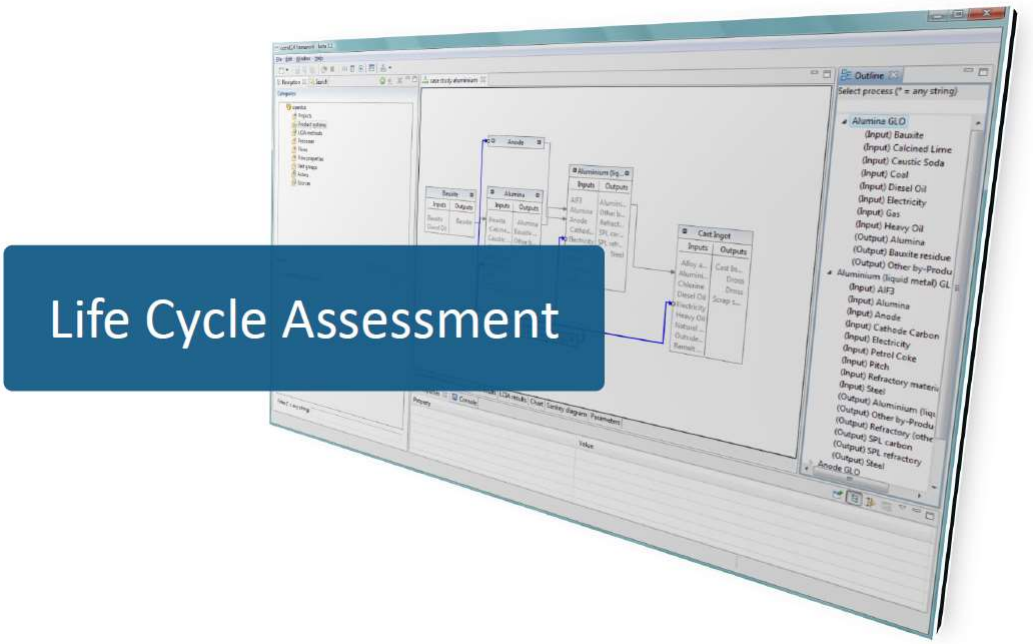
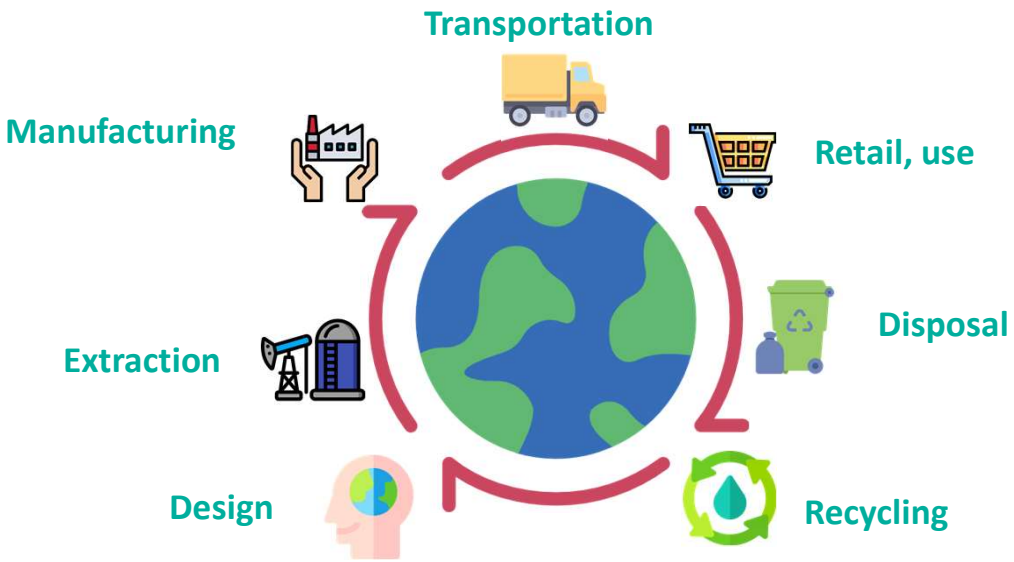


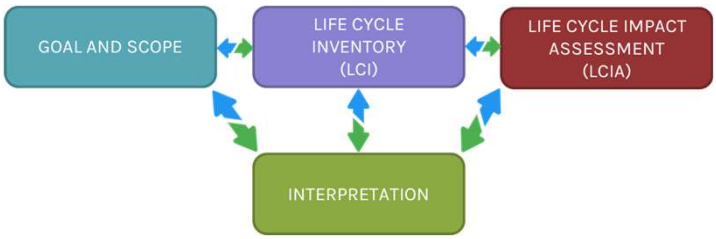
Life Cycle Thinking (LCT)



2

Life Cycle Assessment (LCA)

Life Cycle Assessment is a technique for assessing the environmental (or social) impacts that occur during all stages of a product's life cycle (from cradle-to-grave)



3

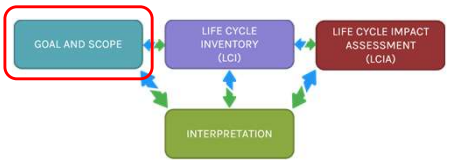
Goal and Scope

Goal of the study

- Context of the study
- Aim of the evaluation
- Intended audience

Scope of the study

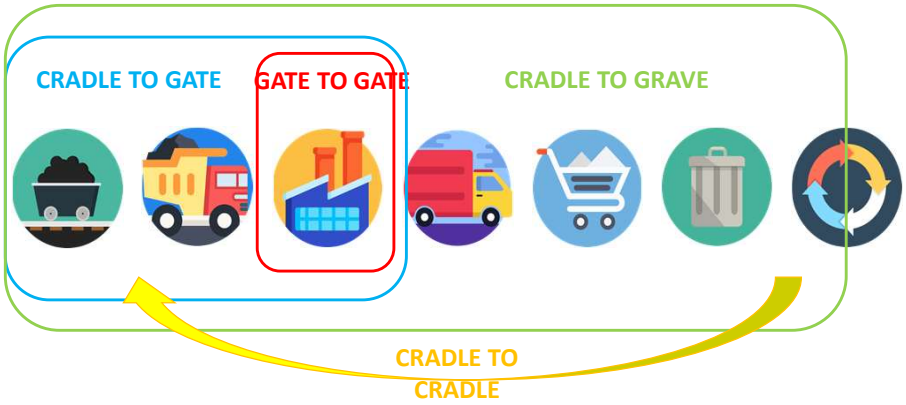
- Functional Unit
- System Boundary
- Data quality
- Limitations and assumptions
- Allocation (Phys, Eco)
- Impact Categories



UNI EN ISO 14044:2006
International Reference Life Cycle Data System (ILCD) Handbook

4

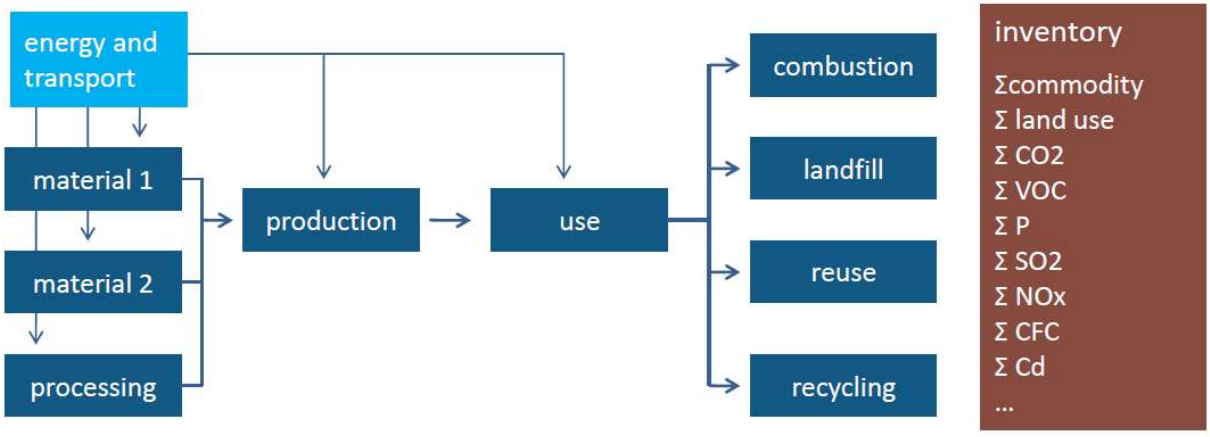
System boundary



UNI EN ISO 14040-44
International Reference Life Cycle Data System (ILCD) Handbook

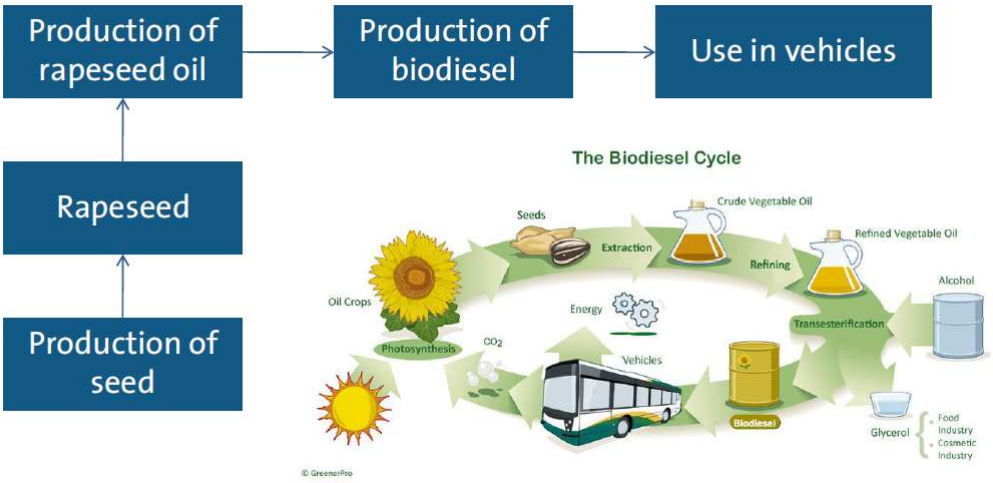
5

Determining the flow diagram



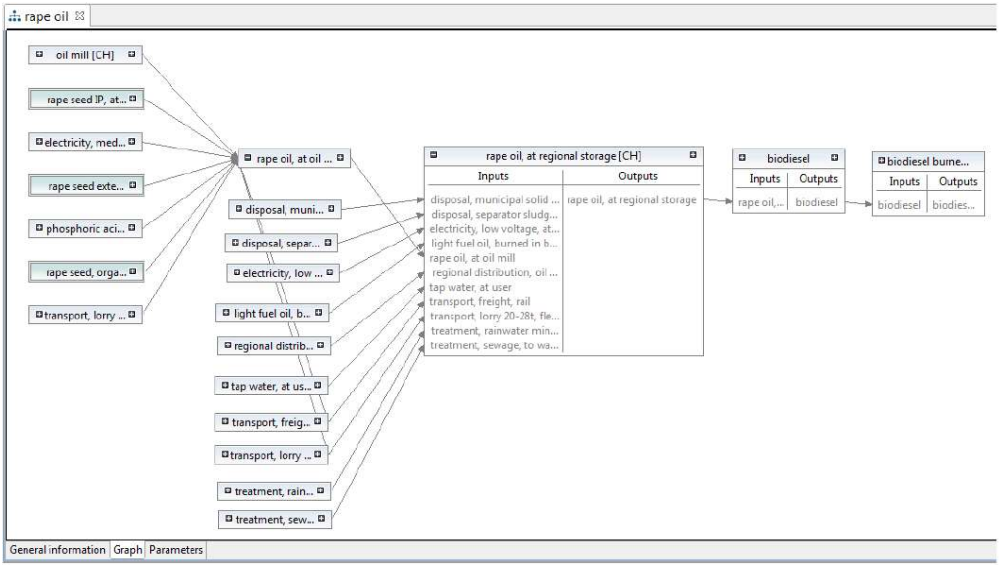
6

Flow diagram example: rapeseed oil as biodiesel



7

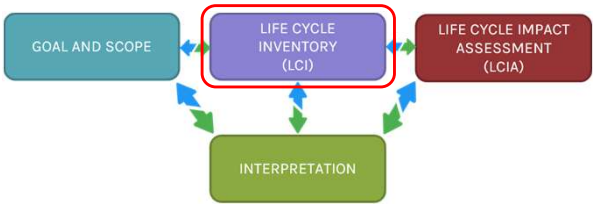
Process network for rapeseed oil-based biodiesel



8

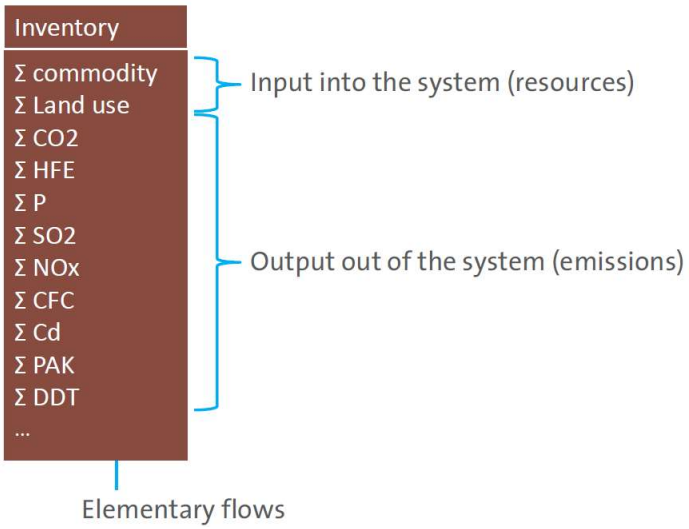
Life Cycle Inventory (LCI)

- Data collection (suppliers, survey, literature, database, reverse engineering, primary data)
- Determining input (resources) and output (product, byproducts, waste, emissions) flows in terms of materials
- If necessary, adjustment of the goal and scope
- Creation of the flow diagram of the product life-cycle



9

Life Cycle Inventory (LCI)



10

Calculated Inventory

Inventory results

Inputs

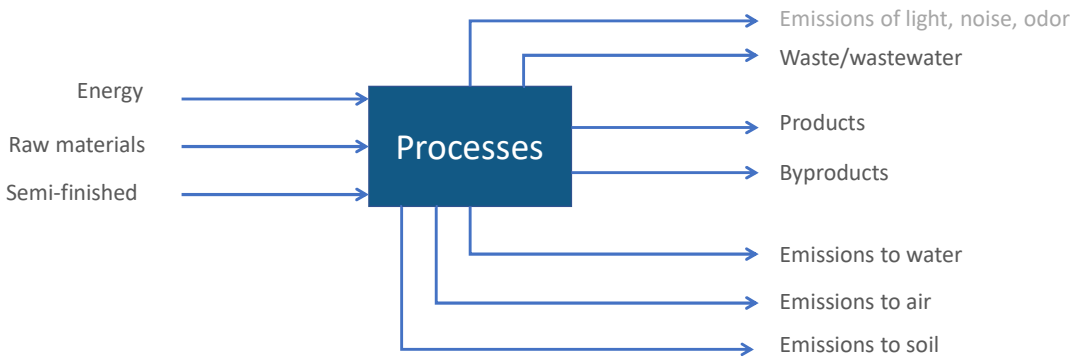
Flow	Category	Sub-category	Unit	Amount
Clay, bentonite, in ground	resource	in ground	kg	0.00010
Transformation, to permanent crop, fruit, intensive	resource	land	m2	1.36330E-8
Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in ground	resource	in ground	kg	2.24214E-8
Gold, Au 4.3E-4%, in ore, in ground	resource	in ground	kg	2.00562E-10
Occupation, tropical rain forest	resource	land	m2*a	0.00076
Transformation, from unknown	resource	land	m2	2.16097E-5
Occupation, traffic area, road embankment	resource	land	m2*a	0.00043
Calcium carbonate, in ground	resource	in ground	kg	0.01250

Outputs

Flow	Category	Sub-category	Unit	Amount
Carbon dioxide, fossil	air	unspecified	kg	0.02676
Benzene	water	surface water	kg	2.25865E-6
Chromium, ion	water	ocean	kg	4.27239E-9
Dimethylamine	water	surface water	kg	2.65300E-8
Cumene	air	unspecified	kg	5.35044E-17
Antimony	water	surface water	kg	2.65496E-8
Protactinium-234	water	surface water	kBq	4.37261E-6
Methyl acrylate	air	high population density	kg	2.21688E-12

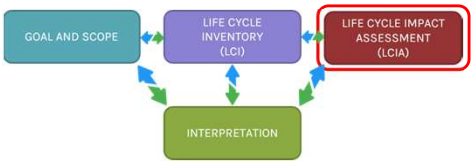
11

Data types



12

Life Cycle Impact Assessment (LCIA)



methods

Inventory results

CO
CO2
SOx
H2S
..

