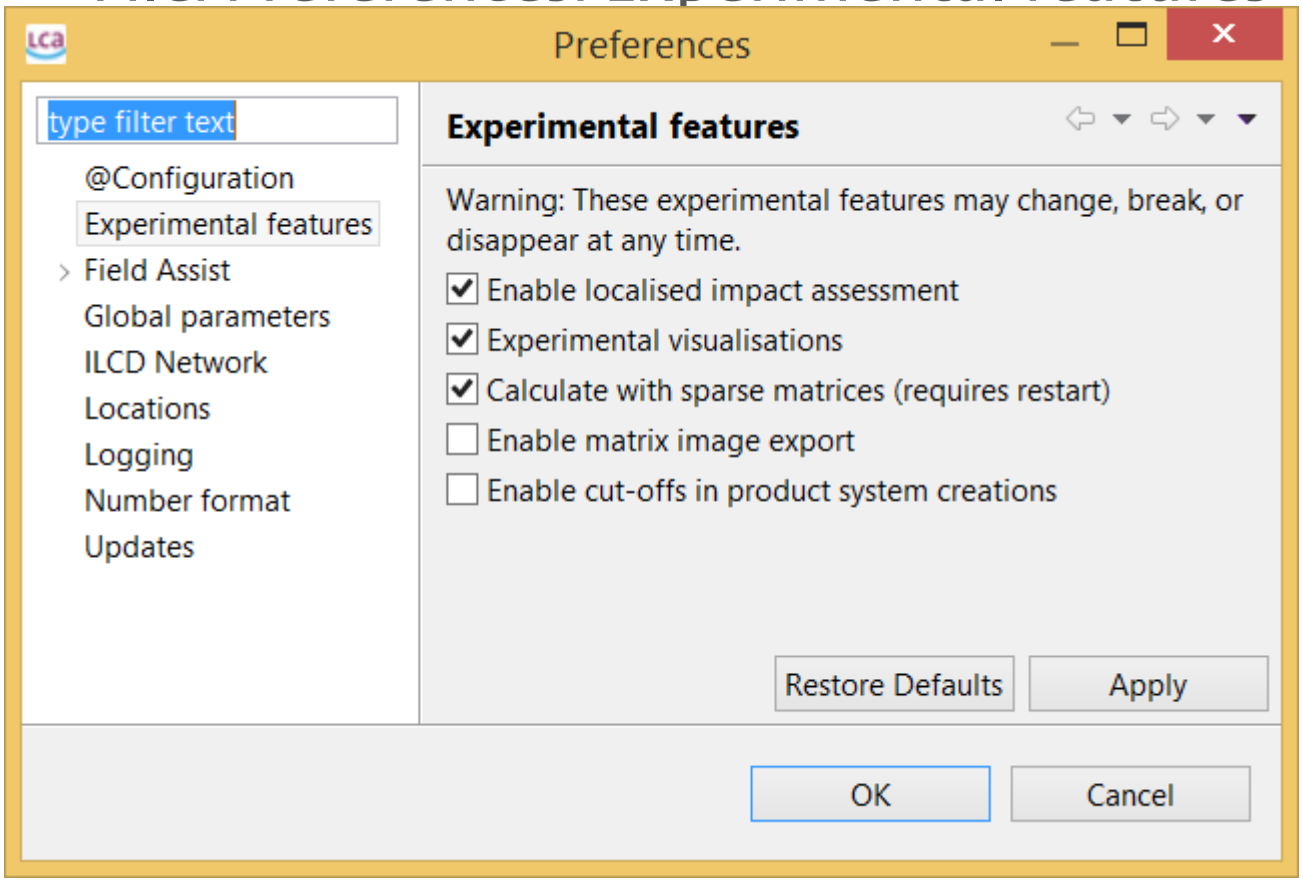
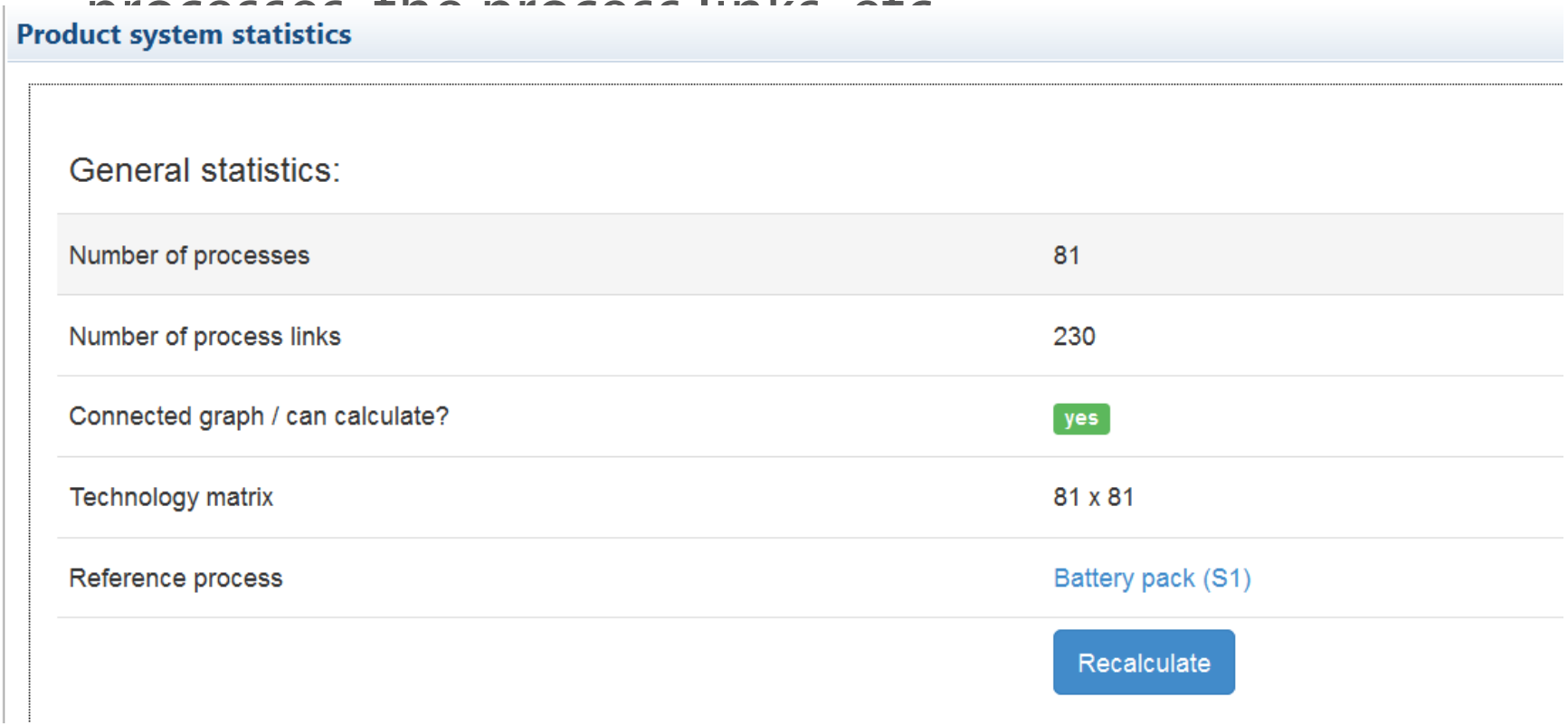
Experimental features

- They can be activated under File/Preferences/Experimental features



Product system Statistics

- Available in the product system editor
- It provides information about the number of processes, the process links, etc.



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Product system Statistics (II)

Product system statistics

Processes with highest in-degree (linked inputs):

Number of input links	Process
8	Lithium carbonate
8	Battery cell, lithium-ion battery (S1)
7	Ethylene dichloride-vinyl chloride monomer, at plant
7	Electricity, at Grid, US, 2008
7	Ethylene, at plant

Processes with highest out-degree (linked outputs)

Number of output links	Process
27	Electricity, at Grid, US, 2008
18	Transport, train, diesel powered

General information | Parameters | Model graph | Statistics | HTML Graph

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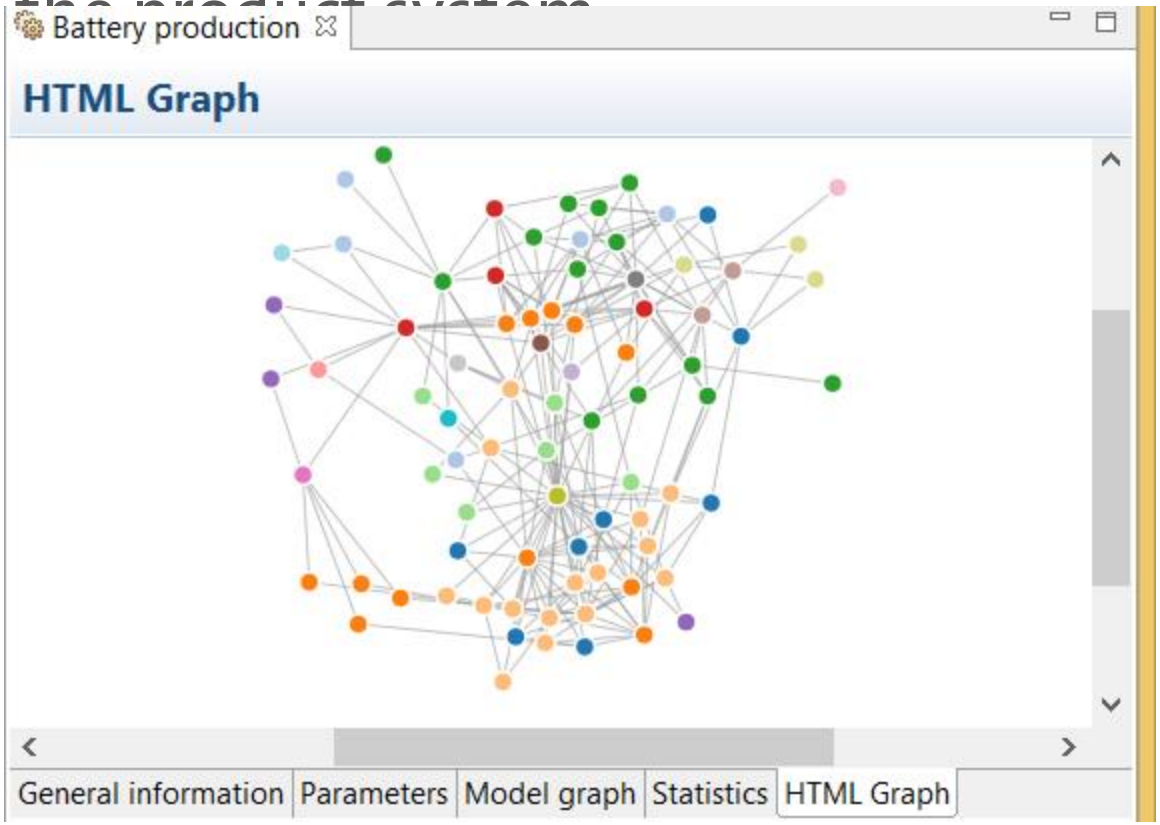
Experimental visualisations: HTML Graph

- Available in the product system editor.
- It provides visual representaion of the process links in the product system.