Impact assessment

Selection of impact categories

Climate change
Ozone depletion
Eutrophization
Human toxicity
...

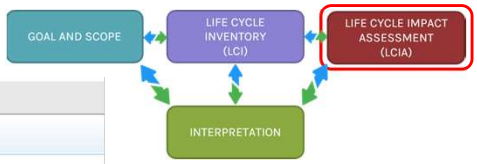
Classification and characterisation

Es. Climate change (IPCC method)

1 kg CO_2 =1 kg CO_2 eq.
1 kg CO = 1,57 kg CO_2 eq.
1 kg CH_4 = 23 kg CO_2 eq.

13

Steps of LCIA



Welcome | ILCD 2011, midpoint [v1.0.10, August 2016]

Impact factors: ILCD 2011, midpoint [v1.0.10, August 2016]

Impact factors

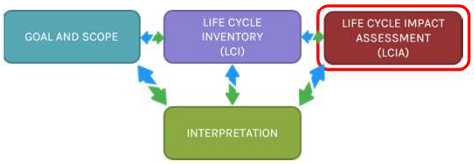
Impact category: Climate change

Flow	Category	Flow pro	Factor	Unit
Butane, perfluoro-	Emission to air/low population densi...	Mass	8860.0	kg CO2 eq./kg
Butane, perfluoro-	Emission to air/lower stratosphere +...	Mass	8860.0	kg CO2 eq./kg
Butane, perfluoro-	Emission to air/unspecified	Mass	8860.0	kg CO2 eq./kg
Butane, perfluorocyclo-, PFC-318	Emission to air/high population density	Mass	10300.0	kg CO2 eq./kg
Butane, perfluorocyclo-, PFC-318	Emission to air/low population density	Mass	10300.0	kg CO2 eq./kg
Butane, perfluorocyclo-, PFC-318	Emission to air/low population densi...	Mass	10300.0	kg CO2 eq./kg
Butane, perfluorocyclo-, PFC-318	Emission to air/lower stratosphere +...	Mass	10300.0	kg CO2 eq./kg
Butane, perfluorocyclo-, PFC-318	Emission to air/unspecified	Mass	10300.0	kg CO2 eq./kg
Carbon dioxide	Emission to air/high population density	Mass	1.0	kg CO2 eq./kg
Carbon dioxide	Emission to air/low population density	Mass	1.0	kg CO2 eq./kg

Classification *Characterisation*

14

Steps of LCIA



Characterisation - Example

Climate change = $\sum GWP_i \cdot mass_i$

Air emissions per 1 kWh of Electricity Mix (IT)

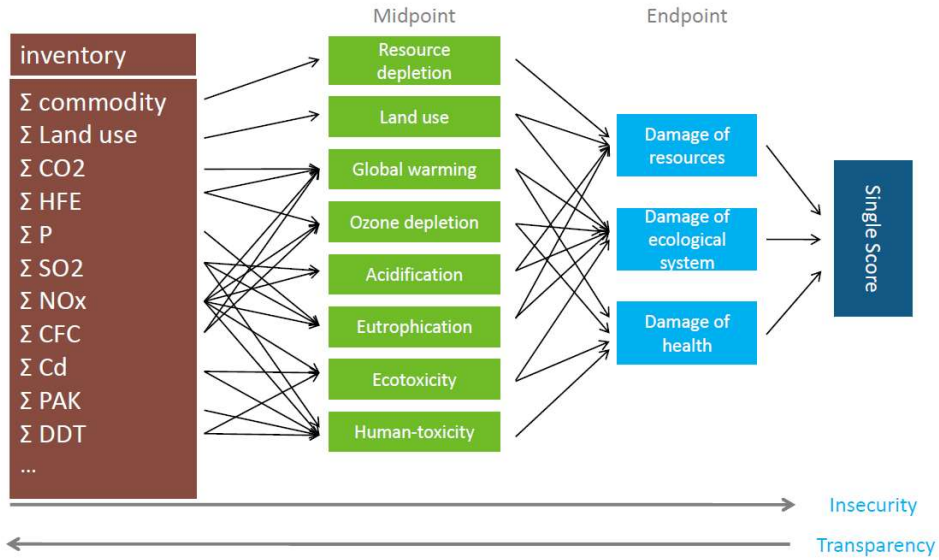
Flow	Factor (IPPC 2007)	Quantity [g]
Carbon dioxide (CO_2)	1	1.55
Methane (CH_4)	25	0.0033
Dinitrogen monoxide (N_2O)	298	2.38 E-5
$Flow_i$	GWP_i	$mass_i$

ILCD 2011, midpoint [v1.0.10, August 2016];
Climate change - IPCC 2007; GWP100 - Reference unit: kg CO2 eq.

GWP of 1 kWh of Electricity Mix (IT) =
= (1 * 1.55) g + (25 * 0.0033) + (298 * 2.38E-5) +$\sum GWP_i \cdot mass_i$

15

Steps of LCIA



16

Steps of LCIA

According to ISO 14040-44

- ***Selection*** of impact categories
- ***Classification***
- ***Characterization***

mandatory

- *Normalization*
- *Grouping*
- *Weighting*

optional

17

Steps of LCIA

Normalization

Calculation of the **magnitude** of category indicator results relative to reference information. Consists in **dividing values of category indicators by a reference measure**.

Example:
JRC EU 27, 2010, total [year]
JRC EU 27, 2010, per person [person/year]

Normalization

Impact category	Amount
Resource depletion - water	8.94635
Human toxicity - carcinogenics	7.16312
Human toxicity - non-carcinogenics	4.18130
Land use	3.23476
Marine eutrophication	1.54674
Photochemical ozone formation	1.18695
Freshwater ecotoxicity	1.08884
Terrestrial eutrophication	0.86622
Acidification	0.72633
Resource depletion - mineral, fossils and rene...	0.62606
Particulate matter/Respiratory inorganics	0.38932
Freshwater eutrophication	0.25511
Ionizing radiaton - human health	0.16675
Ozone depletion	0.04809
Ionizing radiation - ecosystems	0.00000
Nuova categoria di impatto	0.00000
Nuova categoria di impatto	0.00000
Climate change	-5.31630

18

Steps of LCIA

Grouping and weighting

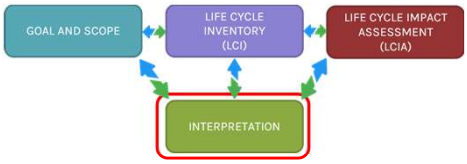
In weighting, the (typically normalised) indicator results for the different impact categories or damages are each multiplied by a **specific weighting factor**, that is intended to **reflect the relative relevance** of the different impact categories / category endpoints among each other.

It becomes possible to add up indicators and obtain a single score indicator!

...there is much less consensus among the scientific community!

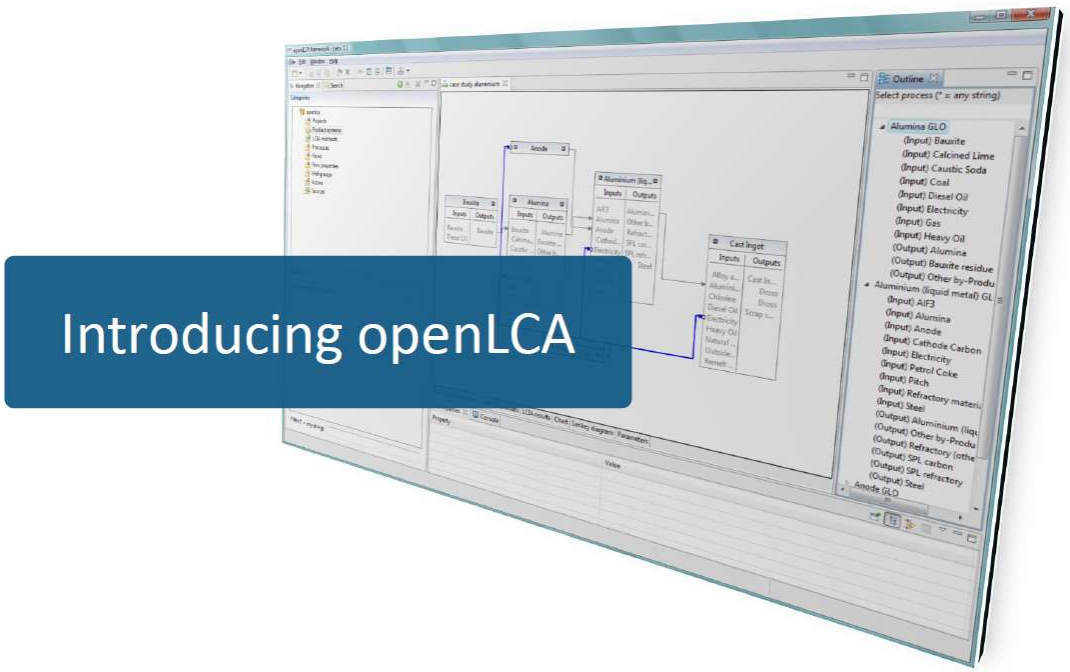
19

Interpretation



- Identification of significant issues
- Based on the LCI and LCIA results
- Sensitivity analysis
- Completeness and consistency checks
- Conclusions / Limitations / Recommendations

20



openLCA

- A free and (yet) professional approach to Life Cycle Assessment: powerful, feature rich, (comparatively) easy to use, technically up to date
- developed by GreenDelta since 2006
- completely Open Source (Mozilla Public License)
- Native to Windows, Mac OS and Linux
- Established and growing community of users: more than 10k downloads/yr
- Broadest selection of relevant, consistent LCI and sustainability databases available worldwide

22

openLCA application

- Life Cycle Assessment, Life Cycle Costing, Social Life Cycle Assessment
- Carbon and Water footprint
- Product Environmental Footprint (PEF)
- Environmental Product Declarations (EPD)
- US Environmental Protection Agency (EPA)'s Design for Environmental Label
- Integrated Product Policy

23

openLCA.org

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

24

openLCA.org/downloads

Downloads

openLCA

Here's presenting the latest version 1.10.3 (release date: June 24th, 2020). We recommend using this version. Our tests have not shown any issues, but should you run into any, please let us know. Thanks in advance!

Windows | Mac | Linux | Sources | Latest build

To use openLCA in windows, download the zip-archive below: Just unzip the archive and start openLCA.exe. To uninstall it, just delete the created folder. You can have several versions of openLCA in different folders on the same computer.

openLCA 1.10.3 zip-archive: openLCA_win64_1.10.3_2020-06-24.zip

Alternatively, you can install openLCA with the installer below. If you have an older openLCA version installed (via the installer) you should uninstall it first.

openLCA 1.10.3 installer: openLCA_win64_1.10.3_2020-06-24

25

openLCA.org/downloads

Impact methods

Several impact methods for use in openLCA are available. The methods are provided for free, as openLCA databases, which can be easily imported into openLCA. If you have any comments or would like to submit own methods, please let us know.

General purpose | Social LCA | EPD creation | ecoinvent | AWARE

A comprehensive package of environmental impact assessment methods for use with all different databases available in the nexus system – including ecoinvent 3, GaBi and ELCD is available here. It includes normalisation and weighting as far as this is foreseen by the method. Please observe the license* (Commons Attribution-ShareAlike 4.0 International) while using it. Please provide feedback – thanks in advance!

Note that **newer openLCA LCIA methods**, especially the comprehensive 2.0 package for "countrified" databases released April 2018, are available on openLCA Nexus from now on only, here: https://nexus.openlca.org/database/openLCA%20LCIA%20methods.

openLCA LCIA method pack 1.5.7 as openLCA database for openLCA 1.6 (and also 1.7), last update: October 22nd, 2017. The newest methods are also available on the Nexus website.

26

openLCA.org/learning

Free resources

To help you get started with openLCA, we are providing many free resources, from manuals on the software to handbooks on specific topics, to guidance on impacts assessment methods and some ready to use case studies to get inspiration on modeling your own LCA study.

Manuals and presentations

Sometimes it is good to have a more comprehensive text which explains details – this section contains some manuals for different openLCA versions and related, typically more specific, topics. Also the format converter documentation is available.

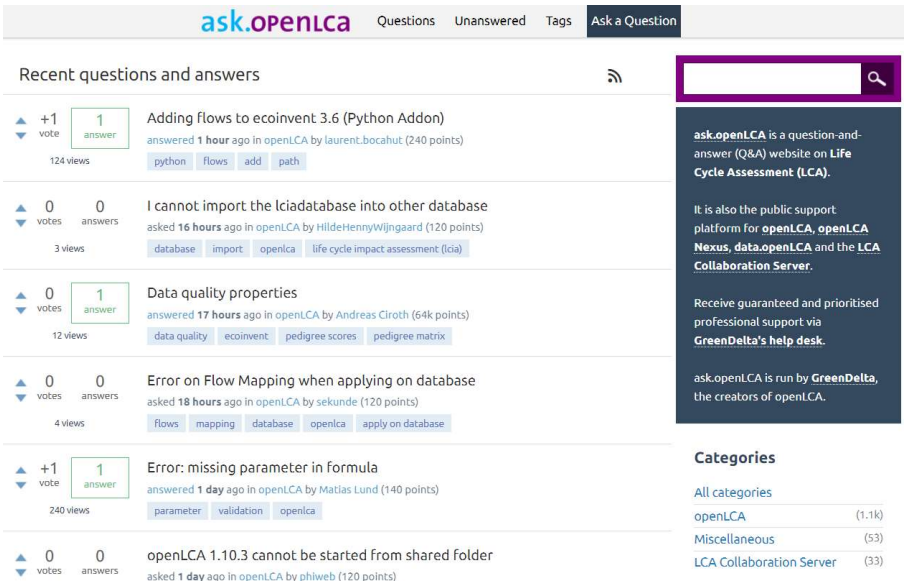
openLCA, general | Specific topics | Databases | Presentations | Format converter

Version 1.10.2

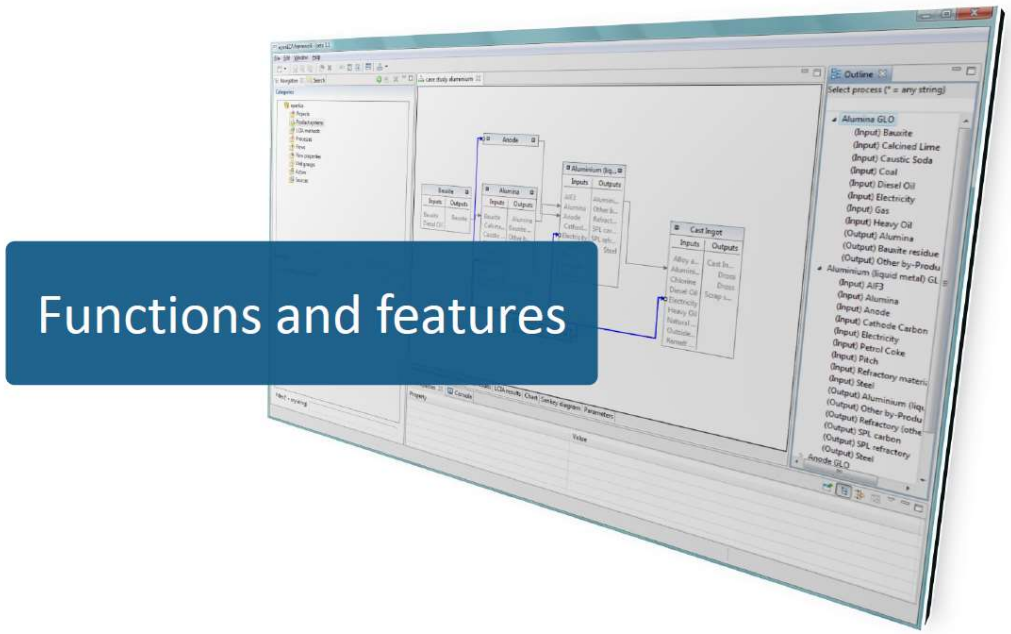
- New! Comprehensive openLCA manual for version 1.10, February 2020