Experimental visualisations:
Treemap

- Available in the quick results and anaylsis editors.
- It visually represents the direct process contributions per flo

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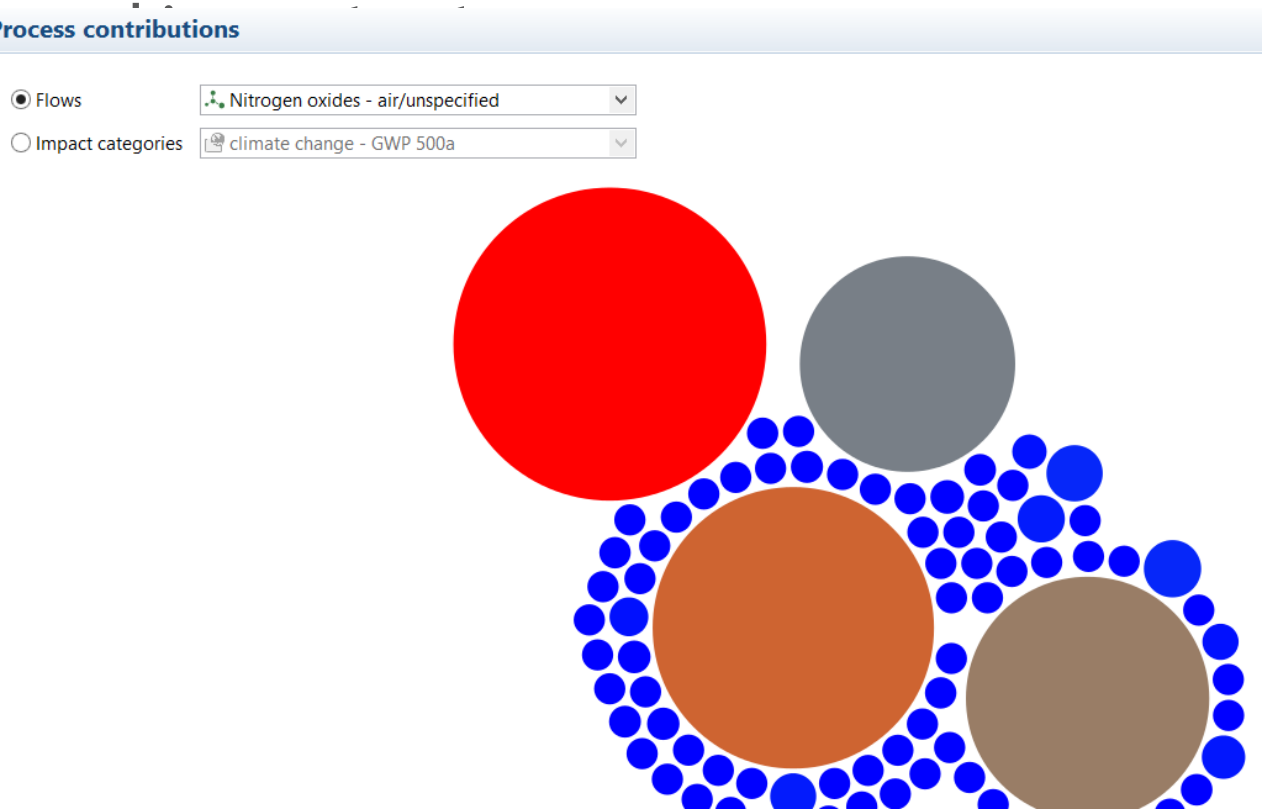
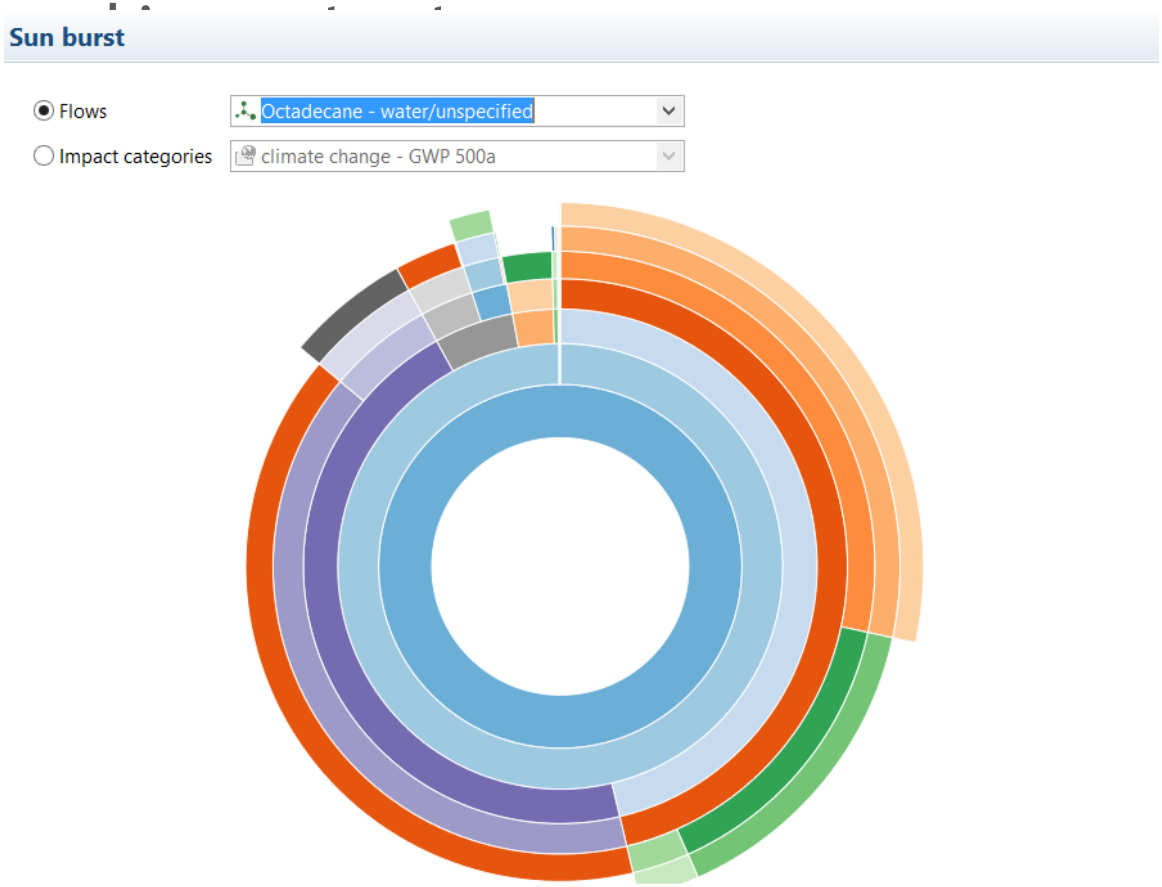
Experimental visualisations: Bubble chart

- Available in the quick results and anaylsis editors.
- It visually represents the direct process contributions per flo



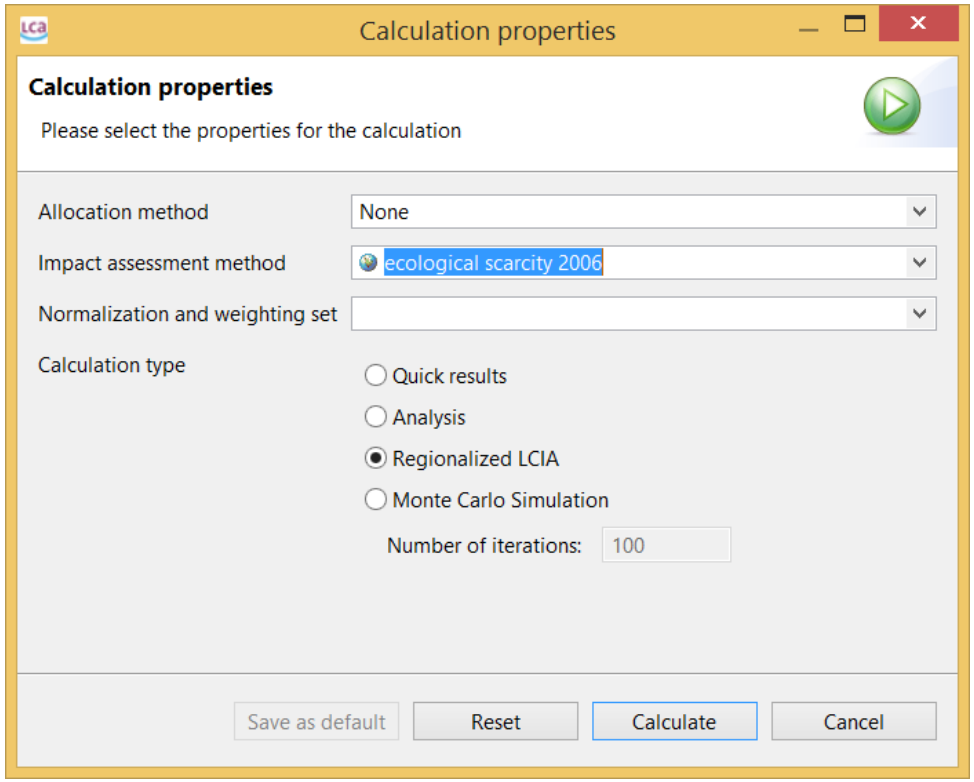
Experimental visualisations: Sun burst

- Available in the anaylsis editor.
- It visually represents the total process contributions per flow

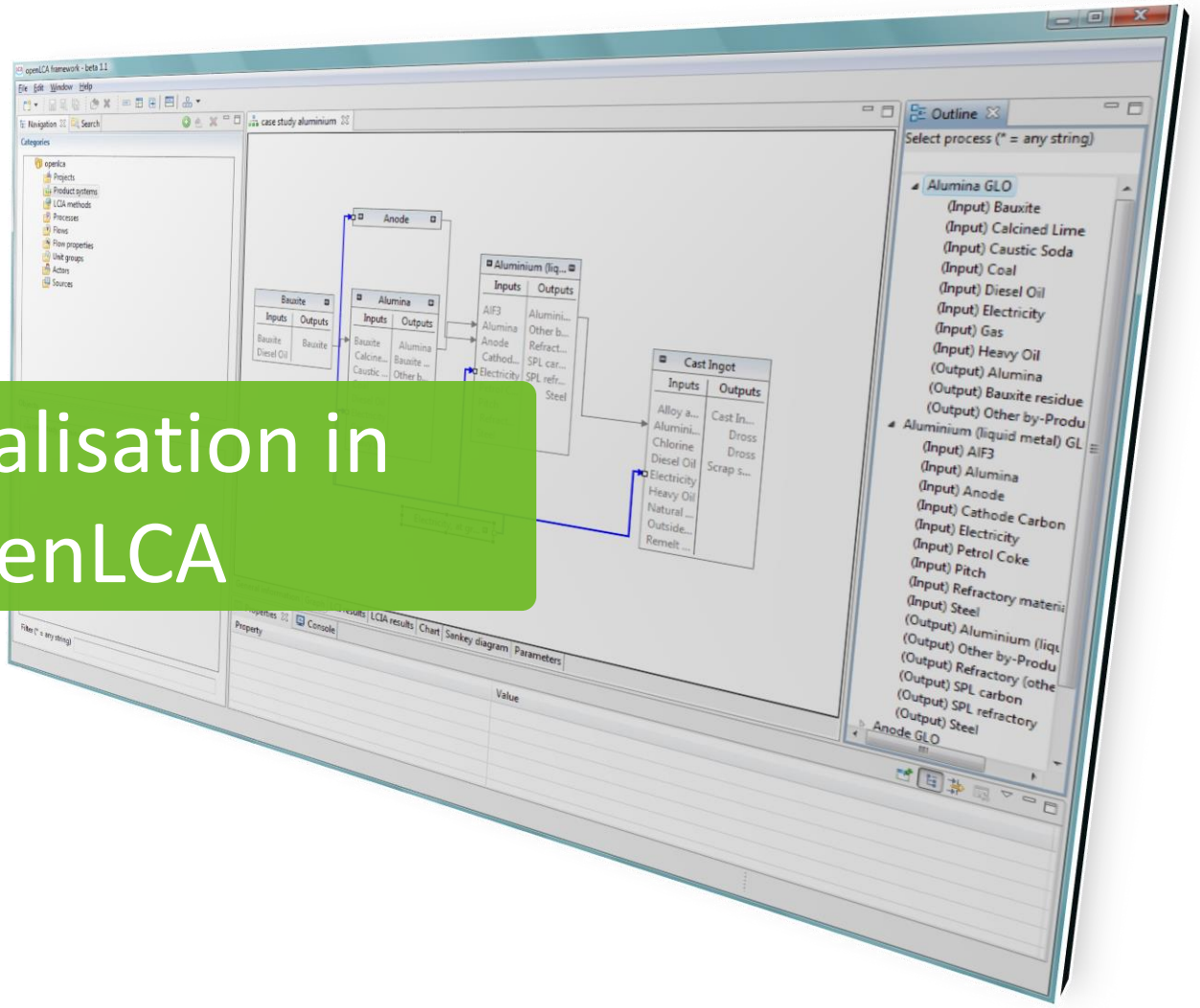


Other experimental features

- Spare matrix calculation: calculates with a different, sparse matrix approach; saves some memory but is still experimental.
- Localised impact assessment:
  - New features in the impact method editor are added to deal with shape files.
  - A new calculation option is shown in the “Calculation properties” menu:



Regionalisation in openLCA



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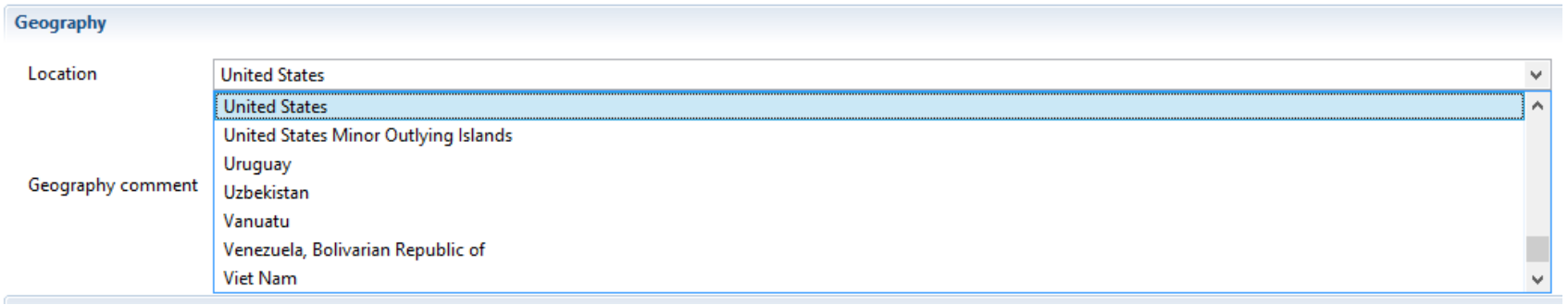
Extension of locations in openLCA (I)

Traditional approach:

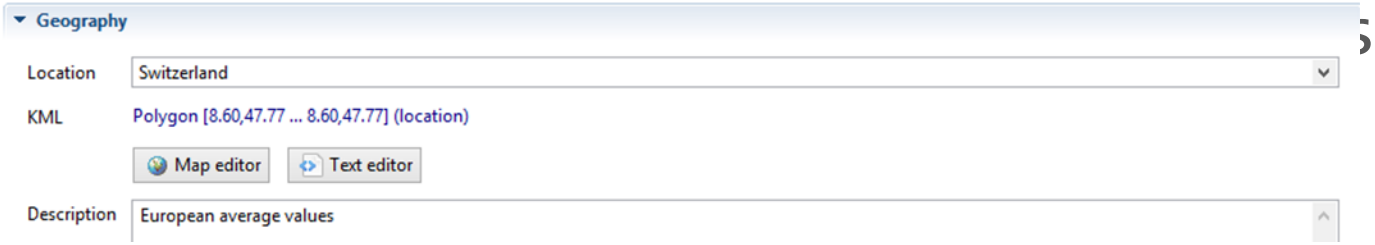
- A list of locations available under File/Preferences/Locations.
- The geographic information of the locations was limited to a pair of latitude, longitude data.
- The processes could only used locations from the pre-defined list.



Extension of locations in openLCA (II)

New approach:

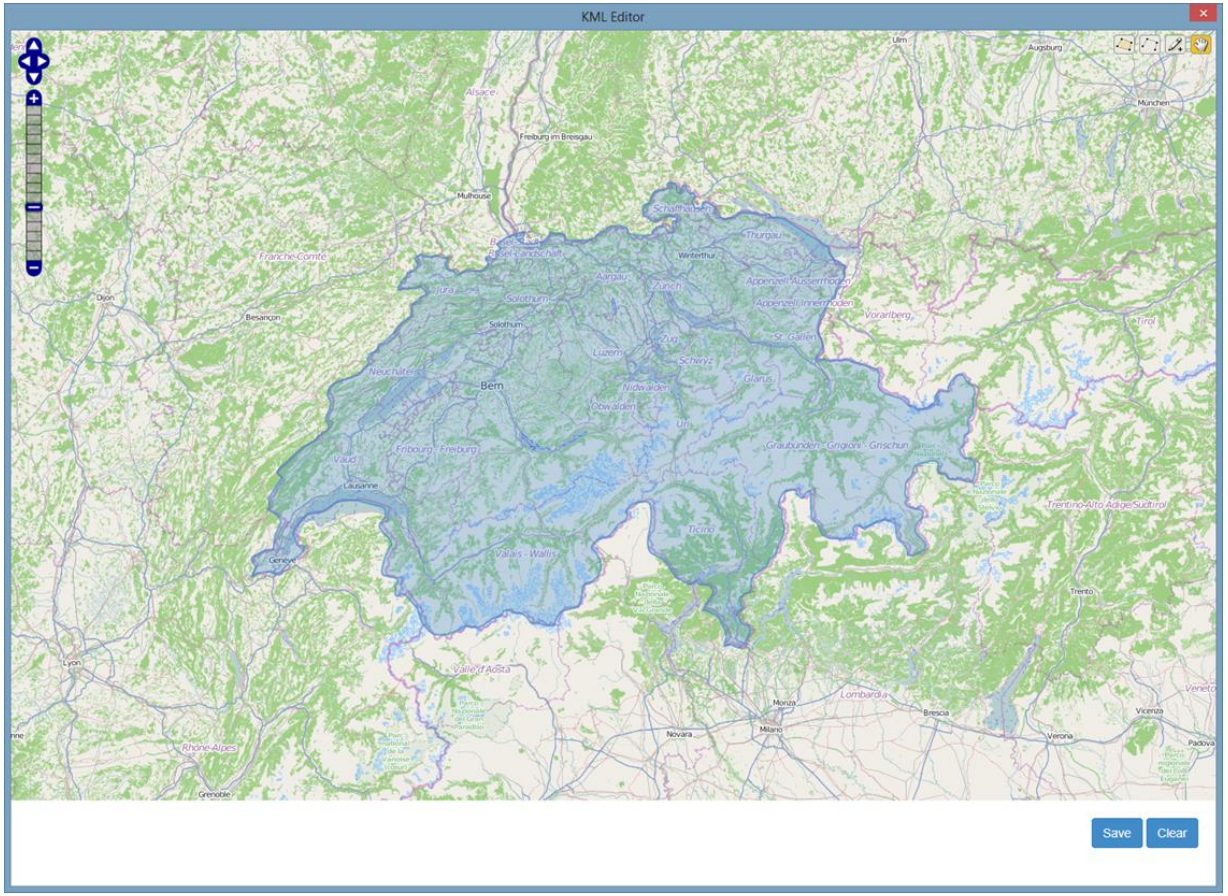
- The list of locations available in the database is shown in File/Edit locations.
- KML data can be added to each location (polygons, lines, points):
  - Import of kmz/xml files with geographic data.
  - Write the coordinates in the “Text editor”.
  - Draw the polygons, lines or points in the KML editor.



s editor.

Extension of locations: KML editor (map)

- KML map editor in the “Edit locations” editor:



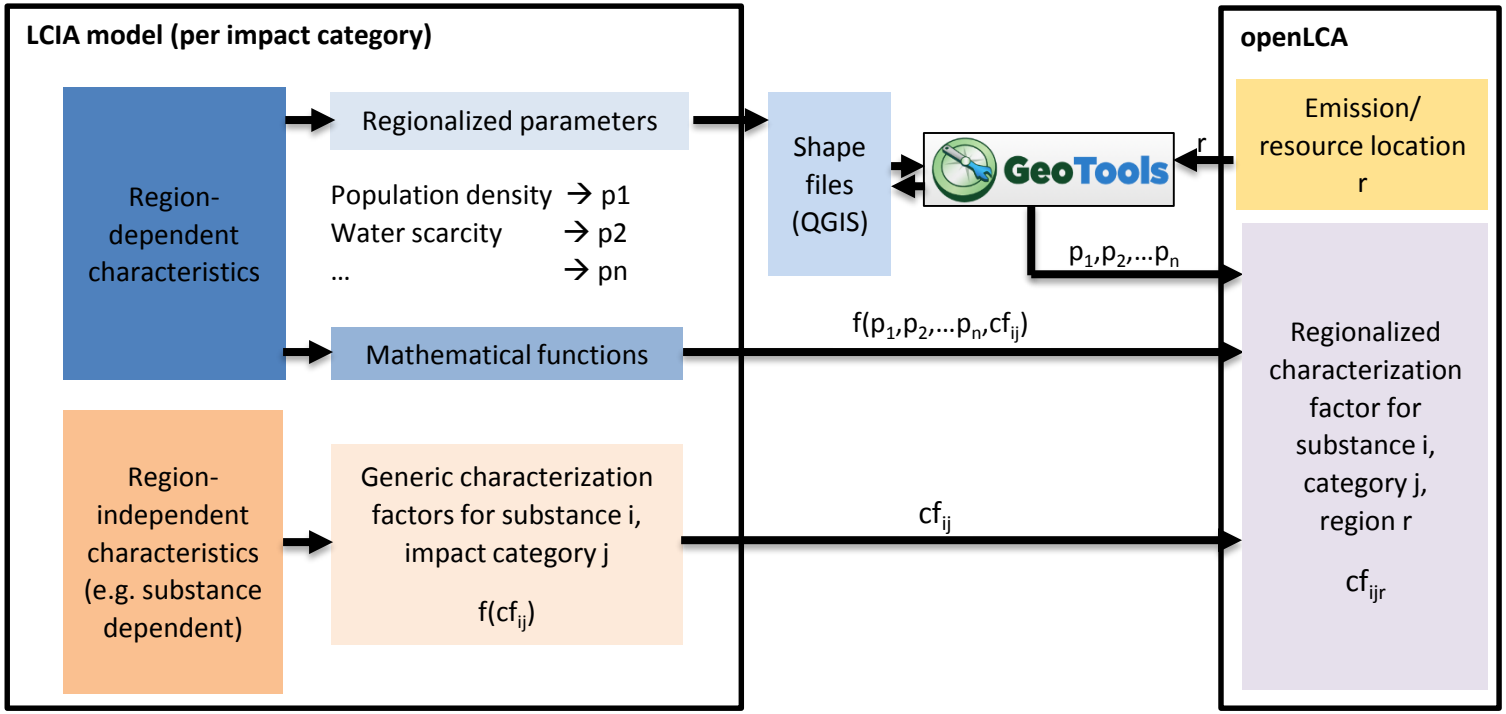
Extension of locations: KML editor (text)

- KML text editor for the checking or modifying the geographic information:

Regionalised LCIA methods in openLCA

- Idea:

  →Parameterization of LCIA methods



Parameterization of LCIA methods

- Formulas for calculating the characterisation factors (CFs) can be defined
  - Input and dependent parameters can be used as in the process data sets

Impact factors

Impact category: Land use

Flow	Category	Flow property	Unit	Factor	Uncertainty
Occupation, arable	resource/land	Area*time	m2*a	(0.60*ratio_biom)/SA_CF	lognormal: gmean=1.36 g...
Occupation, construction site	resource/land	Area*time	m2*a	(0.44*ratio_biom)/SA_CF	lognormal: gmean=1.00 g...
Occupation, forest, intensive	resource/land	Area*time	m2*a	(0.04*ratio_biom)/SA_CF	lognormal: gmean=9.09E-...
Occupation, forest, intensive, clear-c...	resource/land	Area*time	m2*a	(0.18*ratio_biom)/SA_CF	lognormal: gmean=0.41 g...

Parameters

Global parameters

Input parameters

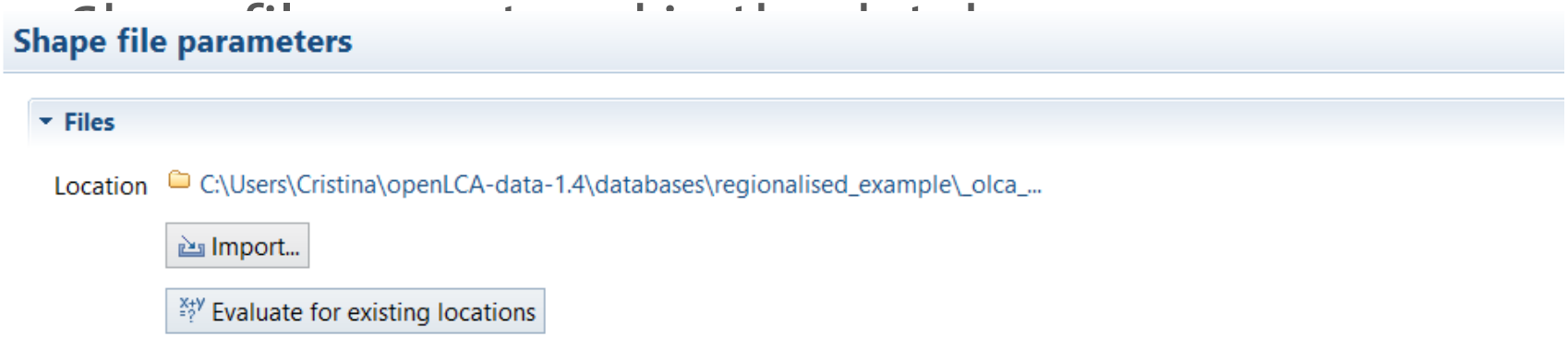
Name	Value	Uncertainty	Description
ratio_biom	1.0	uniform: min=0.21 max=1.97	from shapefile: ecoregions_with_biome_ratio
SA_CF	0.44	none	Settlement Area Characterization Factor
SA_EF	300.0	none	Settlement Area Ecofactor

Shapefiles containing regional characteristics

- Regional characteristics affecting the CFs can be defined with parameters:

  e.g. population density, precipitation variability,etc.