27

Ask.openLCA



28



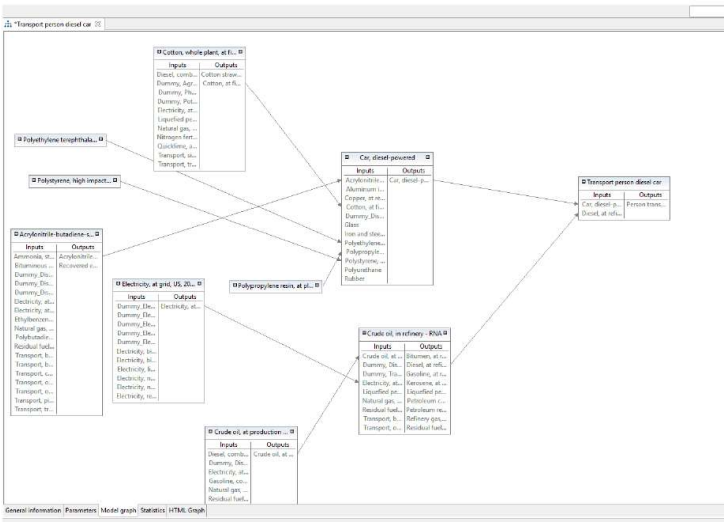
29

Graphical modeling of product systems

- Product system = 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 using the “Projects” feature

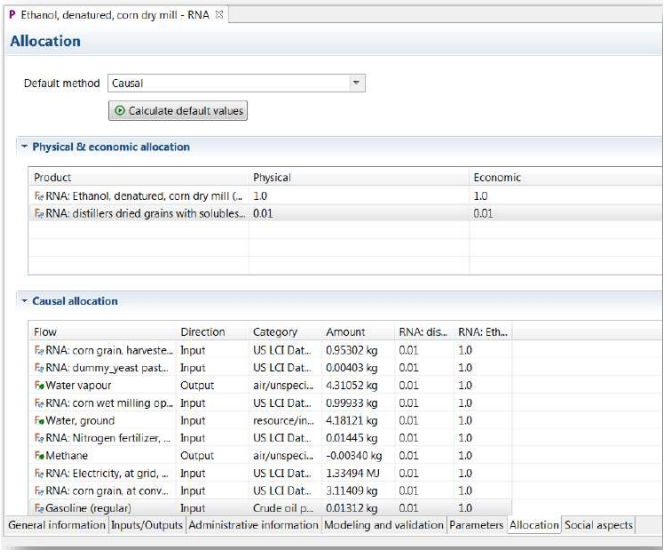
30

Graphical modeling of product system based on Eclipse GEF



31

Allocation and system expansion for modeling multi-output processes



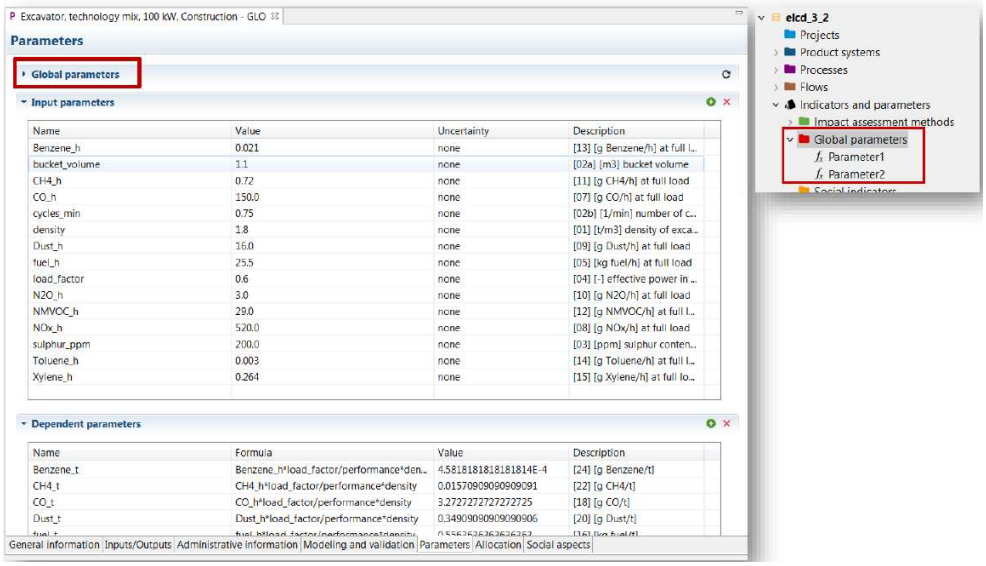
32

Modeling with parameters

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

33

Local and global parameters



34

Inventory Calculation

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

```
> 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
>
```

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

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

35

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 ; parametrization is also available

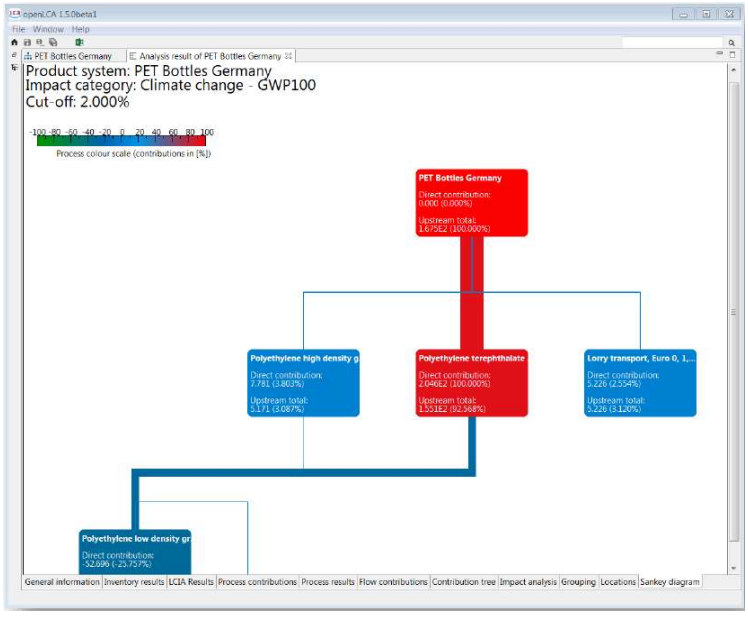
36

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)
  - …

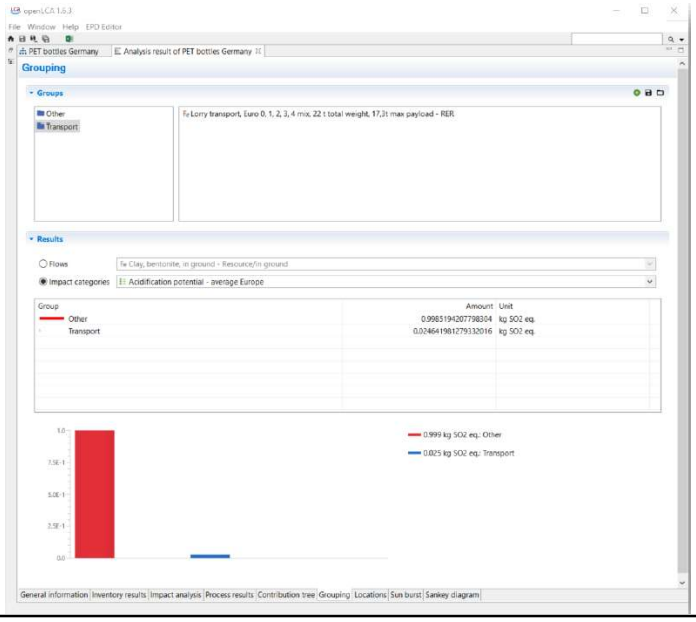
37

Sankey Diagram

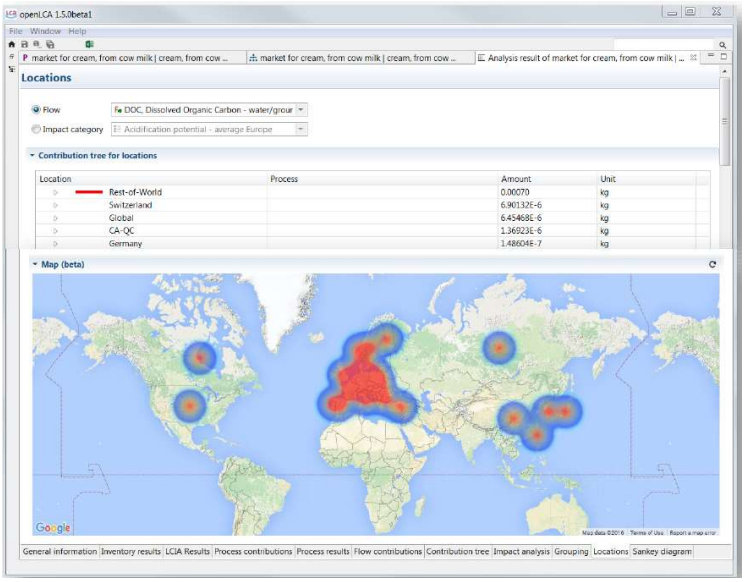


38

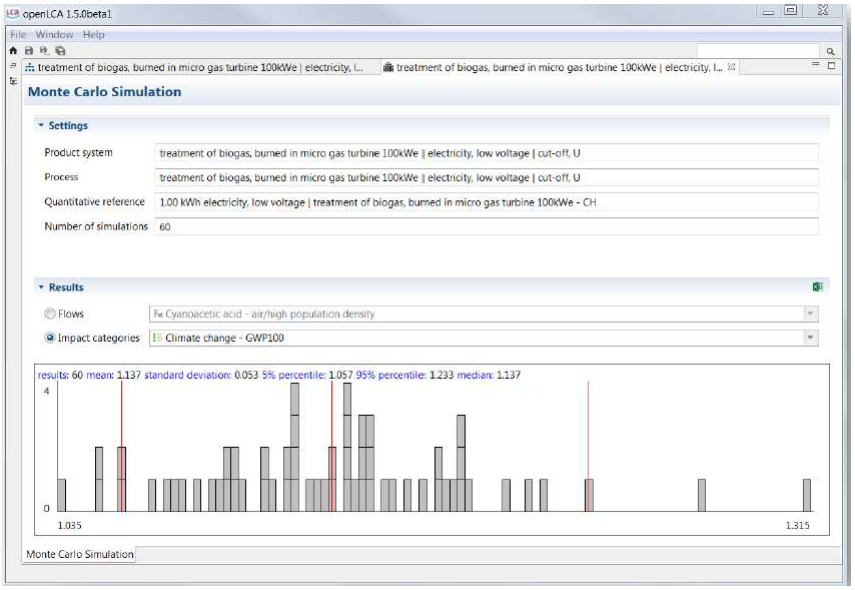
Grouping



Localisation



Uncertainty Analyses



Further characteristics

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

43

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)

44

Task #1: Download and installation of openLCA

- Download openLCA @ https://www.openlca.org/download/

Downloads

openLCA

Here's presenting the latest version 1.10.3 (release date: June 24th, 2020). We recommend using this version. Our tests have not shown any issues, but should you run into any, please let us know. Thanks in advance!

Windows | Mac | Linux | Sources | Latest build

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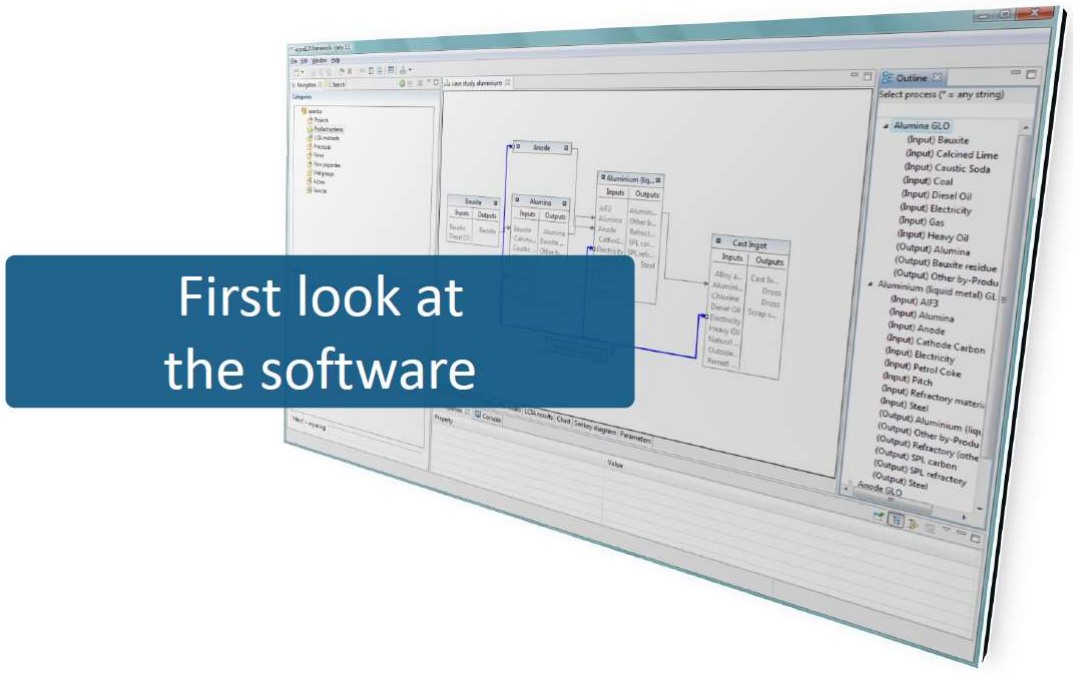
openLCA 1.10.3 installer: openLCA_win64_1.10.3_2020-06-24

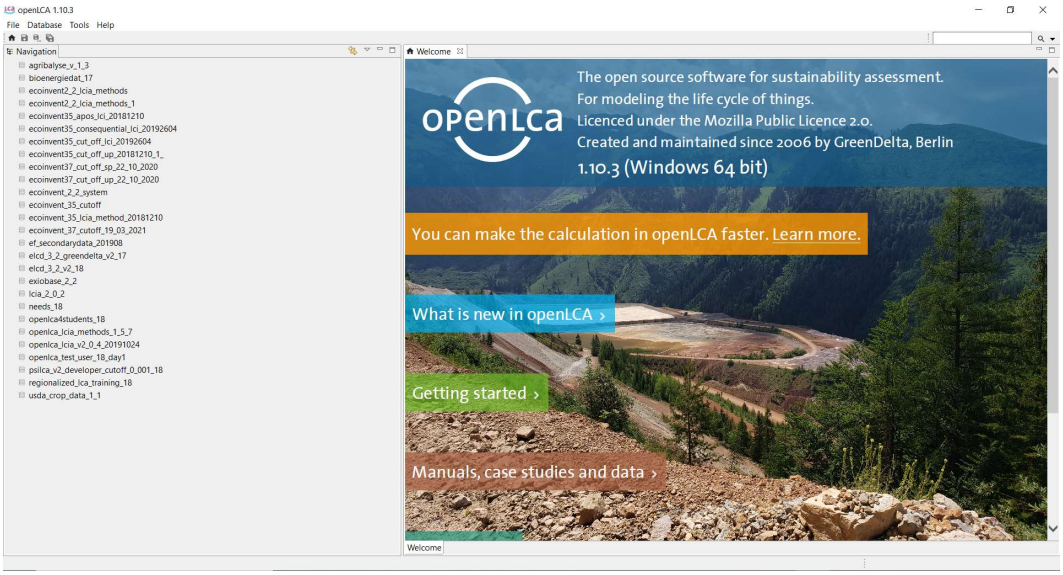
- Two options available: Installer version and zip file

45



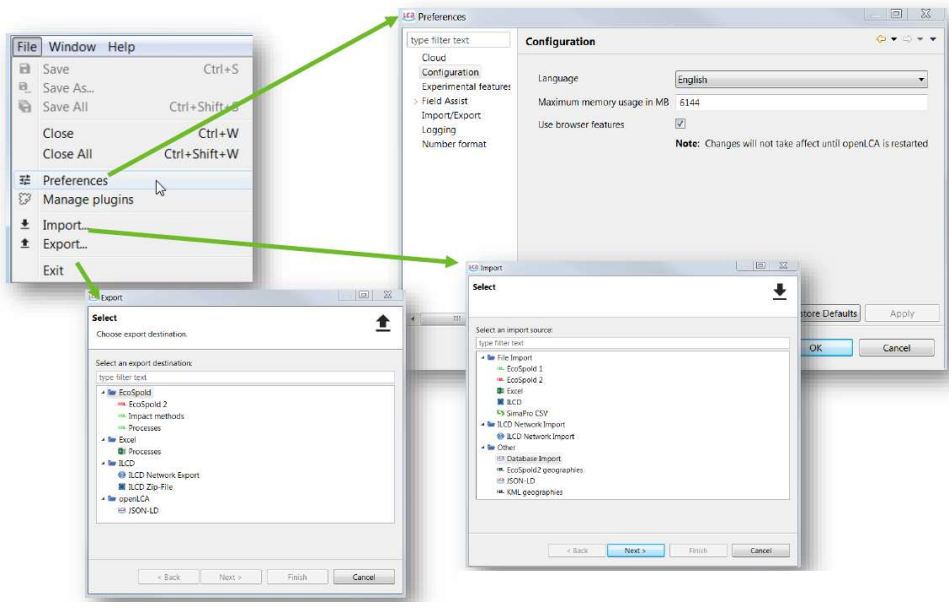
46

Homepage



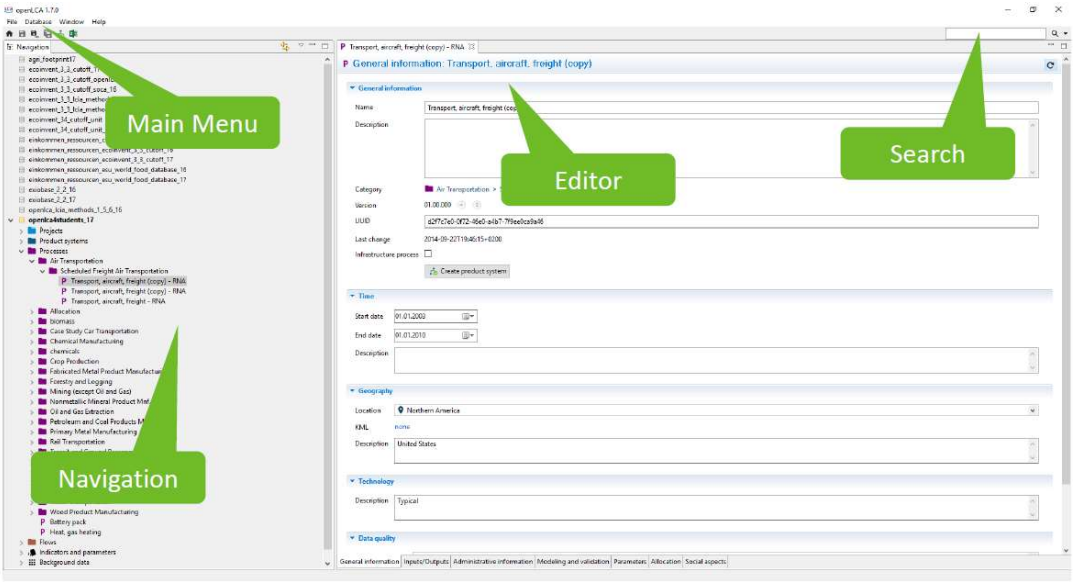
47

Main menu functions



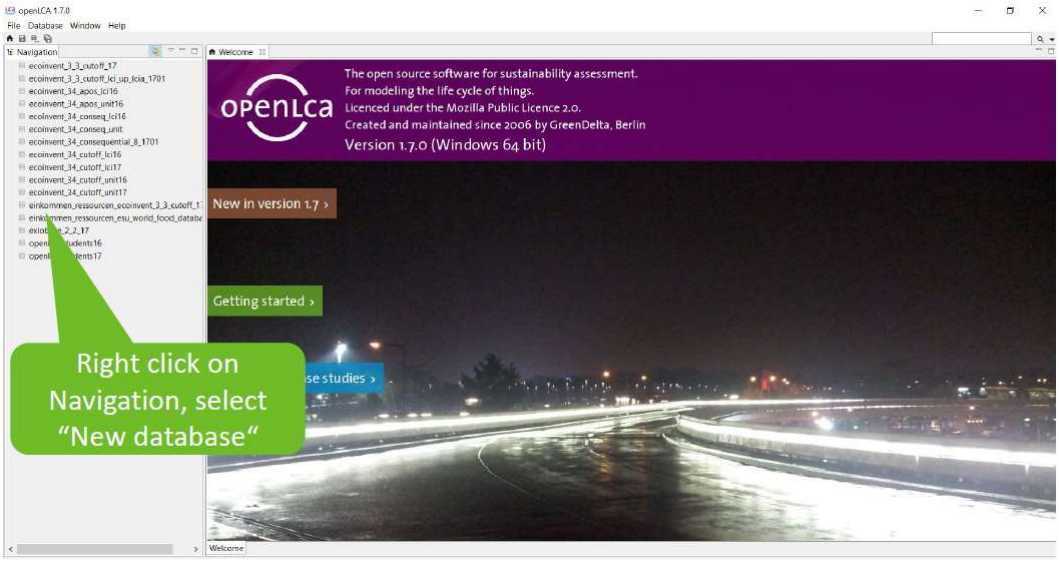
48

openLCA overview



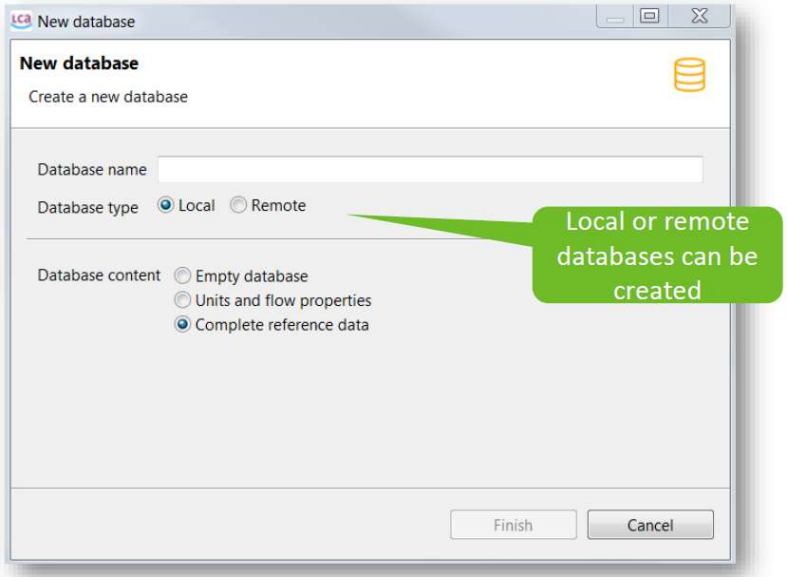
49

Create a new database



50

Create a new database (local)

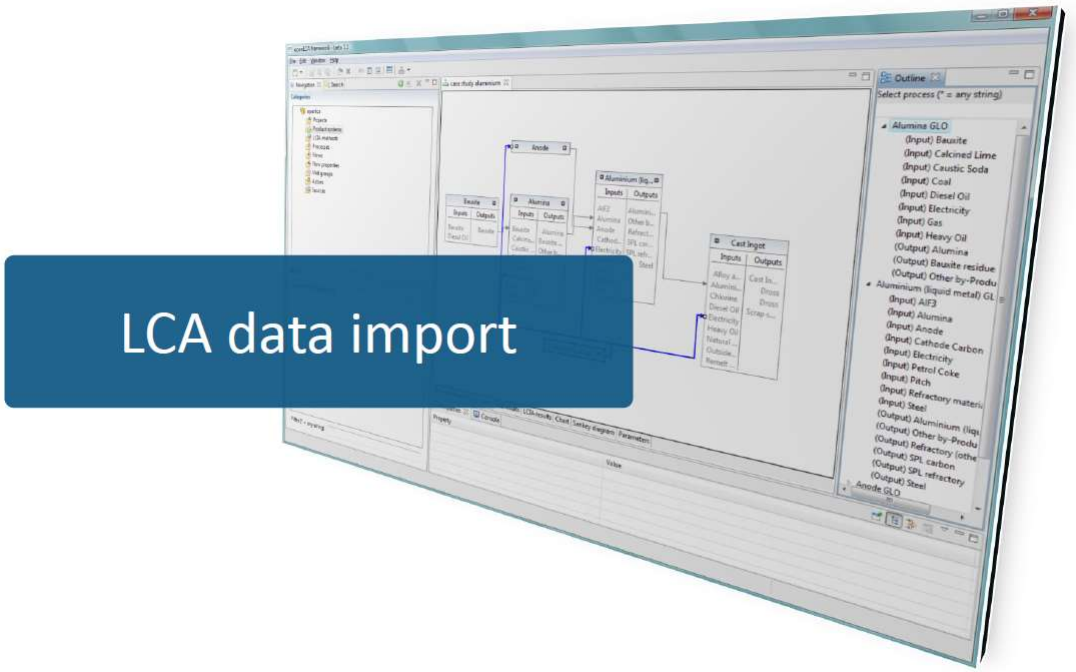


51

Task #2: Create a new database

- Create a local database
- Accept default values (local database & complete reference data)

52



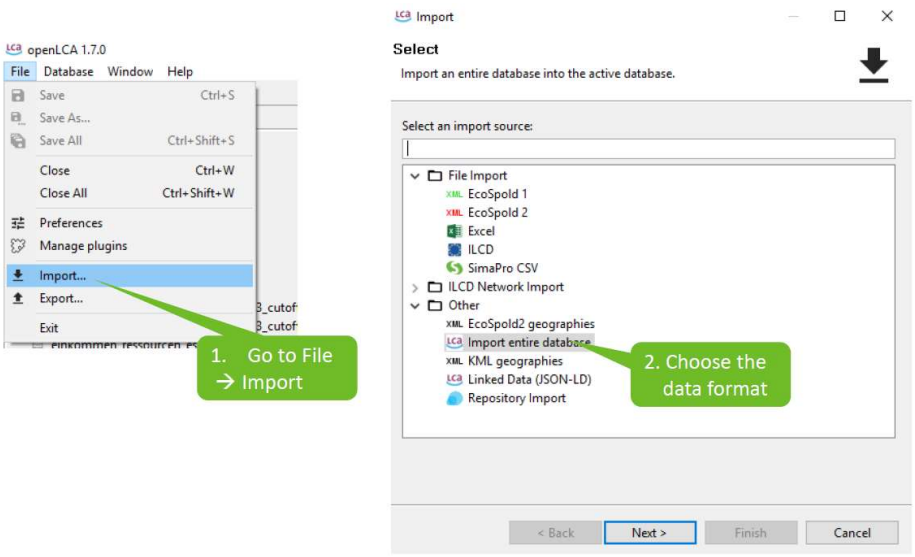
53

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 and Export formats:
  - EcoSpold1 (ecoinvent format)
  - ILCD (zip format)
  - EcoSpold2 (ecoinvent format)
  - Excel
  - SimaPro CSV (modified version of Ecospold, used by SimaPro)
  - Zolca (openLCA format)
- 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

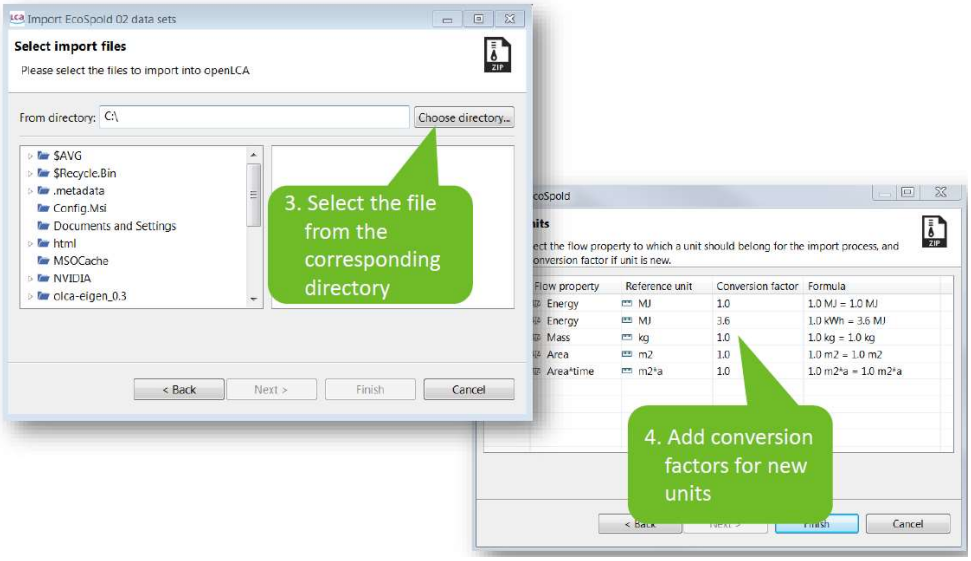
54

Import data sets



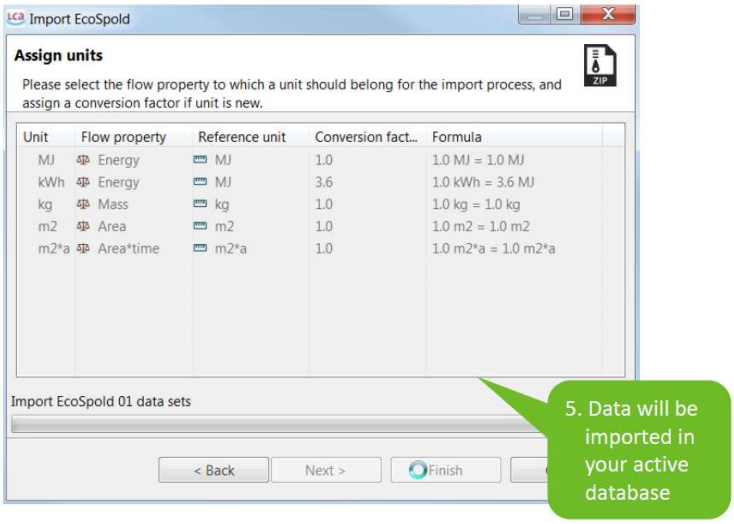
55

Import data sets (II)