- Data for those characteristics is contained in shapefiles, which can be imported to openLCA
- Parameters are extracted during the shapefile import



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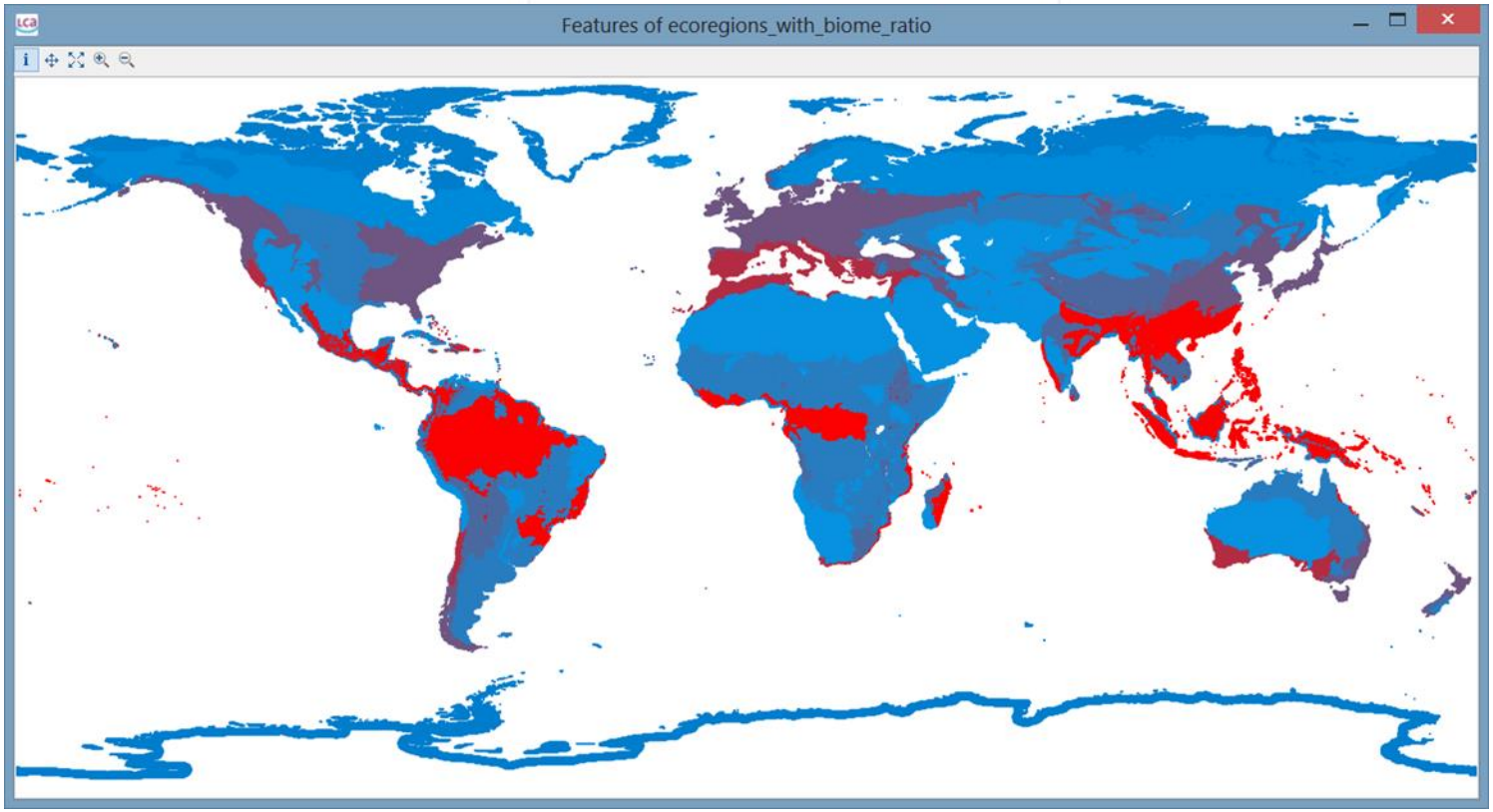
Shapefiles containing regional characteristics

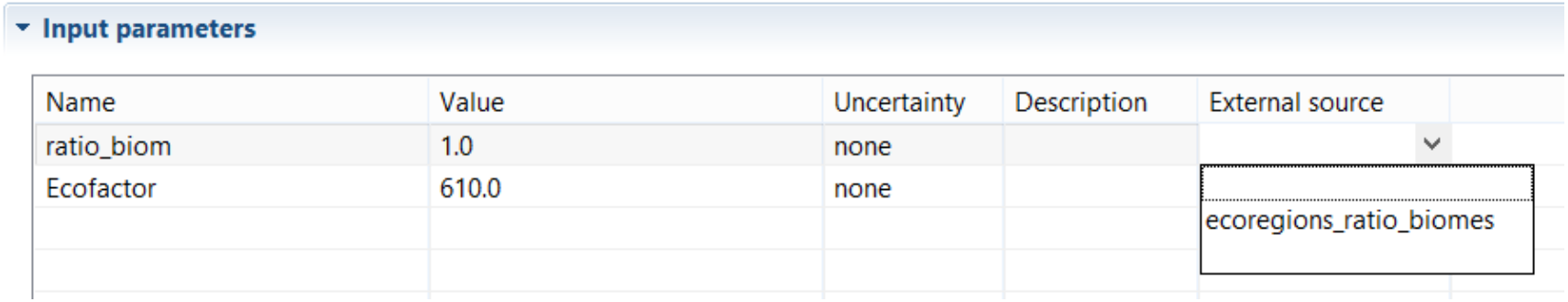
Parameters of ecoregions_with_biome_ratio

Name	Minimum	Maximum
f_x CLS_CODE	0.0	1144.0
f_x ECO_ID_U	10000.0	17109.0
f_x ECO_NUM	1.0	99.0
f_x ratio_biom	0.20929077	1.96750671



Binding shapefiles and LCIA method parameters

- Parameters of shapefiles can be bound to input parameters
- Default value of parameters is used for normal calculations and formula evaluation
- In regionalized assessment the parameter value derived from the shapefile is used for the formula



Calculation framework

Linking of process locations and LCIA methods spatial units

- GeoTools libraries integrated in openLCA
  - The intersection between shapefiles features and process geometries is calculated.

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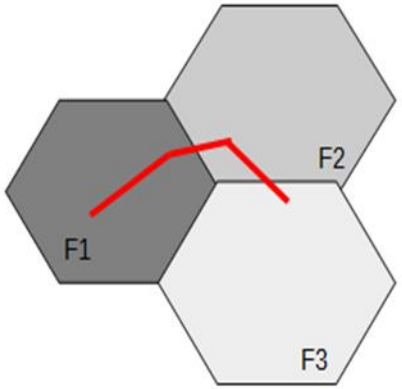
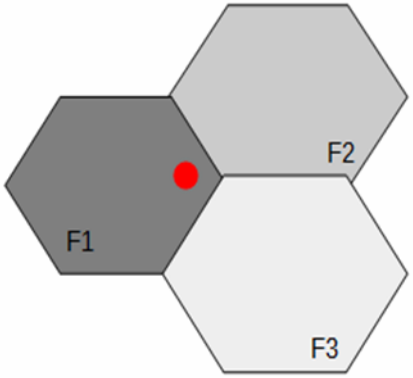
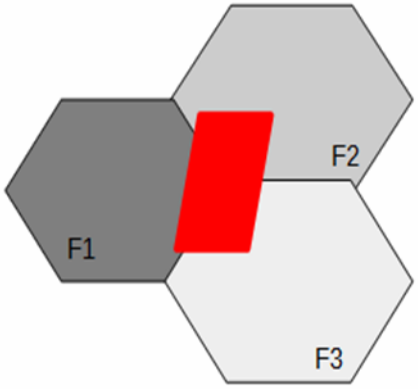






$(p(F_1)*L(F_1) + p(F_2)*L(F_2) \ldots) / L$ $p(F_1)$ $(p(F_1)*A(F_1) + p(F_2)*A(F_2) \ldots) / A$

Calculation framework

Regionalised LCIA calculation

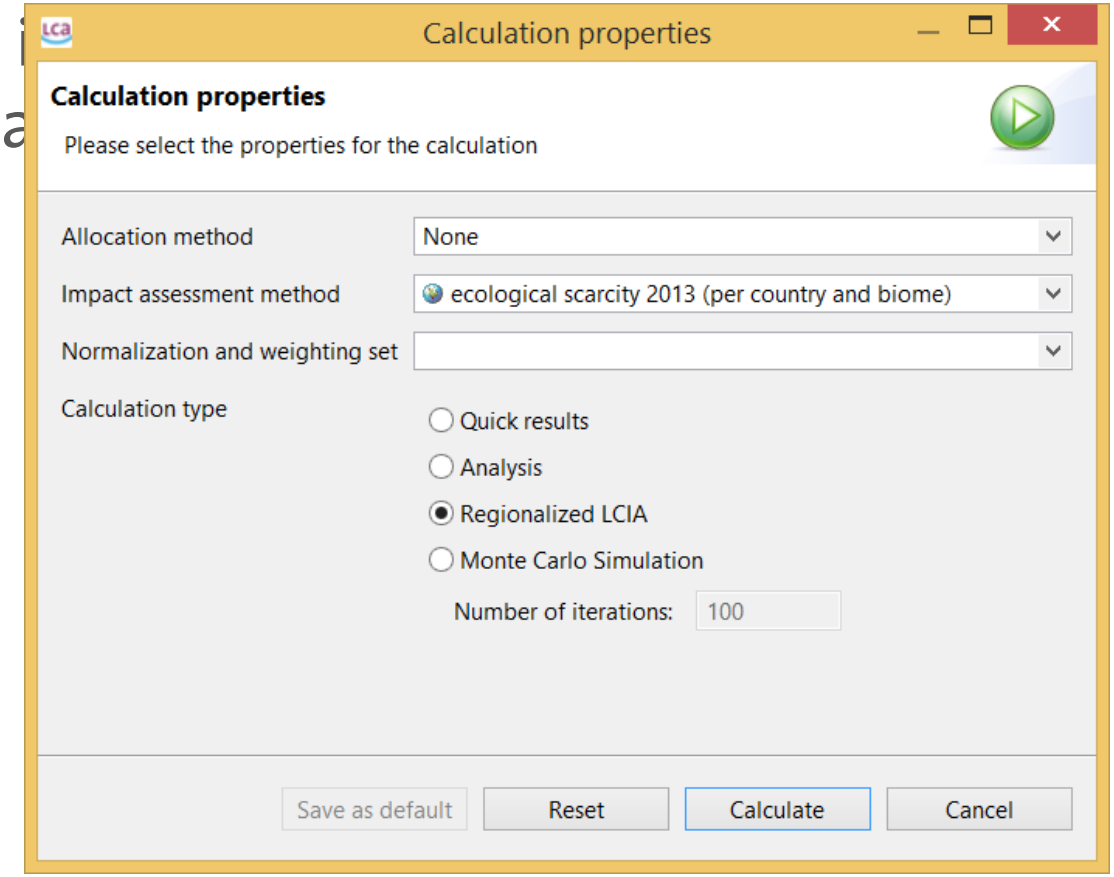
- Creation of a regionalised result matrix for the inventory (GR)
- Creation of a regionalised LCIA matrix (CR)
- Creation of the regionalised LCIA result (RR)

$$RR = CR * GR$$

Regionalised LCIA: Calculation procedure

- Select the “Regionalised LCIA” option in the calculation properties window:

→ The i
regiona



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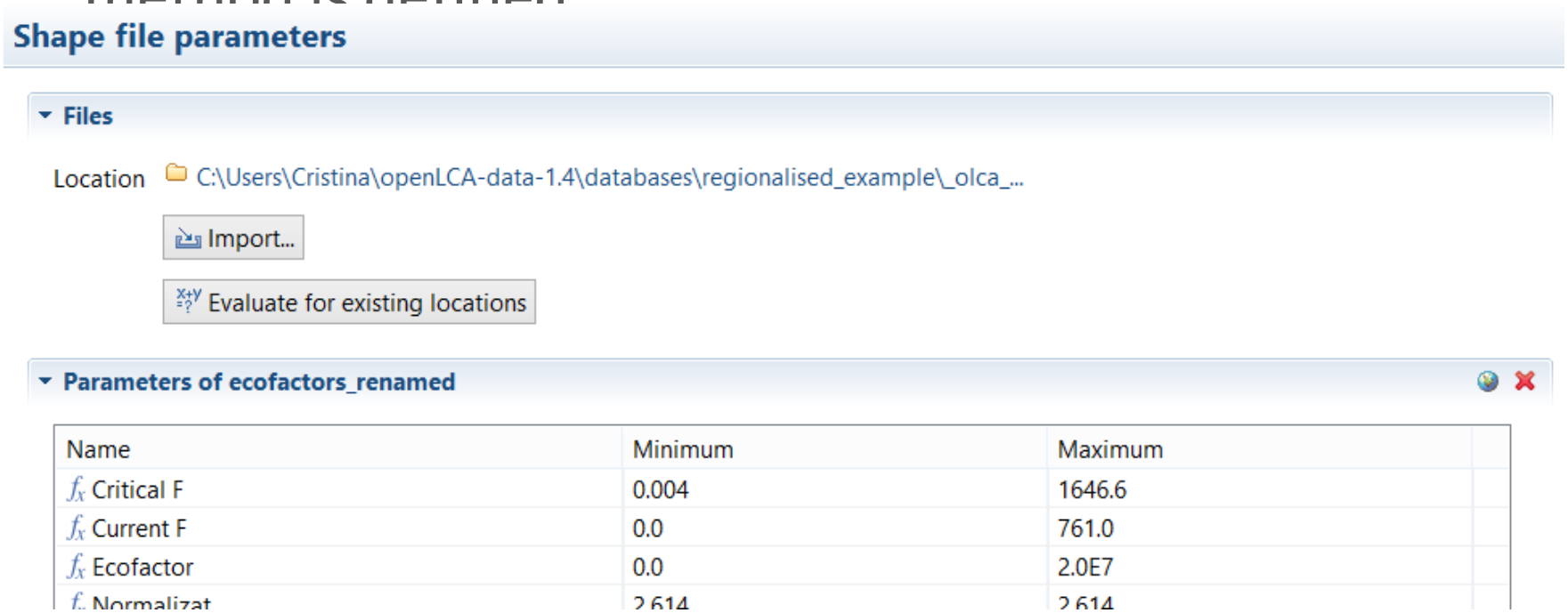
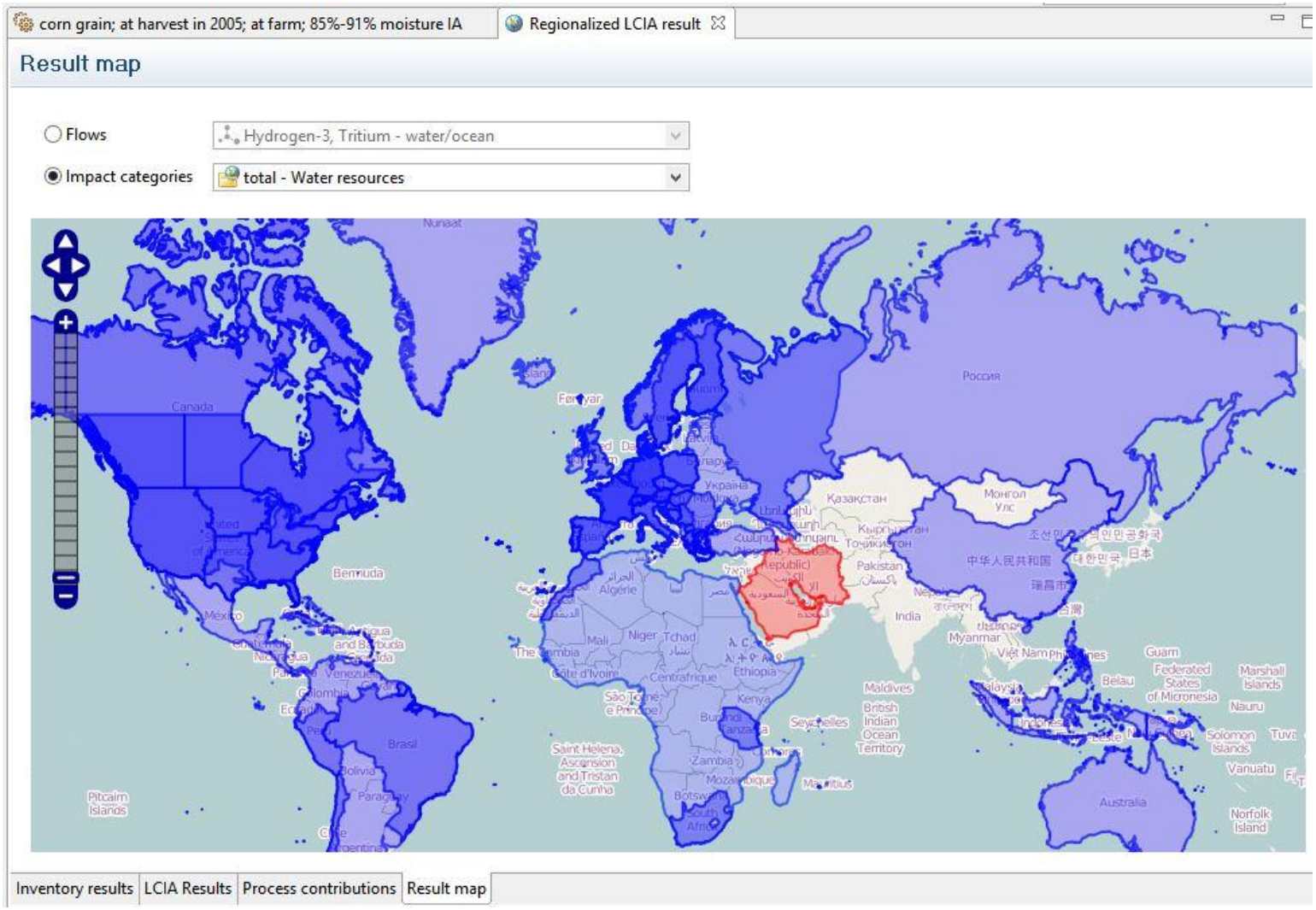
Regionalised LCIA: Calculation procedure

- To reduce the calculation time for complex systems, it is recommended to evaluate the intersections with the existing database locations when the impact method is defined.



Regionalised LCIA: Results



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Exercise: Regionalised impacts of corn production

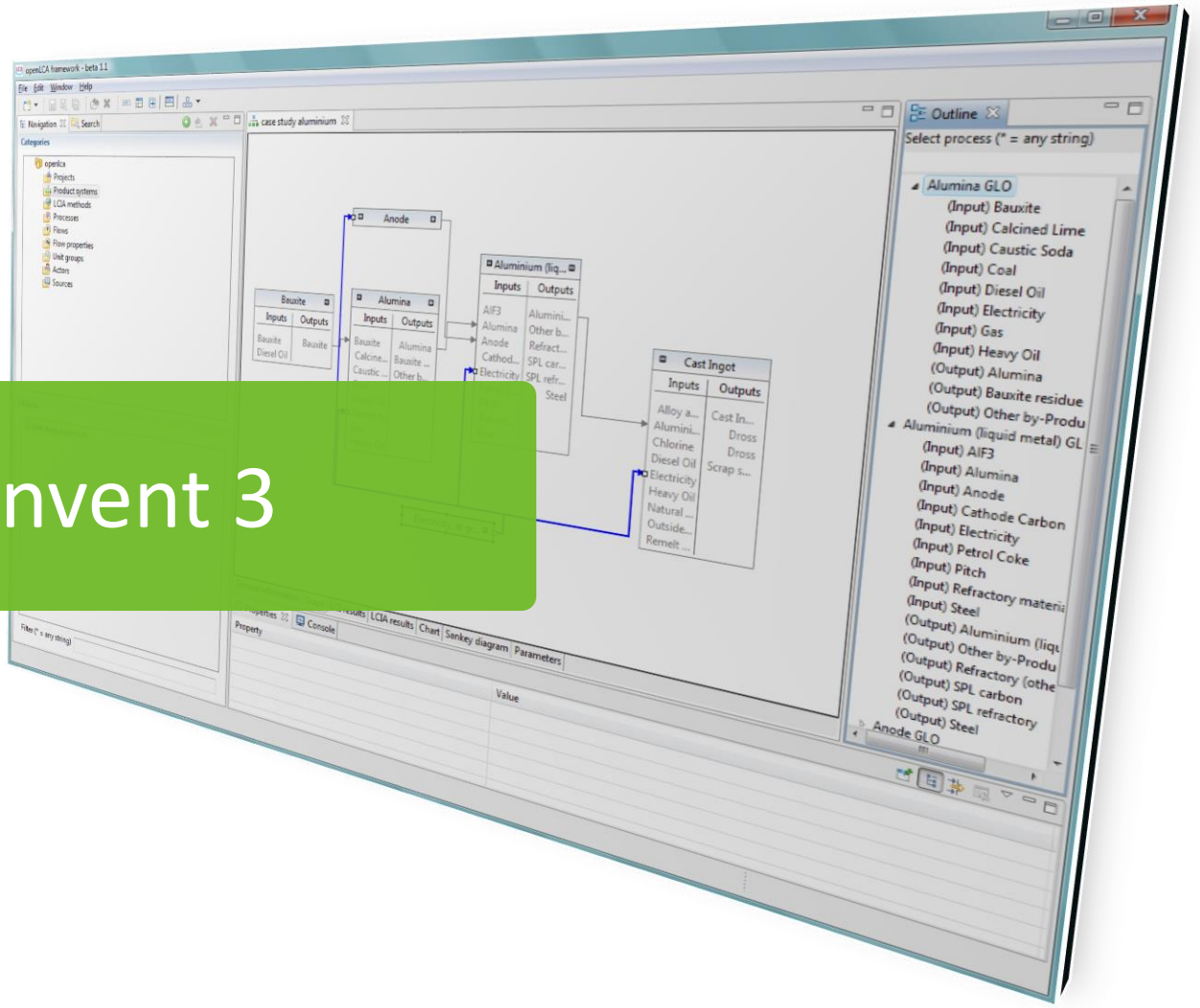
Import the database “regionalised_lcia4students”. Bind the parameters in the LCIA method to the shapefiles parameters. Then calculate regionalised LCIA results of the process “corn grain; at harvest in 1996; at farm; 85%-91% moisture” for the US states of:

- Nevada (NE)
- Iowa (IA)
- Illinois (IL)

Which state has lower environmental impacts?

- 10 min

ecoinvent 3



GreenDeLTa

Ecoinvent 3 Overview

- Third version of the ecoinvent database, developed by the Swiss ecoinvent Centre, with technical modifications respect to version 2:
  - Data format
  - Market modelling
  - Around 8000 “Activity” data sets (former process data sets)

Ecoinvent 3, Details

- Data format
- Market modelling
- New data?
- Consequences for openLCA

Ecoinvent 3, Data format

- In ecoinvent 2, Ecopsold 1:
  - No parameters,
  - Only two languages,
  - Usually process=product
  - No IDs, processes were identfied by location, time, unit and name
  - It only had processes and metadata
  - Each flow had only one unit
- Ecospold 2;
  - Parameters
  - Different data sets (Activity, flow, etc.)
  - Unique Ids
  - “Intelligence” in data format

EcoSpold 2

```
<?xml version="1.0" encoding="utf-8"?>
<ecoSpold xmlns="http://www.EcoInvent.org/EcoSpold02">
  <childActivityDataset>
    <activityDescription>
      <activity id="0a5c6801-e080-4b4e-b029-b80b73a54fd7" activityNameId="11916431-4240-4fb7-b7a2-90f90e35c400" parentActivityId="d63fcb68-86ed-4554-ab3c-b4ba5c7b0
        <activityName xml:lang="en">titanium zinc plate production, without pre-weathering</activityName>
        <includedActivitiesStart xml:lang="en" />
        <includedActivitiesEnd xml:lang="en">The dataset describes the production of titanium zinc alloy from primary zinc and the fabrication of titanium zinc pla
        <generalComment>
          <text xml:lang="en" index="2">[This is a dataset transferred from ecoSpold v1 / ecoinvent database version 2. It may not in all aspects fulfill the requi
          <text xml:lang="en" index="1">The production steps pre-alloying, melting, casting, rolling, coiling, stretch forming and cutting are approximated using "
        </generalComment>
        <tag>ConvertedDataset</tag>
      </activity>
      <classification classificationId="aeaec32d-b5a4-44e0-bb50-25c0f4fe3d37">
        <classificationSystem xml:lang="en">EcoSpold01Categories</classificationSystem>
        <classificationValue xml:lang="en">metals/extraction</classificationValue>
      </classification>
      <classification classificationId="6fe7bc2b-4be4-48f7-92b0-f27dea9053ce">
        <classificationSystem xml:lang="en">ISIC rev.4 ecoinvent</classificationSystem>
        <classificationValue xml:lang="en">2420:Manufacture of basic precious and other non-ferrous metals</classificationValue>
      </classification>
      <geography geographyId="0e0e1020-7d7e-11de-9ae2-0019e336be3a">
        <shortname xml:lang="en">DE</shortname>
        <comment>
          <text xml:lang="en" index="1">Data from a leading titan zinc plate producer in Germany. Applicable for Europe.</text>
        </comment>
      </geography>
      <technology technologyLevel="3">
        <comment>
          <text xml:lang="en" index="1">Induction furnace for all the pre-alloying and melting steps, roll stands with 5 rolling pairs for the rolling step. Coilin
        </comment>
      </technology>
      <timePeriod startDate="1997-01-01" endDate="2013-12-31" isDataValidForEntirePeriod="false" />
      <macroEconomicScenario macroEconomicScenarioId="d9f57f0a-a01f-42eb-a57b-8f18d6635801">
        <name xml:lang="en">Business-as-Usual</name>
      </macroEconomicScenario>
    </activityDescription>
    <flowData>
      <intermediateExchange id="8fcd8ca4-28b0-46dd-bf9e-54c44bc0c82e" unitId="487df68b-4994-4027-8fdc-a4dc298257b7" casNumber="007440-66-6" amount="1.06" intermedi
        <name xml:lang="en">zinc</name>
        <unitName xml:lang="en">kg</unitName>
        <comment xml:lang="en">(1,4,1,3,1,5,3)</comment>
        <comment>EcoSpold01Location=RER</comment>
        <uncertainty>
          <lognormal meanValue="1.06" mu="0.06" variance="0.01" varianceWithPedigreeUncertainty="0.0121" />
```