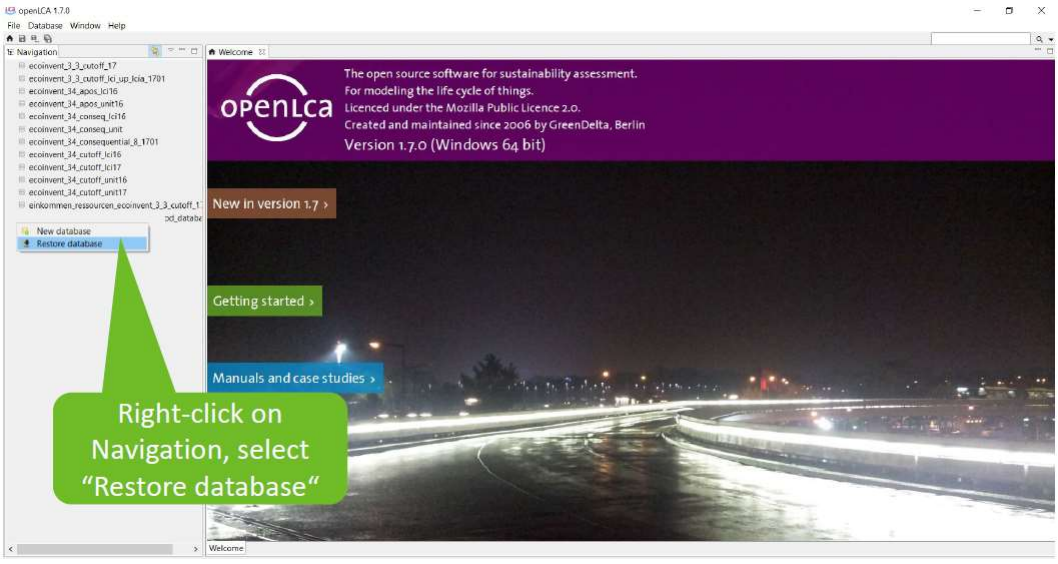
56

Import data sets (III)



57

openLCA database import



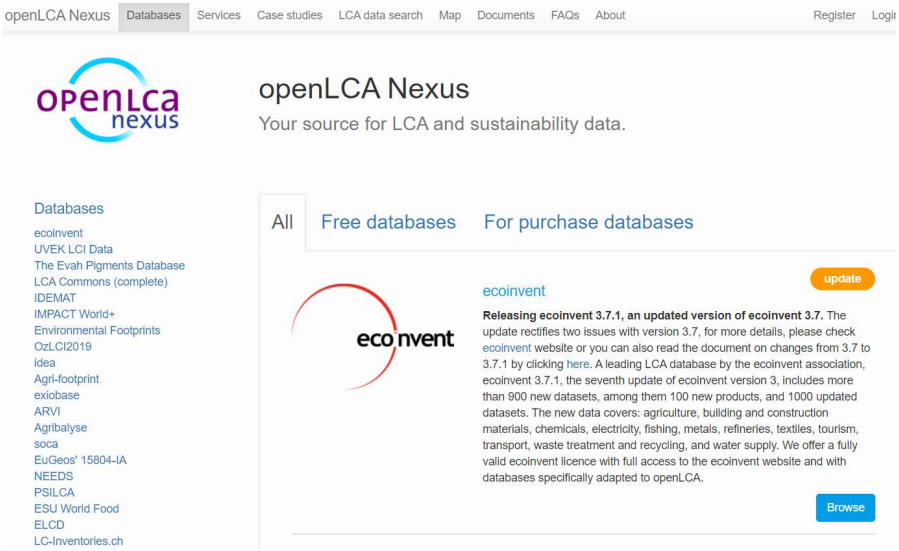
58

openLCA Nexus

- LCA data web repository @ https://nexus.openlca.org/
- Direct purchase/download of data mainly for use with openLCA (some databases for SimaPro, too)

59

openLCA Nexus (II)



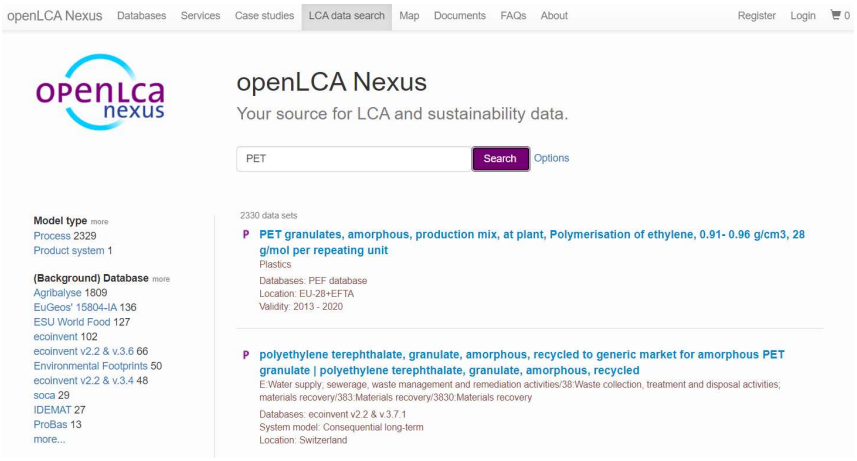
60

openLCA Nexus (III)

61

openLCA Nexus search engine

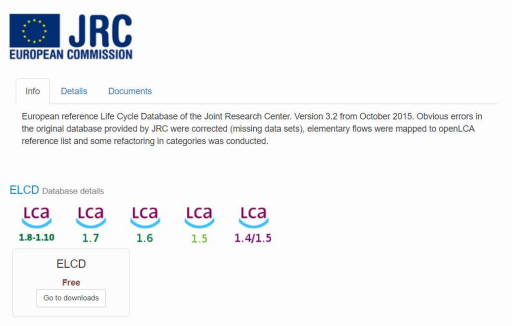
- Multiple filtering options:
  - Name
  - Database
  - Location
  - Type of dataset
  - Category
  - Start of validity
  - Price



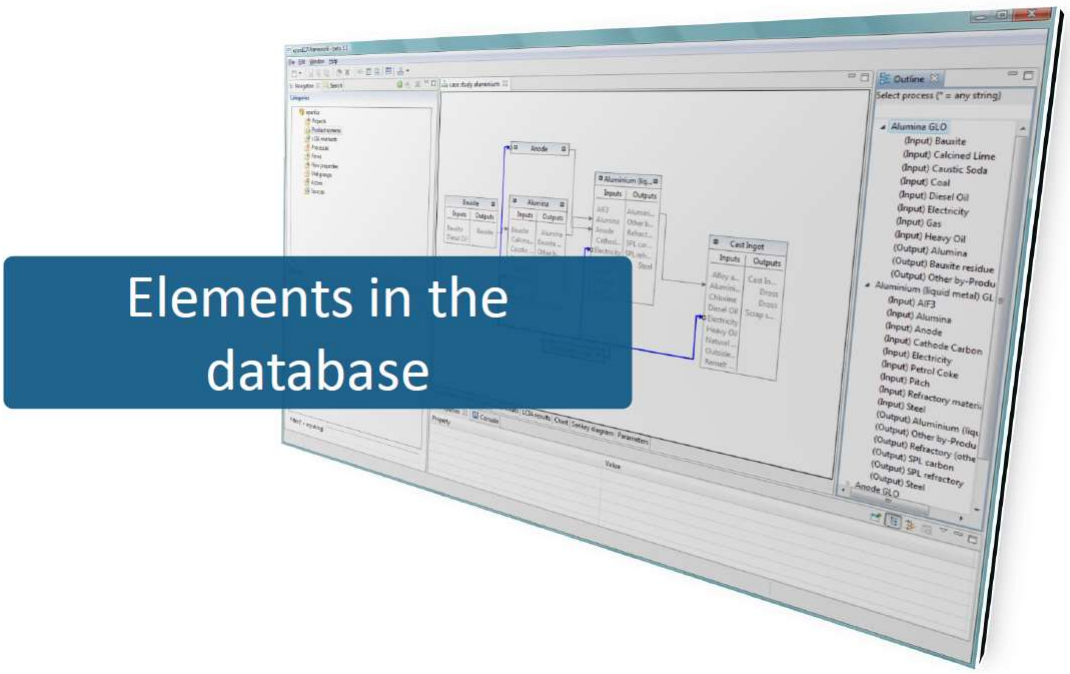
62

Task #3: Import ELCD database

- Restore the database ELCD in openLCA
- Import the openLCA LCIA methods within the database

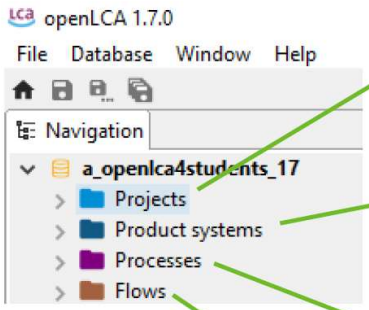


63



64

Database elements



Projects: comparison of numerous product systems

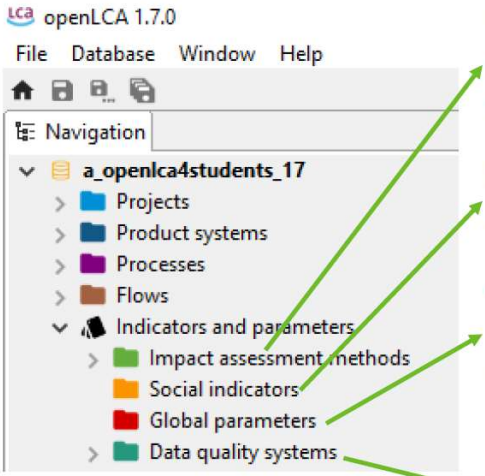
Product systems: process networks (necessary to calculate inventory results and impact assessment)

Processes: Production or modification of materials/products

Flows: Flow of products and materials and elementary flows

65

Database elements (II)



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

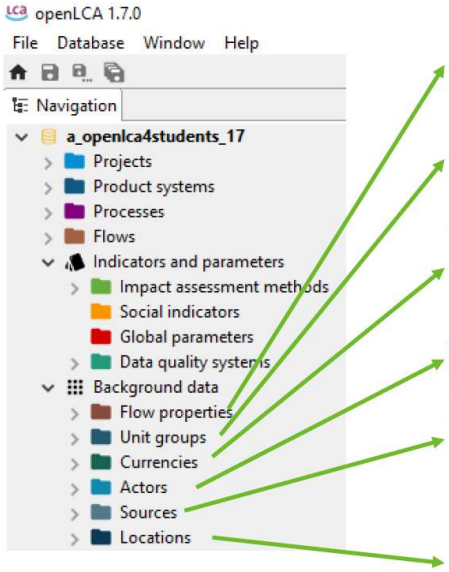
Social indicators: Indicators for social LCA

Global parameters: Parameters that are available within the whole database

Data Quality Systems: Systems for defining the data quality of processes and exchanges

66

Database elements: Background data



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

Unit groups: Groups of units

Currencies: Currencies and exchange rates (Euro, US Dollar etc.)

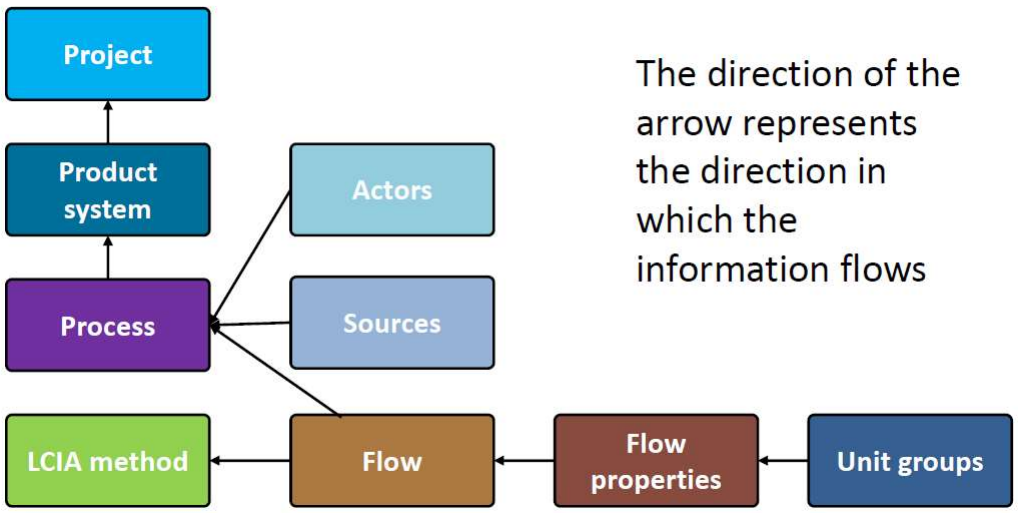
Actors: People who have provided data or modified

Sources: Literature

Locations: Locations for processes

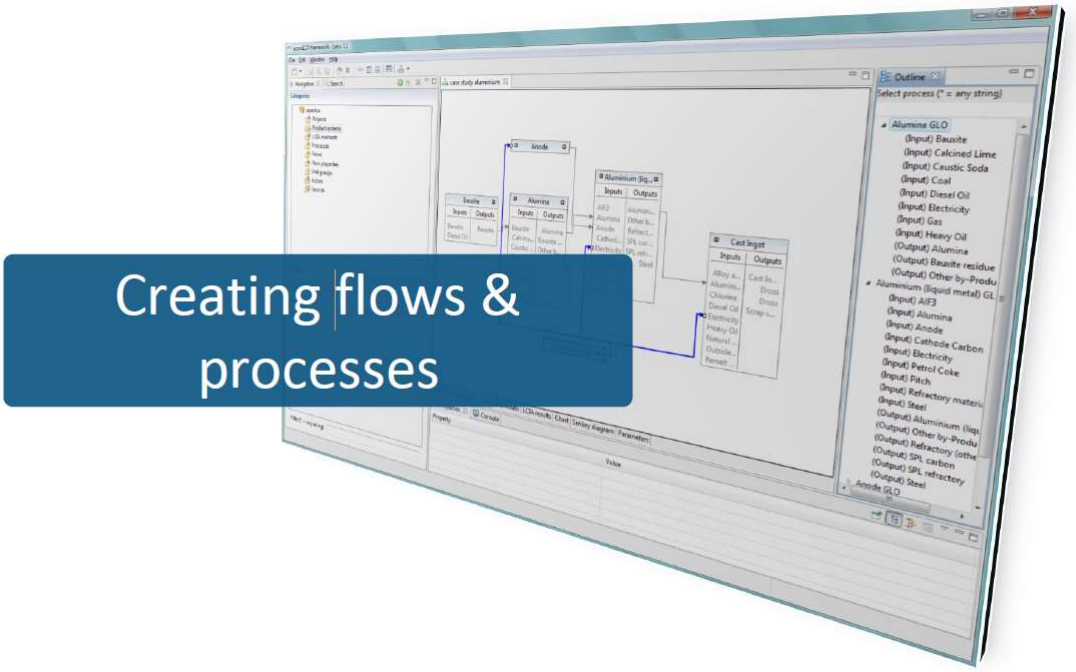
67

Elements structure in openLCA



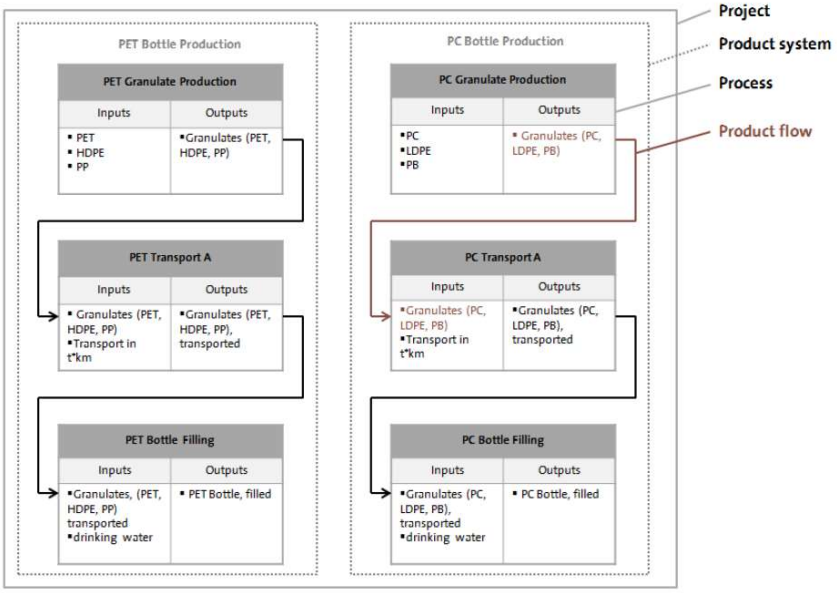
The direction of the arrow represents the direction in which the information flows