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EcoSpold 2

- Flow properties (before only in ILCD format): water content, etc., different units possible

```
<elementaryExchange id="d567a064-d1e0-4905-96e5-23f4684d10f4" unitId="487df68b-4994-4027-8fdc-a4dc298257b7" casNumber="022537-50-4" amount="1.5714E-07" eleme
  <name xml:lang="en">Tin, ion</name>
  <unitName xml:lang="en">kg</unitName>
  <comment xml:lang="en">This flow is issued during the process "contouring, brass". Contouring, brass is used as a proxy for rolling and colling of titanium
  <uncertainty>
    <lognormal meanValue="1.5714E-07" mu="-15.67" variance="0.81" varianceWithPedigreeUncertainty="1.02" />
    <pedigreeMatrix reliability="5" completeness="5" temporalCorrelation="5" geographicalCorrelation="5" furtherTechnologyCorrelation="5" />
  </uncertainty>
  <property propertyId="c74c3729-e577-4081-b572-a283d2561a75" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content, fossil</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="6d9e1462-80e3-4f10-b3f4-71febd6f1168" amount="0" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">water in wet mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="67f102e2-9cb6-4d20-aa16-bf74d8a03326" amount="1" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">wet mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="6393c14b-db78-445d-a47b-c0cb866a1b25" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content, non-fossil</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="a9358458-9724-4f03-b622-106eda248916" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">water content</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="3a0af1d6-04c3-41c6-a3da-92c4f61e0eaa" amount="1" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">dry mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="a301a838-7975-4d89-9e74-8eb77ad03cd1" amount="0" isDefiningValue="false" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content</name>
    <unitName xml:lang="en">dimensionless</unitName>
    <comment xml:lang="en">carbon content on a dry matter basis (reserved; not for manual entry)</comment>
  </property>
  <property propertyId="f2283db2-62e4-467f-b9ac-c4f45be563b4" amount="0" isDefiningValue="false" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">carbon allocation</name>
    <unitName xml:lang="en">kg</unitName>
    <comment xml:lang="en">carbon content per unit of product (reserved; not for manual entry)</comment>
  </property>
  <compartment subcompartmentId="e47f0a6c-3be8-4027-9eee-de251784f708">
    <compartment xml:lang="en">water</compartment>
    <subcompartment xml:lang="en">unspecified</subcompartment>
```

EcoSpold 2

- Flow properties: details for each process data set
  - e.g.: Flow: “Tin, ion”; Summary: water content (o), carbon content (o), etc. (!)

```
<elementaryExchange id="d567a064-d1e0-4906-96e5-23f4684d10f4" unitId="487df68b-4994-4027-8fdc-a4dc298257b7" casNumber="022537-50-4" amount="1.5714E-07" eleme
  <name xml:lang="en">Tin, ion</name>
  <unitName xml:lang="en">kg</unitName>
  <comment xml:lang="en">This flow is issued during the process "Contouring, brass". Contouring, brass is used as a proxy for rolling and colling of titanium
  <uncertainty>
    <lognormal meanValue="1.5714E-07" mu="-15.67" variance="0.81" varianceWithPedigreeUncertainty="1.02" />
    <pedigreeMatrix reliability="5" completeness="5" temporalCorrelation="5" geographicalCorrelation="5" furtherTechnologyCorrelation="5" />
  </uncertainty>
  <property propertyId="c74c3729-e577-4081-b572-a283d2561a75" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content, fossil</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="6d9e1462-80e3-4f10-b3f4-71febd6f1168" amount="0" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">water in wet mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="67f102e2-9cb6-4d20-aa16-bf74d8a03326" amount="1" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">wet mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="6393c14b-db78-445d-a47b-c0cb866a1b25" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content, non-fossil</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="a9358458-9724-4f03-b622-106eda248916" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">water content</name>
    <unitName xml:lang="en">dimensionless</unitName>
  </property>
  <property propertyId="3a0af1d6-04c3-41c6-a3da-92c4f61e0eaa" amount="1" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">dry mass</name>
    <unitName xml:lang="en">kg</unitName>
  </property>
  <property propertyId="a301a838-7975-4d89-9e74-8eb77ad03cd1" amount="0" isDefiningValue="false" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
    <name xml:lang="en">carbon content</name>
    <unitName xml:lang="en">dimensionless</unitName>
    <comment xml:lang="en">carbon content on a dry matter basis (reserved; not for manual entry)</comment>
  </property>
  <property propertyId="f2283db2-62e4-467f-b9ac-c4f45be563b4" amount="0" isDefiningValue="false" unitId="487df68b-4994-4027-8fdc-a4dc298257b7">
    <name xml:lang="en">carbon allocation</name>
    <unitName xml:lang="en">kg</unitName>
    <comment xml:lang="en">carbon content per unit of product (reserved; not for manual entry)</comment>
  </property>
  <compartment subcompartmentId="e47f0a6c-3be8-4027-9eee-de251784f708">
    <compartment xml:lang="en">water</compartment>
    <subcompartment xml:lang="en">unspecified</subcompartment>
```

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EcoSpold 2

- Flow properties: details for each process data set
  - Auto generated flow properties

```
    <outputGroup>2</outputGroup>
</intermediateExchange>
<intermediateExchange id="eb369ed2-ccf9-449f-b7ff-3a1eda104871" unitId="487df68b-4994-4027-8fdc-a4dc298257b7" amount="0" intermediateExc
    <name xml:lang="en">palladium</name>
    <unitName xml:lang="en">kg</unitName>
    <property propertyId="40ca2c51-2da6-4351-bd4c-d6f181fc7d55" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_2</name>
    </property>
    <property propertyId="13706ab5-1a8c-42fd-8329-c93266943c87" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_16</name>
    </property>
    <property propertyId="db2e27d1-47cd-4180-8416-4f79369de00c" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_6</name>
    </property>
    <property propertyId="3db02346-808f-4eb6-9232-317a23c63484" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_7</name>
    </property>
    <property propertyId="9909d836-d0a3-45ed-a8d6-62f5febc763e" amount="100">
      <name xml:lang="en">EcoSpold01Allocation_undefined_21</name>
    </property>
    <property propertyId="9c38ea07-adcd-4018-8636-eb32382f39a7" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_5</name>
    </property>
    <property propertyId="e2bdc7a2-bfb2-4db4-9fa2-12e46f767097" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_19</name>
    </property>
    <property propertyId="9676ed7d-a99c-40ed-9ff5-55081521ad8b" amount="37.91">
      <name xml:lang="en">EcoSpold01Allocation_undefined_8</name>
    </property>
    <property propertyId="a9358458-9724-4f03-b622-106eda248916" amount="0" unitId="577e242a-461f-44a7-922c-d8e1c3d2bf45">
      <name xml:lang="en">water content</name>
      <unitName xml:lang="en">dimensionless</unitName>
```

EcoSpold 2

- “Intelligence” in data format:
  - Child and parent data sets:
    - “parent data set: a dataset referred to by a child dataset as the dataset from which field values in the child dataset are to be inherited to the extent defined, i.e. parent datasets serve as basis of their associated child datasets. “ (ecoinvent.org)
    - “Only geographical inheritance is allowed in the ecoinvent v3 database, i.e. some regional datasets (such as Brazilian soybean production) might be modelled as a child dataset of the global dataset. “ (ecoinvent.org)

EcoSpold 2

- "Intelligence" in data format: child and parent data sets
  - Child and parent data sets:
    - "In child datasets values can be set to relate to the corresponding value in the parent dataset. When such a related value is changed in the parent dataset it is automatically changed in the child dataset as well."
    - "it is automatically changed" → better: it is meant to be automatically changed.
    - Idea: save space; avoid redundancies.
    - In current ecoinvent database: values for all the child data sets present; redundancies exist

    → (possible) task for software developers: keep redundant information consistent

Ecoinvent 3, market modelling

- Basically, products are not exchanged directly between processes, but through a market
  - Advantage: more flexible modelling of process chains
  - However, the current version is linked→ flexibility lost
  - But…different default "system models":

  "system model; a model describing how activity data sets are linked to form product systems. A system model may determine factors such as whether to use allocation (and which type of allocation) or substitution […], or whether to use average or marginal suppliers. It may also affect how by-product treatments are assessed."
  - Originally two system models: "Allocation, ecoinvent default" and "Consequential, substitution, long-term".
    - From version 3.0.1 also "cut-off" model.

Ecoinvent 3, market modelling

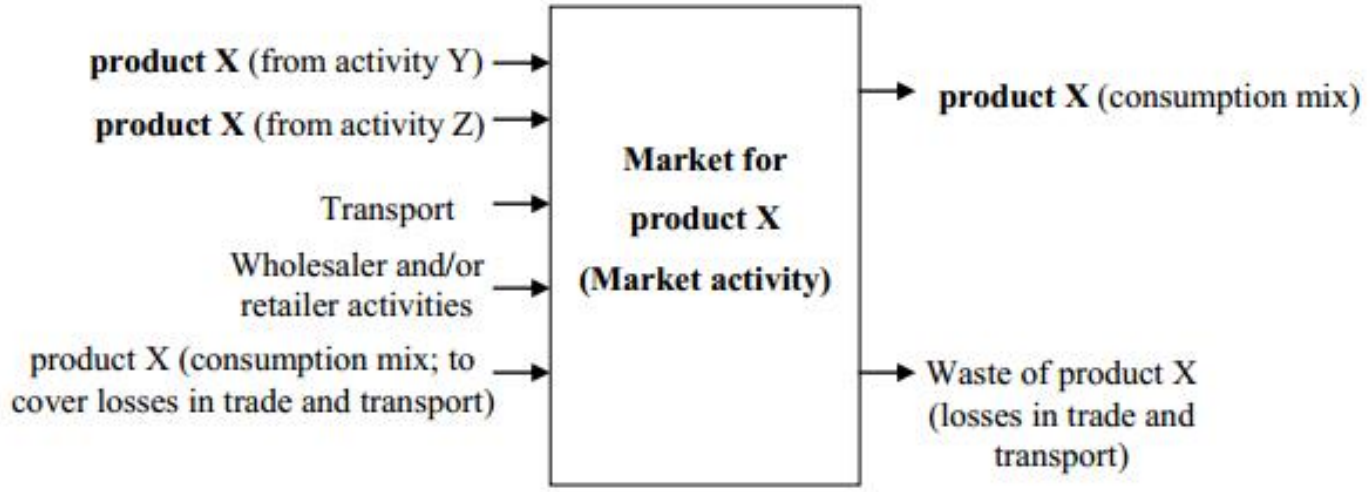
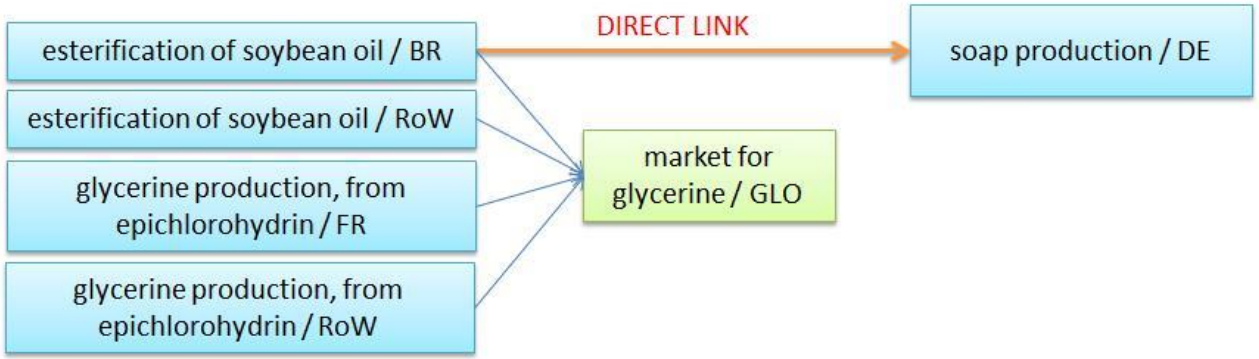


Figure 4.2. A market activity with its intermediate exchanges. Texts in brackets are not part of the name of the exchange.