68



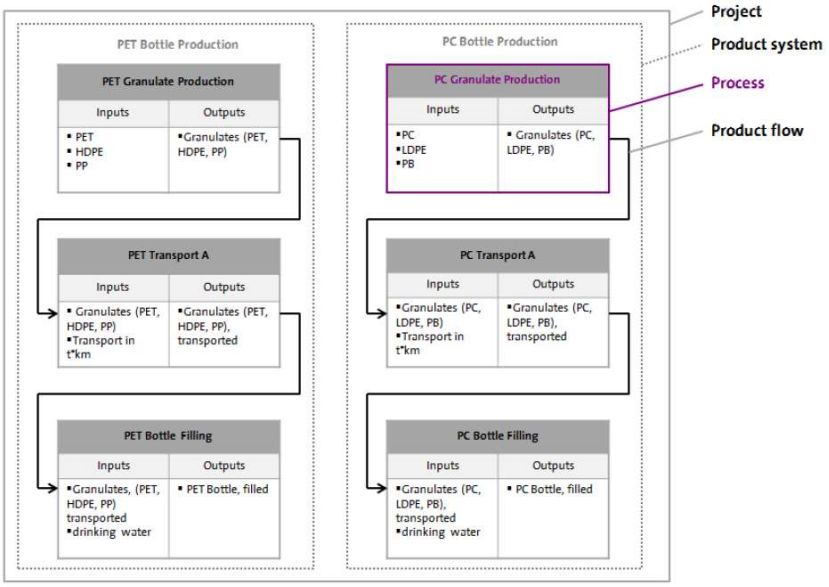
69

Database Modeling in openLCA: Flows



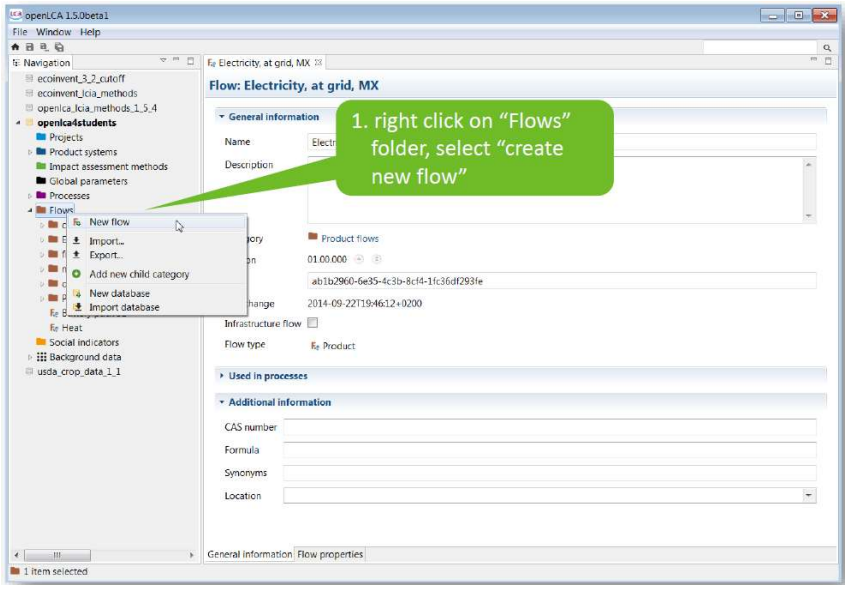
70

Database Modeling in openLCA: Processes



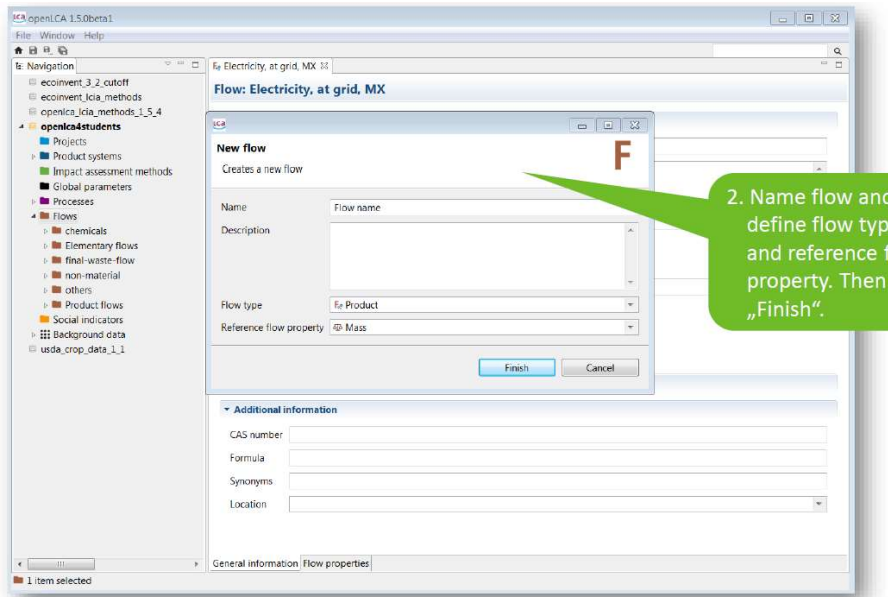
71

Flows: Create a new flow

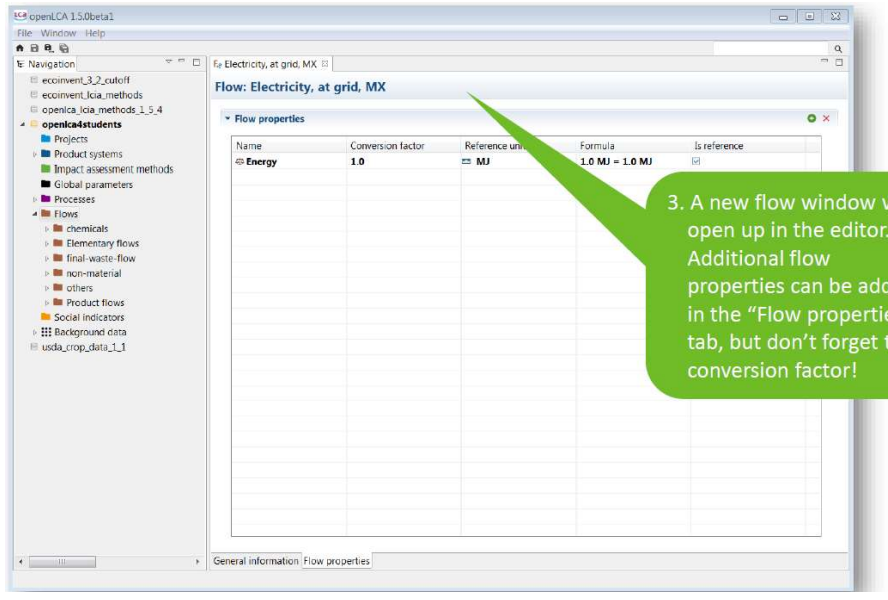


72

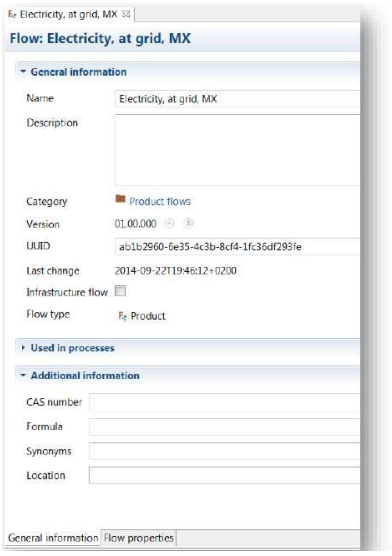
Flows: Create a new flow (II)

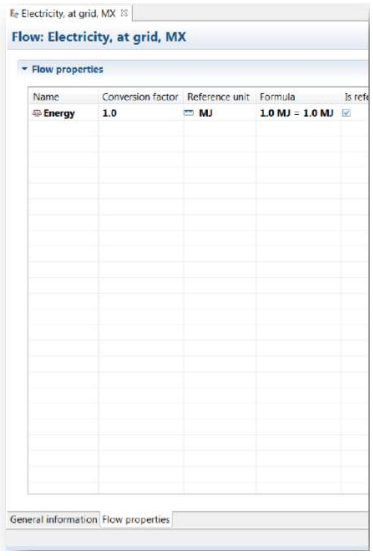


Flows: Create a new flow (III)



Flows: Information & props





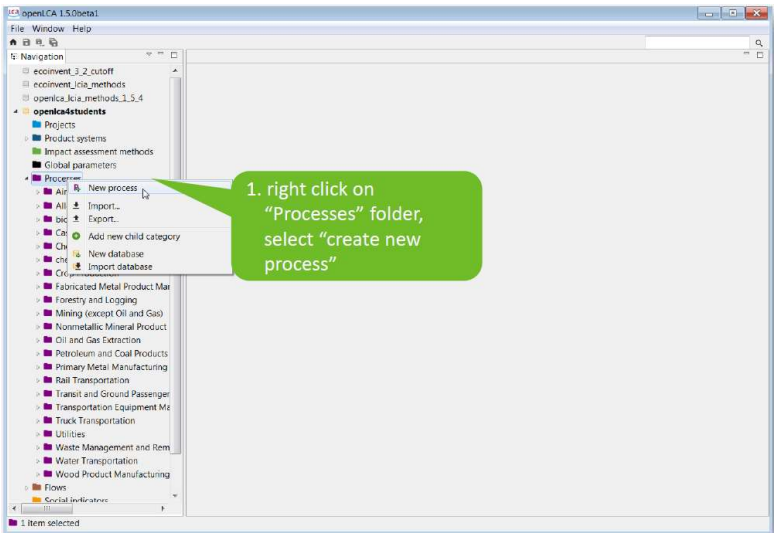
75

Task #4: Flow information

- Open the product flow: polyethylene low density foil(PE-LD)
- In which processes within your active database is this flow an input flow?
- In which processes is it an output flow?

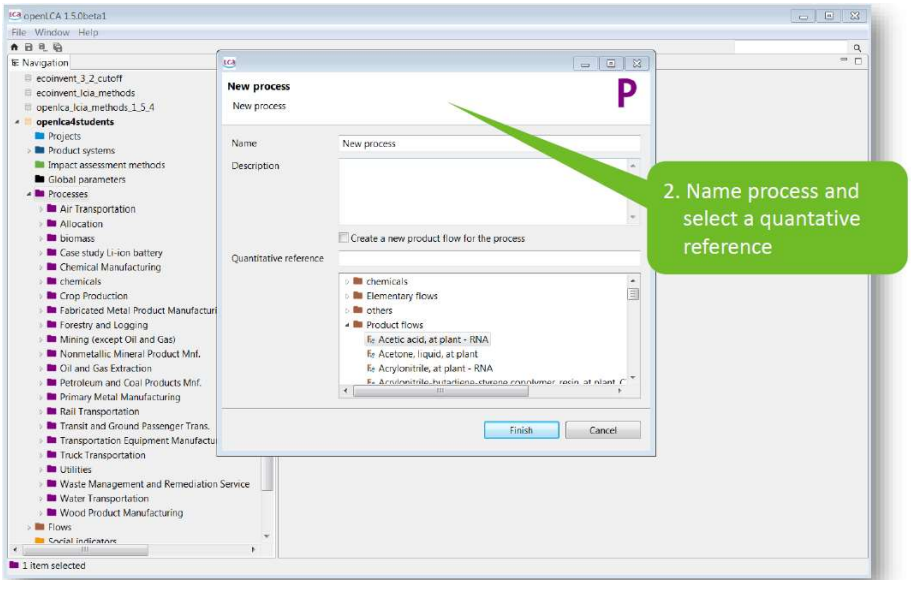
76

Process: Create a new process



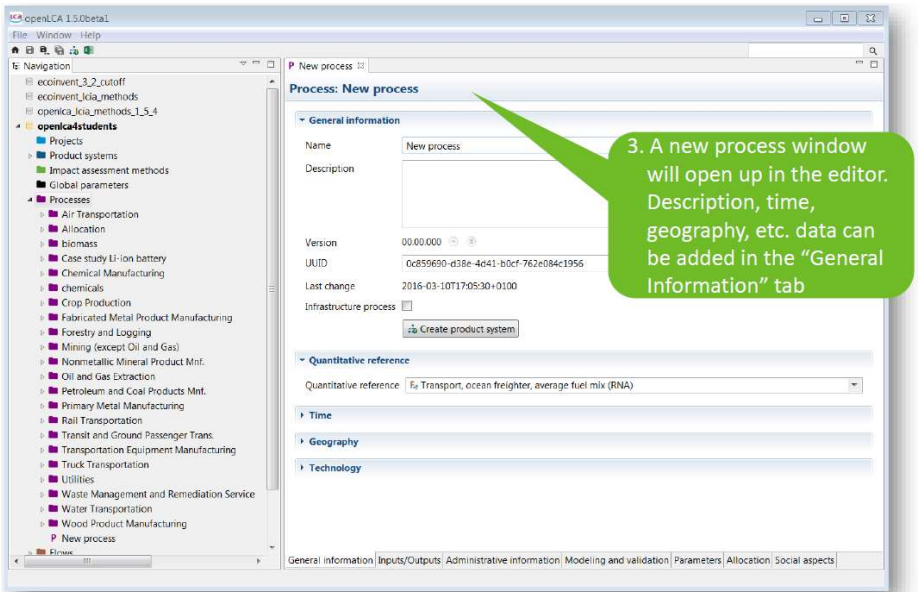
77

Process: Create a new process (II)

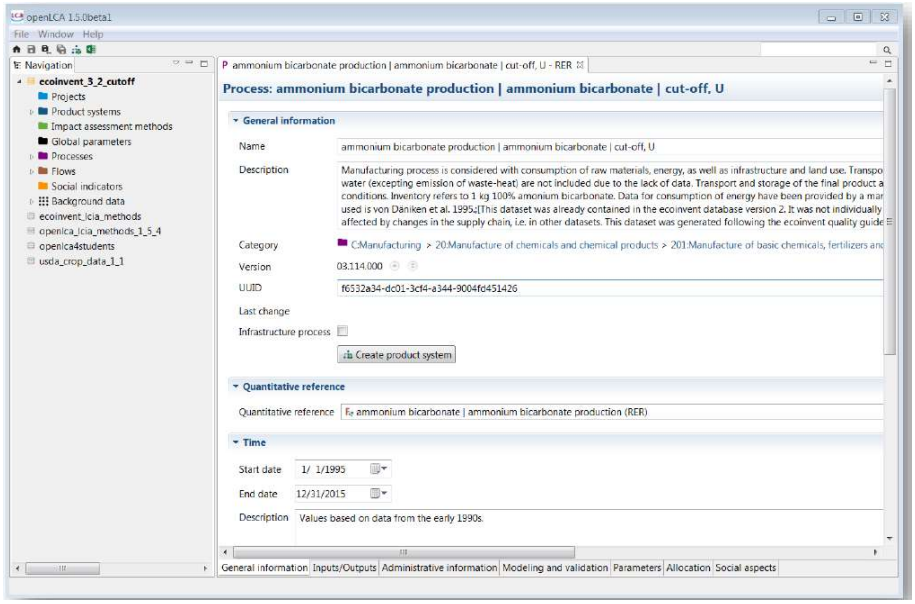


78

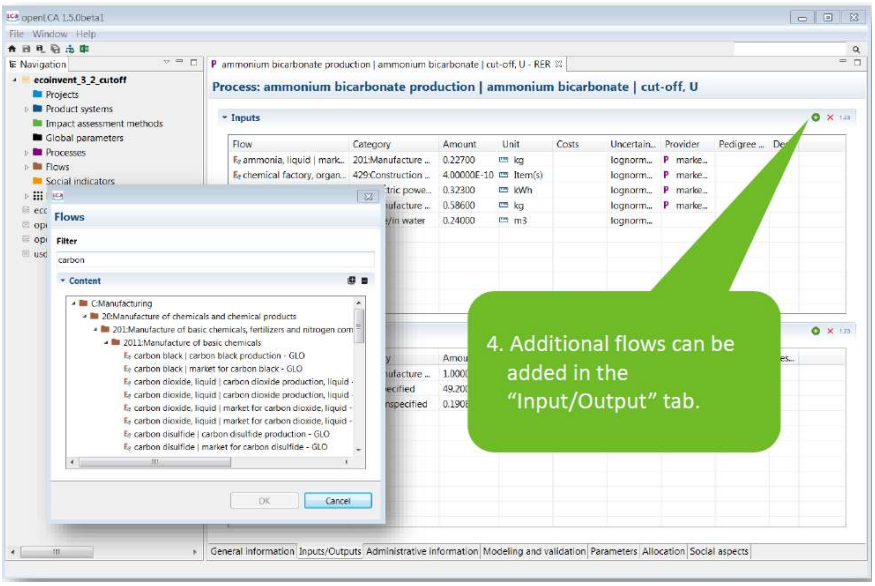
Process: Create a new process (III)



Process: General information

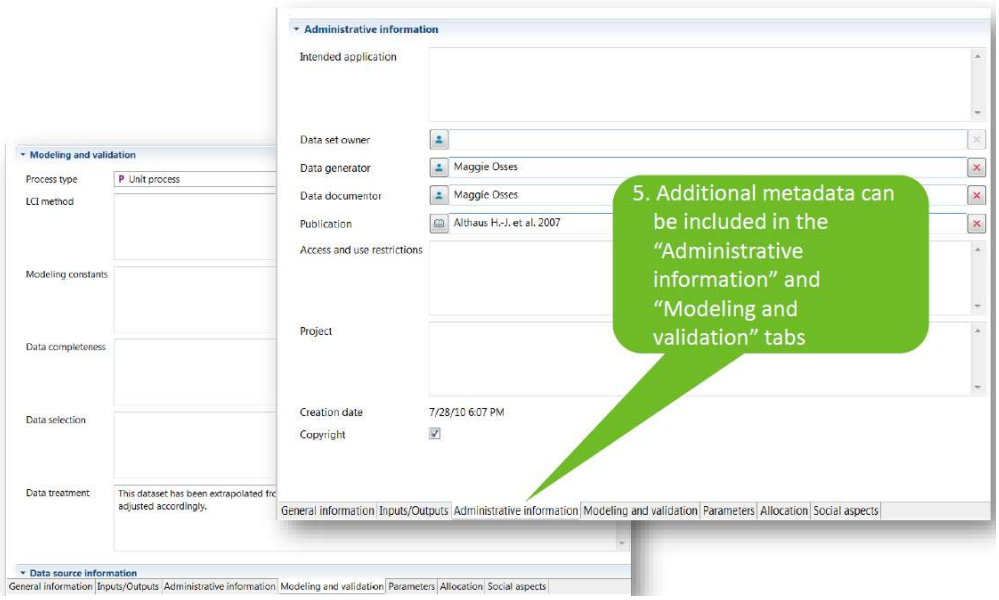


Process: Inputs/Outputs



81

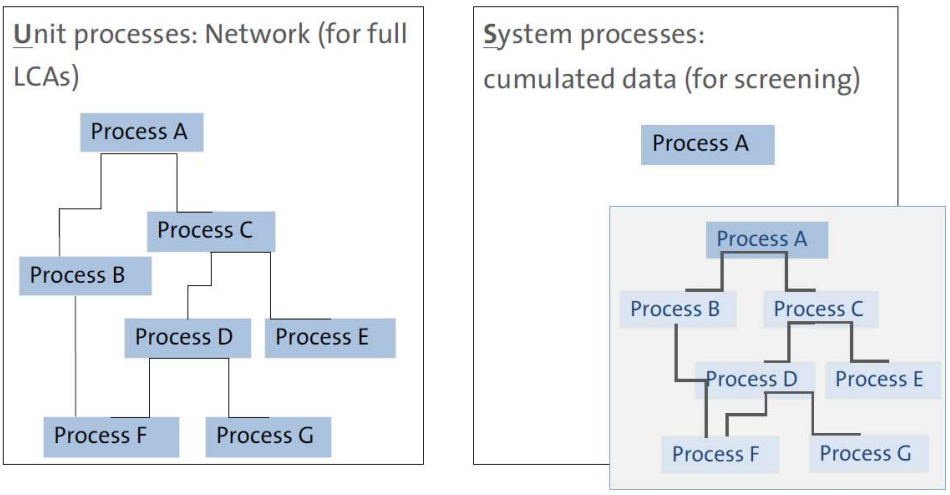
Process: Administrative Information & Modeling and validation



82

Dataset in LCI databases

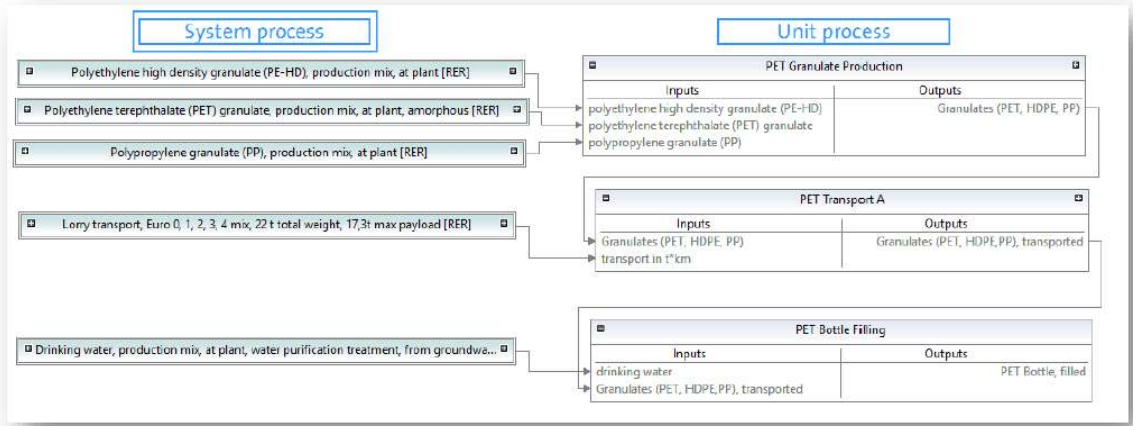
- Ecoinvent database includes Unit & System Processes



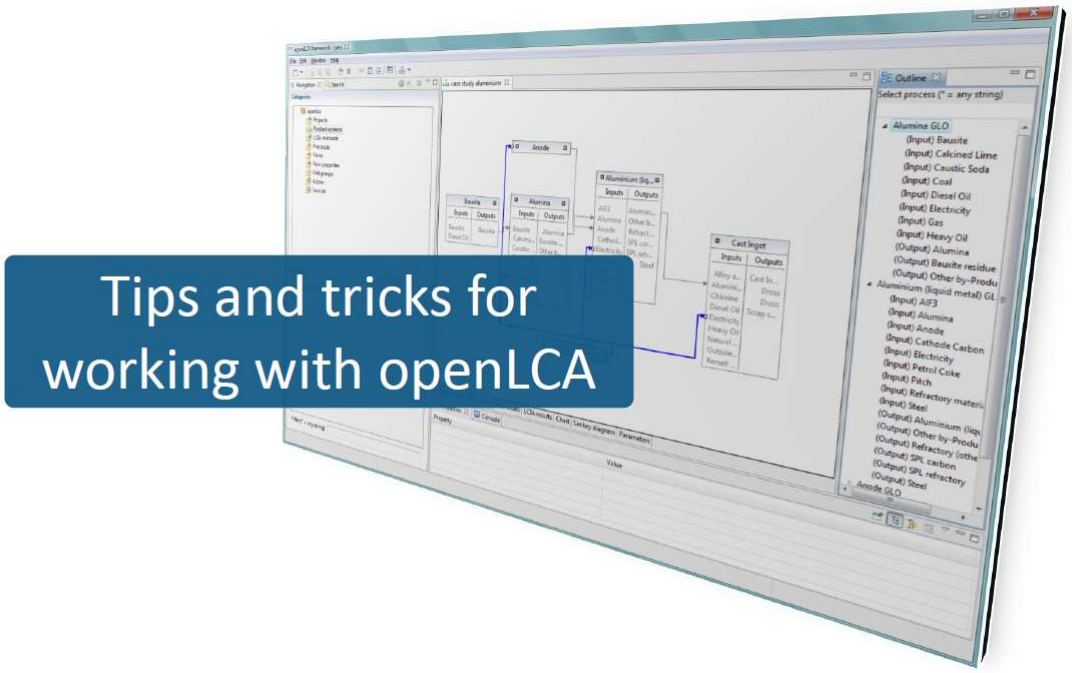
83

Dataset in LCI databases

- Ecoinvent database includes Unit & System Processes



84



85

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 

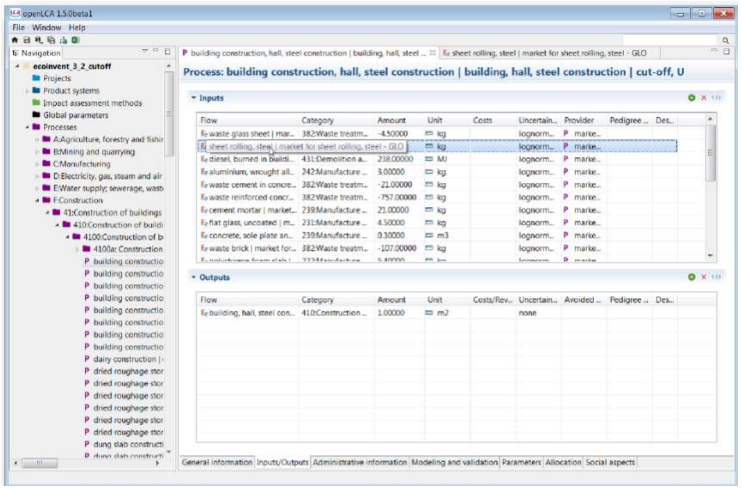
Save image: right mouse button → save image

Minimise/maximise element: 

86

Basic commands

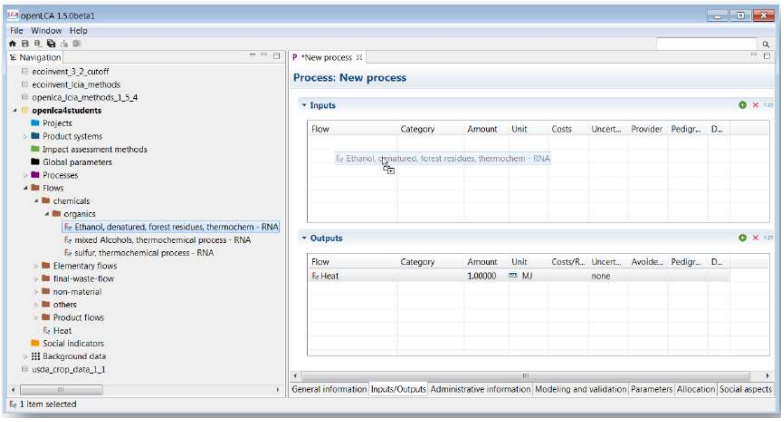
- If you double click on a flow in the process editor it will be opened in a separate window and can be modified:



87

Basic commands

- Drag and drop flows from the Navigation pane to the Input/Outputs tab in the process editor
- Drag and drop processes from the Navigation pane to the Model Graph in the product system editor



88

Folder structure

- Divide system and unit processes

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

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

89

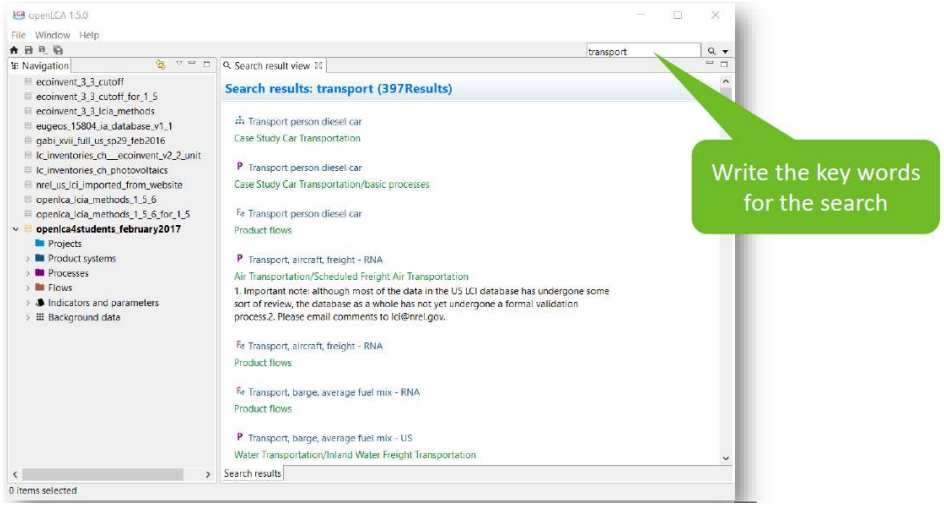
Windows

- 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

90

Search

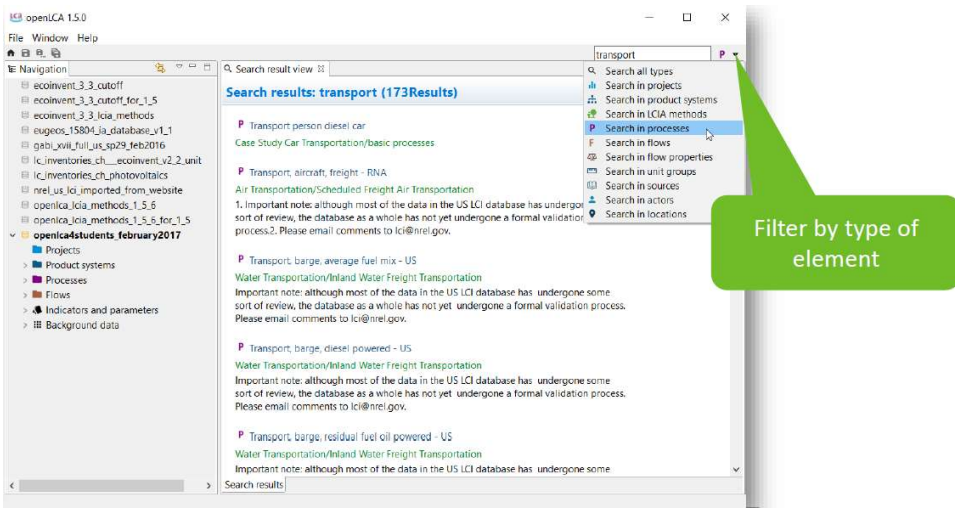
- Search any elements from the database



91

Search (II)

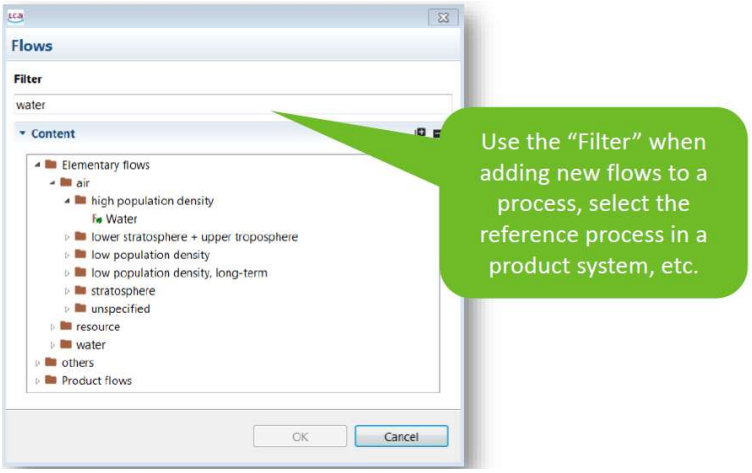
- Search within a specific element from the database