(ecoinvent methodology report p.17)

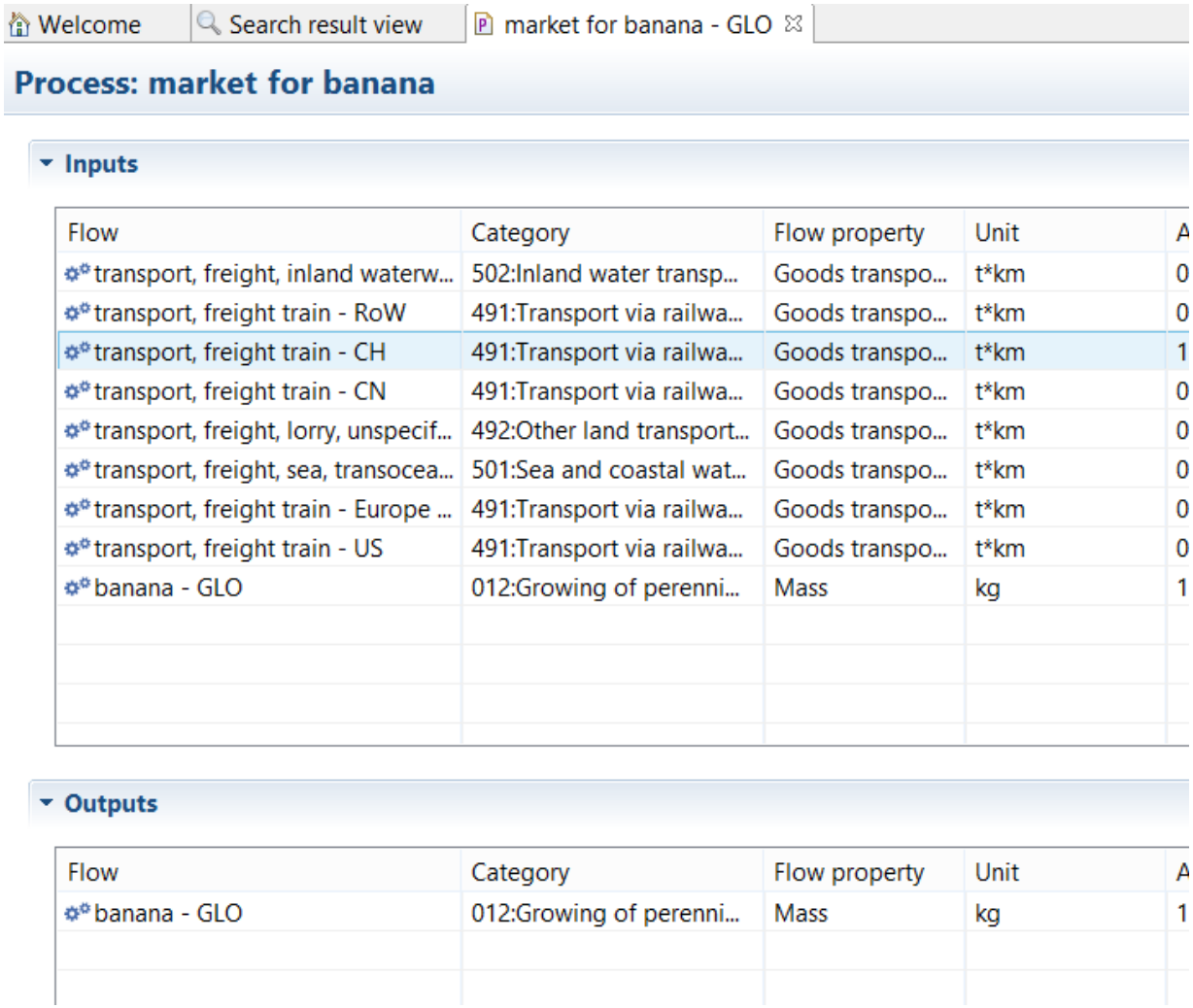
Ecoinvent 3, market modelling

- Example for the difference between each system model:
  - Direct link: Consequential model
  - Market: Attributional / default model



(ecoinvent.org)

Ecoinvent 3, example: market for banana



3.1 allocation defaul

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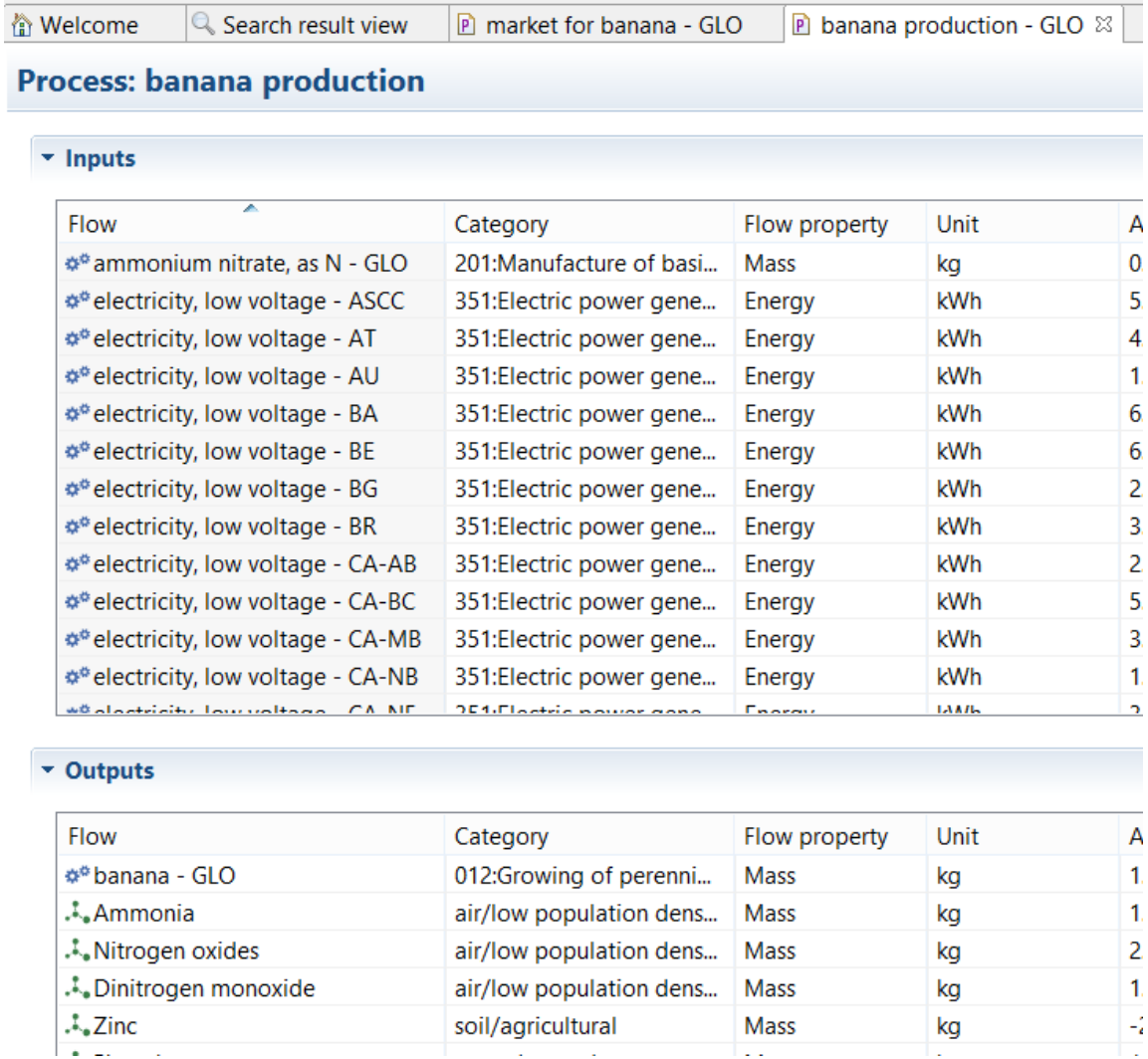
Ecoinvent 3, example: banana production



3.1 allocation default

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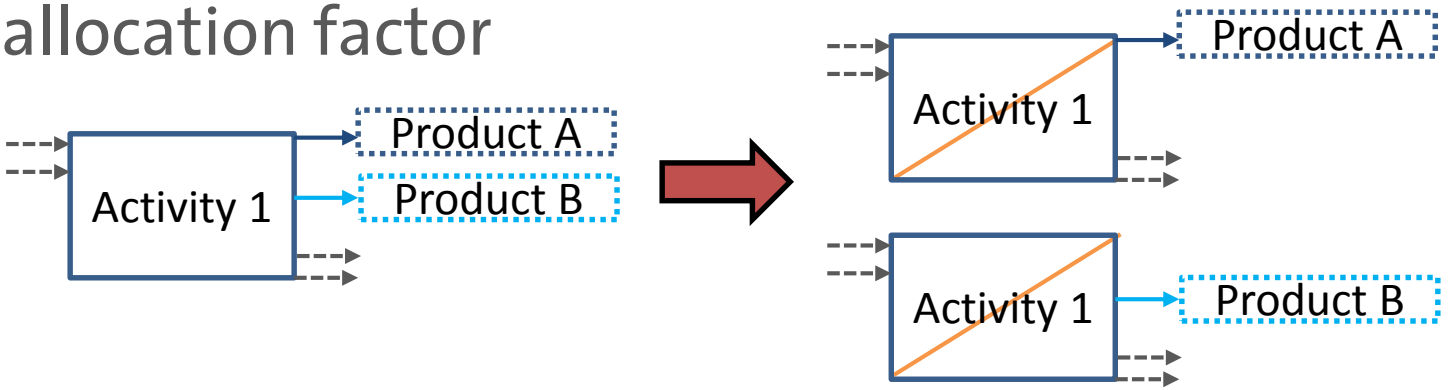
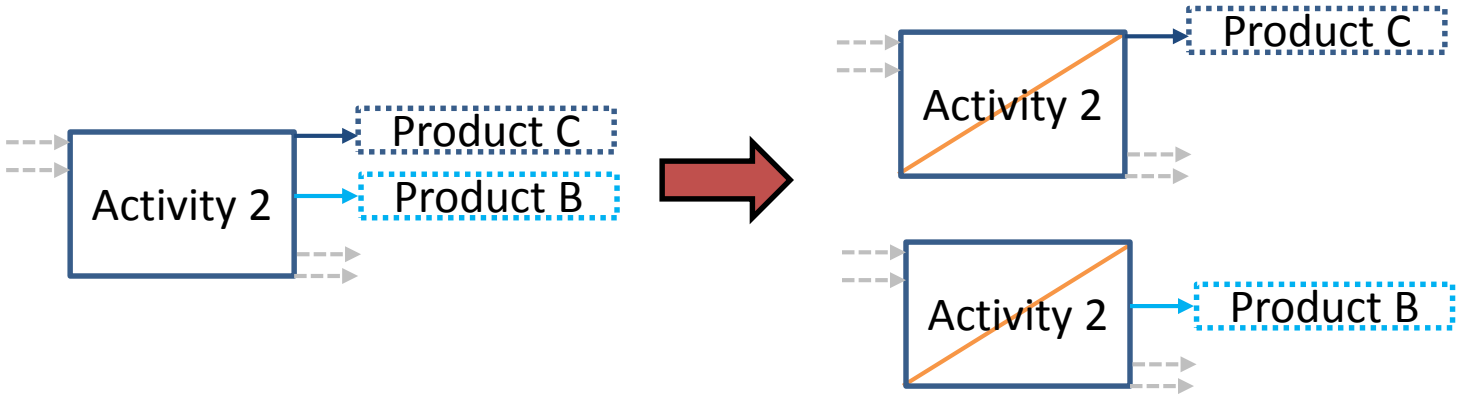
Ecoinvent 3, system models

- Common rules:
  - By-products/wastes identified as materials for treatment are moved to the input with negative sign.
  - Intermediate inputs without activity link specified, are linked to the local market activity data set.
  - Data sets with “combined” products are divided into an equivalent number of data sets.
  - For “joint” products:
    → Allocation (partitioning)
    → System expansion (substitution)

Ecoinvent 3, allocation model

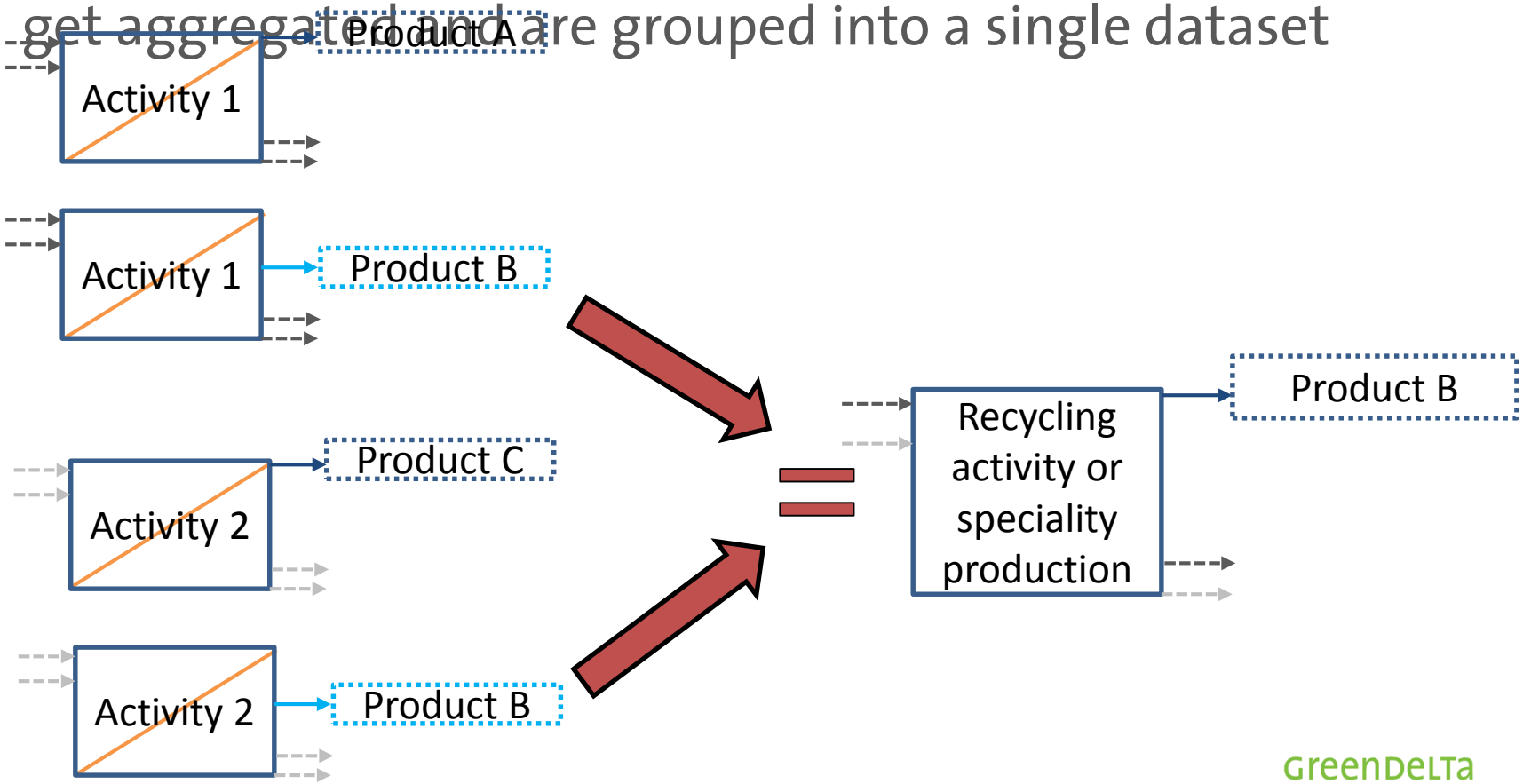
- Divide the data sets into new activities according the allocation factor





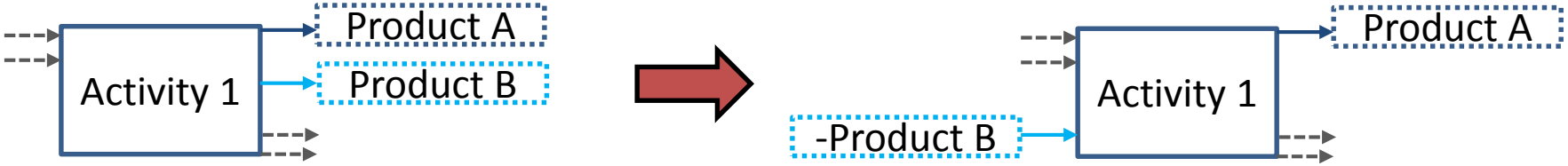
Ecoinvent 3, allocation model

- After allocation, all activities producing the same marketable by-product yielded from a treatment activity get aggregated and are grouped into a single dataset

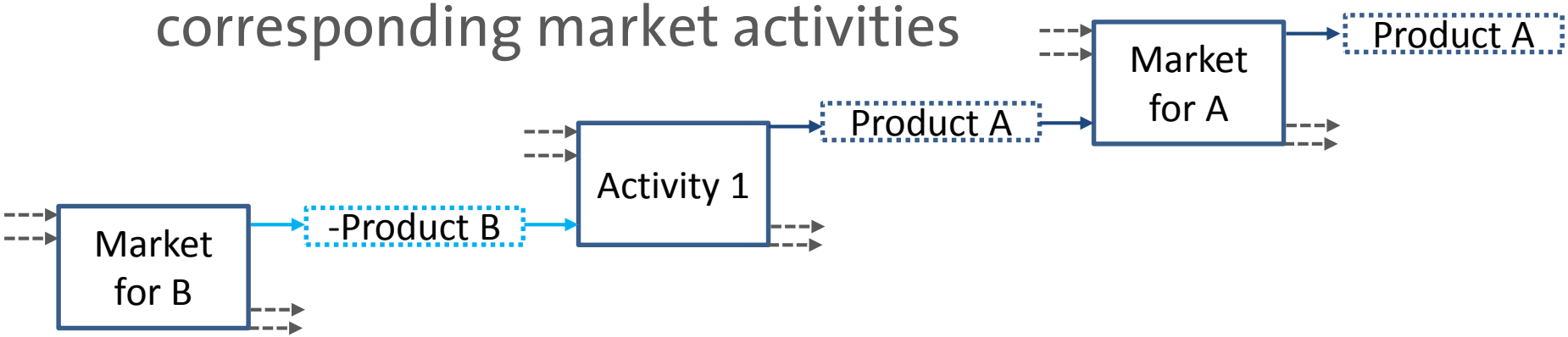


Ecoinvent 3, substitution model

- All by-products are moved to the input side with negative sign



- All inputs and outputs are linked to their corresponding market activities



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Ecoinvent 3, cut-off model

- Based on the Recycled Content, or Cut-off, approach.
- Primary (first) production of materials is always allocated to the primary user of a material.
- If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. As a consequence, recyclable materials are available burden-free to recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes.
- Furthermore, producers of wastes do not receive any credit for recycling or re-use of products resulting out of any waste treatment.

e.g.: recycled paper? Waste incineration?

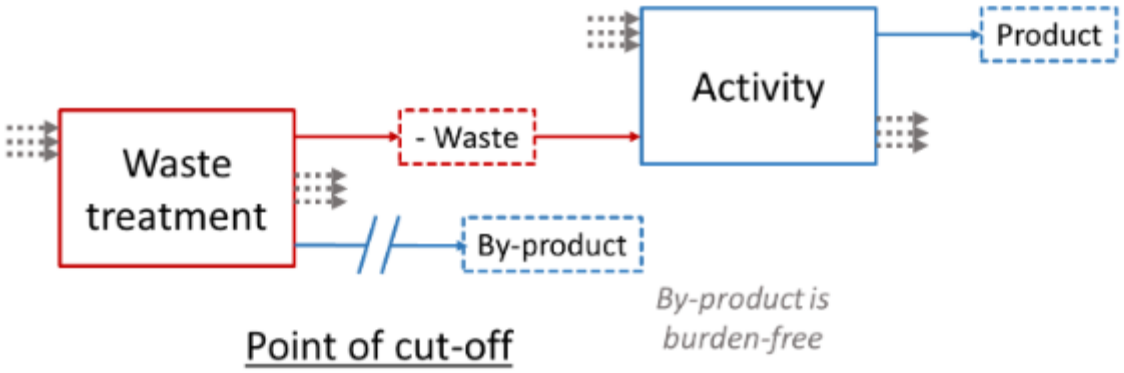
Ecoinvent 3, cut-off model (II)

- All technosphere flows are classified as:
  - ordinary by-product (treated just as common products, but they are not reference)
  - recyclable material ("Materials with no or little economic value that can serve as the input or resource for a recycling activity"), or
  - waste ("Materials with no economic value, and no interest in their collection without compensation")

http://www.ecoinvent.org/fileadmin/documents/en/System_Models/System_model_description_and_specification-Cutoff.pdf

Ecoinvent 3, cut-off model (IV)

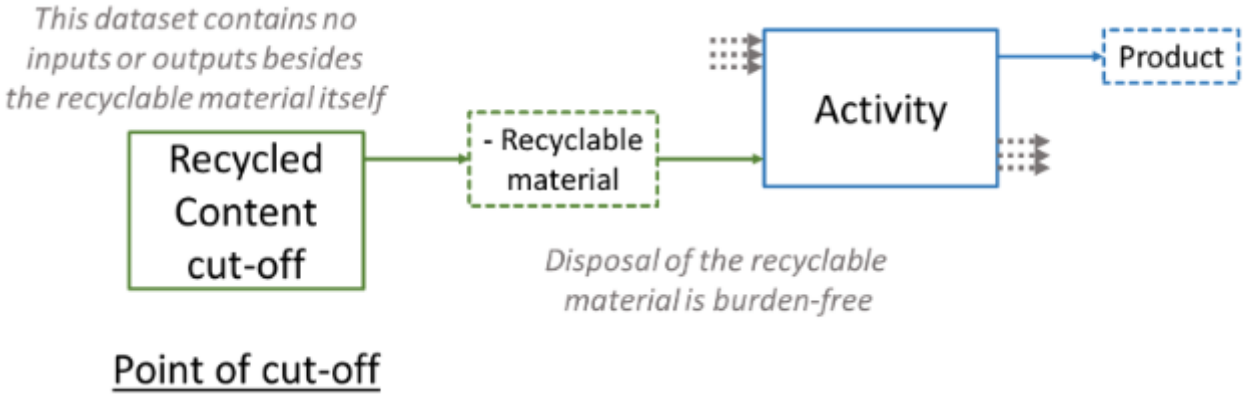
- Waste products handling: by-product is burden-free



http://www.ecoinvent.org/fileadmin/documents/en/System_Models/System_model_description_and_specification-Cutoff.pdf

Ecoinvent 3, cut-off model (V)

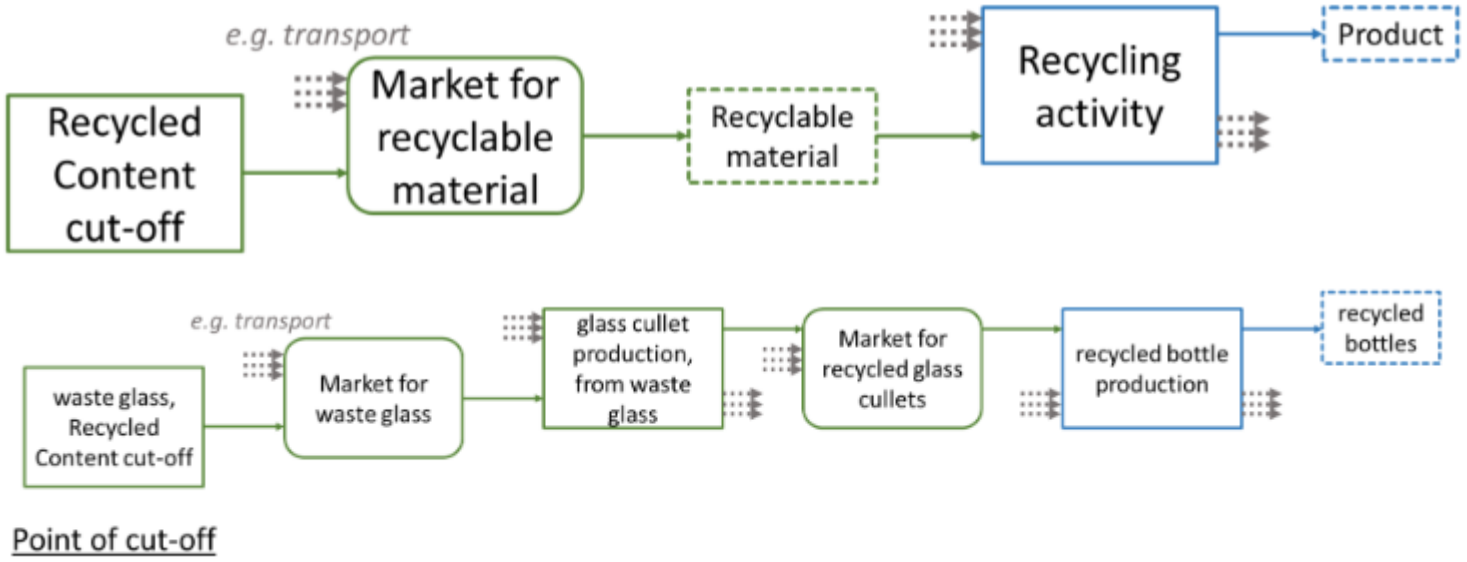
- Handling of recyclable materials: negative input (=output) of a dummy process recycled content cut-



http://www.ecoinvent.org/fileadmin/documents/en/System_Models/System_model_description_and_specification-Cutoff.pdf

Ecoinvent 3, cut-off model (VI)

- Handling of recyclable materials: when used in markets, markets get additional transport effort as



http://www.ecoinvent.org/fileadmin/documents/en/System_Models/System_model_description_and_specification-Cutoff.pdf

Ecoinvent 3, new data

- (very few: some international data; water data)
- Data updates
  - e.g. electricity mixes, transport

Ecoinvent 3, consequences for openLCA

- Much larger systems

  → Optimization of performance in product sytems (open, create new): before 2 min, now 10s

  → Optimization of the calculation (Background: matrix inversion, memory use, speed)
- Modelling corrections (correct some links; uncertainty information)
- (openLCA structure adapts well already)

Feedback

- Did you learn in the training what you expected to learn?
- What do you like/dislike in openLCA?
- Which functions do you miss?

Thank you!

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