92

Filter

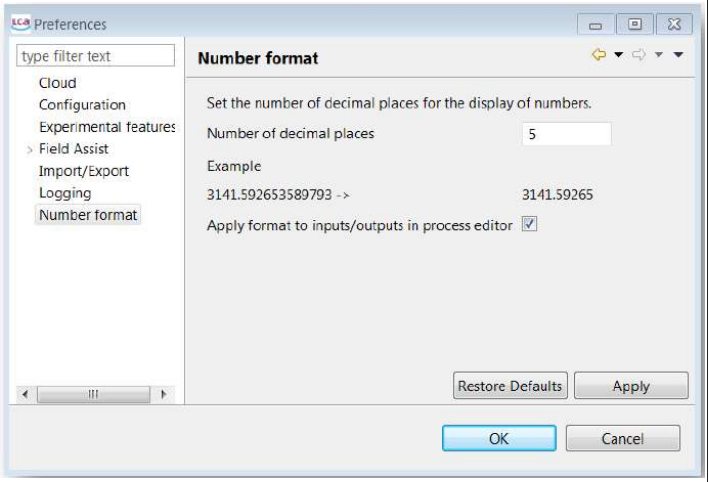
- The “add new” editors contain a filter for facilitating the search of the desired element



93

Numbers

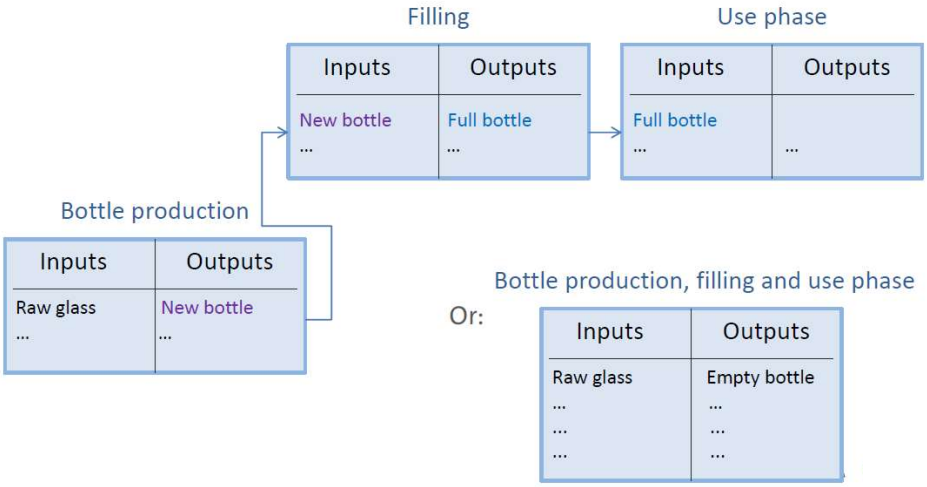
- Use always a point for floating point numbers, a comma is not accepted (1.5 instead of 1,5)
- Under File/Preferences/Number format you can choose the number format of results



94

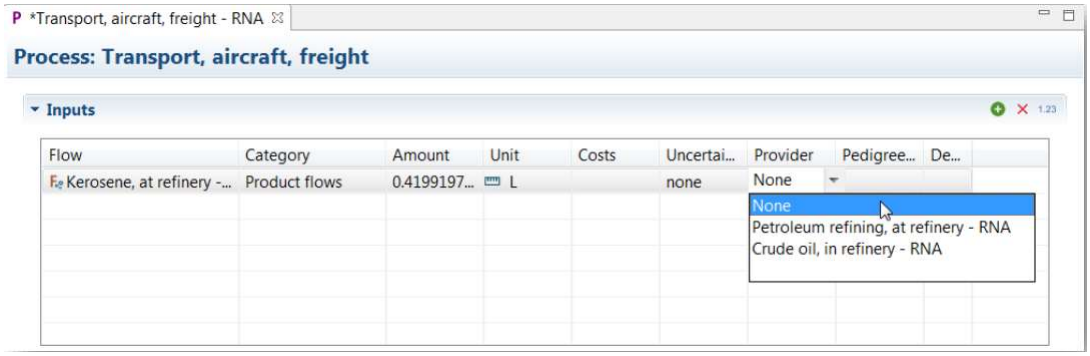
Modeling with product flows

- 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



Plastic bottle for drinking water
PET vs PC

97

Plastic bottle for drinking water
PET vs PC

- Goal: Conduct an LCA of one PET water bottle produced and consumed in Italy from cradle to gate

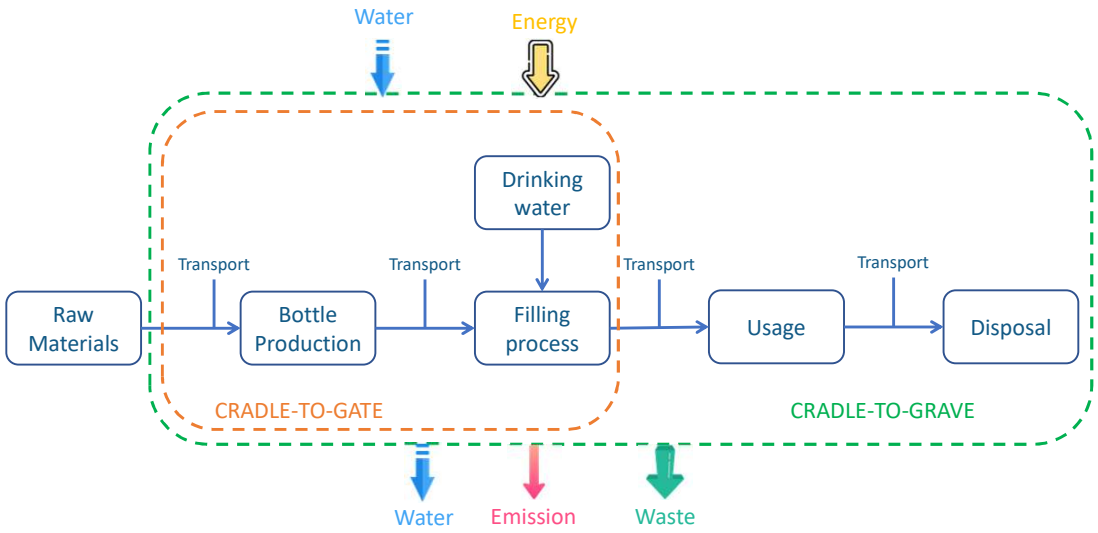
- FU: 1 bottle containing 1 litre of still water

- Production chain

1. Plastic granulate production:
   - polyethylene terephthalate granulate (PET) for the bottle (bottle grade, RER)
   - Polyethylene high density granulate (PE HD) for the lid (RER
   - Polypropylene granulate (PP) for the labels (RER)
2. Transport of PET, HDPE and PP granulates for further processing (Transport A)
3. Production of a PET pre form bottle, the HDPE lid and the PP label from the respective granulates produced in step 1.
4. Transport of bottle pre form, lid and label to bottle filling location (Transport B)
5. Blow PET bottle, fill with water and attach lid and label

98

Plastic bottle for drinking water
Block diagram



99

Task #5: Creation of a process

- Create a new folder for this case study within the Processes folder
- Create a new process called "Production of PET granulates"

Input	Amount	Unit
Polyethylene high density granulate (PE-HD)	0.004	kg
Polyethylene terephthalate (PET) granulate	0.06	kg
Polypropylene granulate (PP)	0.001	kg

Output	Amount	Unit
PET granulates	0.065	kg

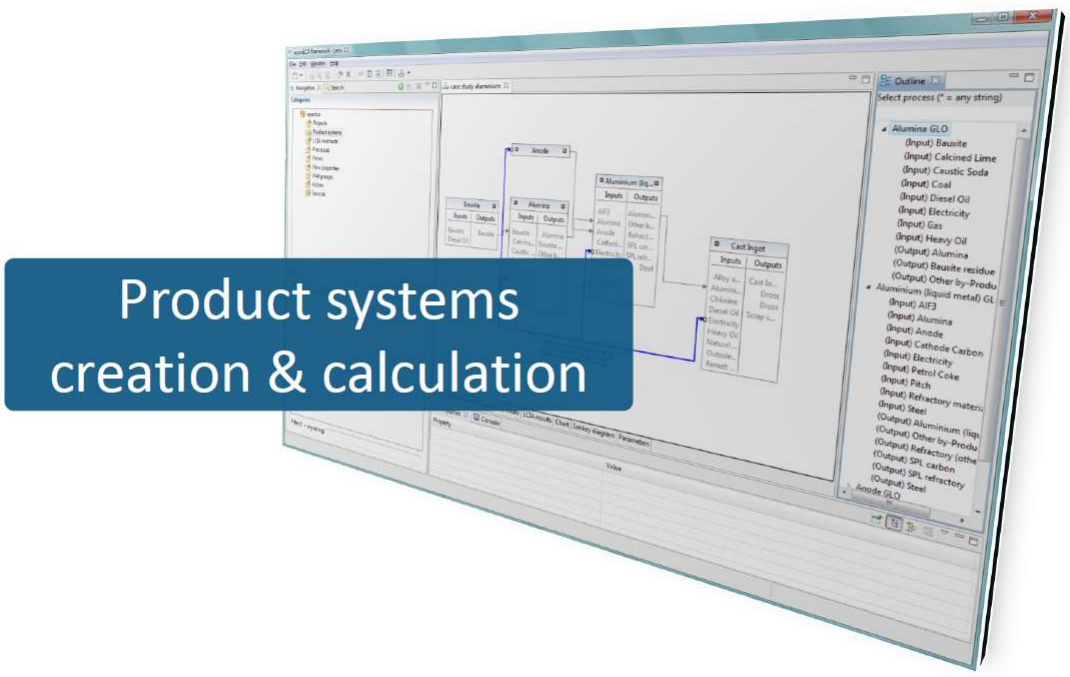
- Remember to add the provider for the raw materials
- For the production of the bottles, lids and labels, it is assumed that 100% of the respective granulate is utilized in forming the final product, without waste

100

Task #5: Creation of processes (II)

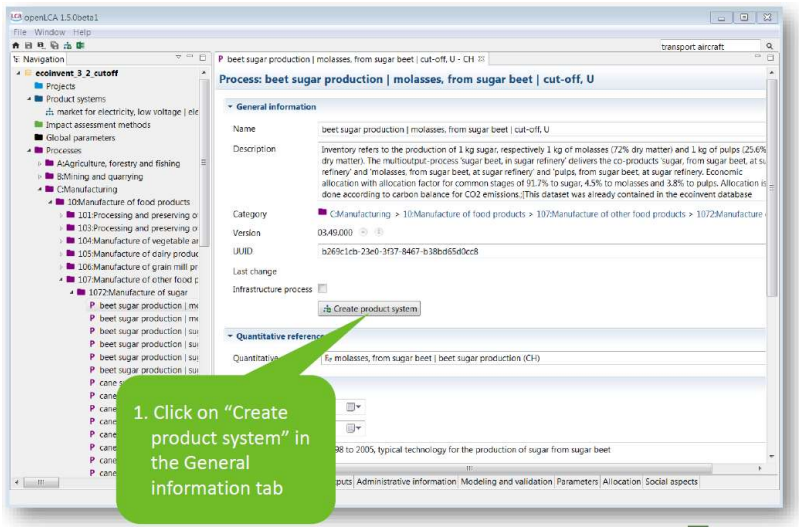
- Create a new process called “PET transport A”
  - The reference flow is called “PET granulates, transported”, expressed in mass units
  - The mix of PET granulates need to be transported for 200 km using a medium-sized lorry
- Create a new process called “PET Production of bottle preform, lid and lable”
  - The reference flow is called “PET empty bottle”, expressed in number of items
  - The production of 1 bottle made of 0.065 kg of “PET granulates, transported” needs 1 MJ of in medium voltage (MV) of electricity for a grid European average consumer mix
- Create a new process called “PET empty bottle, transported”
  - The reference flow is called “PET empty bottle, transported”, expressed in number of items
  - The bottle needs to be transported for 100 km using a medium-sized lorry
- Create a new process called “PET full bottle”
  - The reference flow is called “PET full bottle”, expressed in number of items
  - The bottle needs to be filled with 1 kg of drinking water (find the right provider!)
  - The filling process requires 2 MJ of MV electricity from the European average grid consumer mix

101



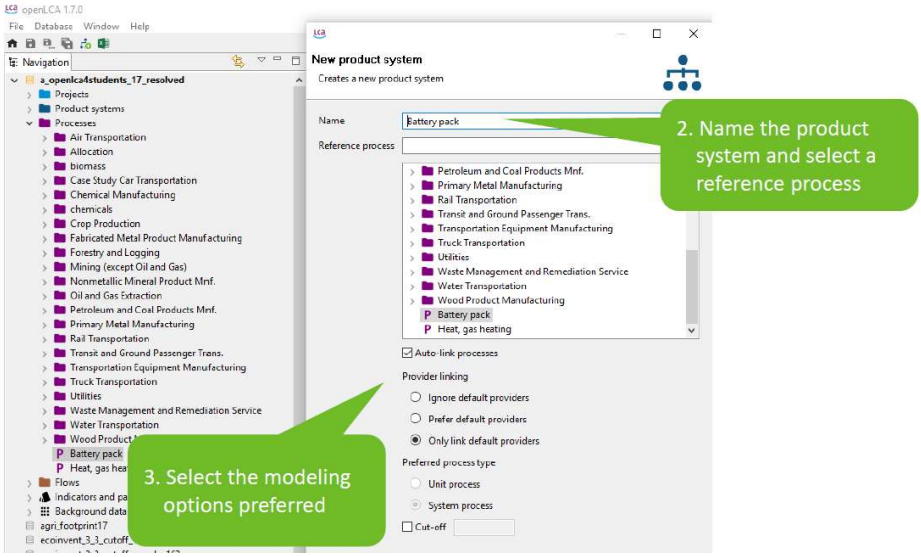
102

Product system: Creation



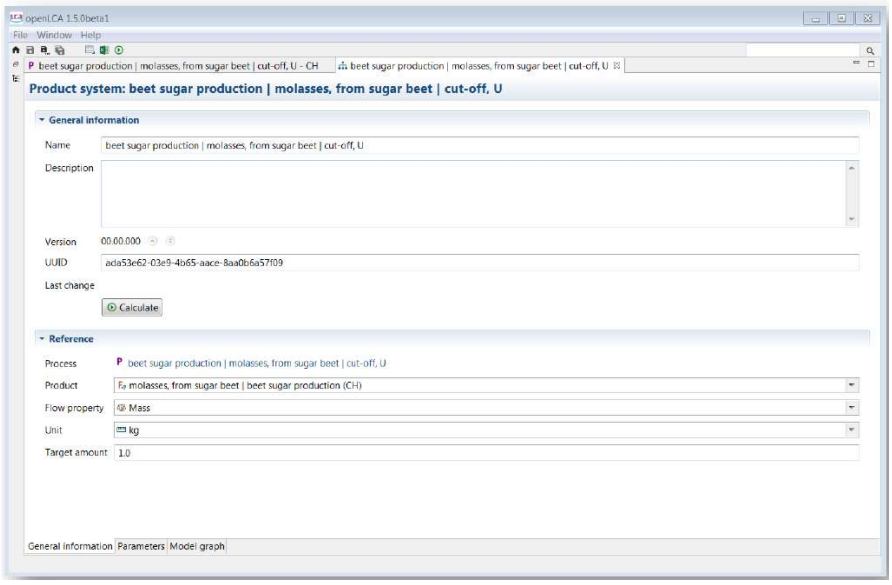
103

Product system: Creation (II)

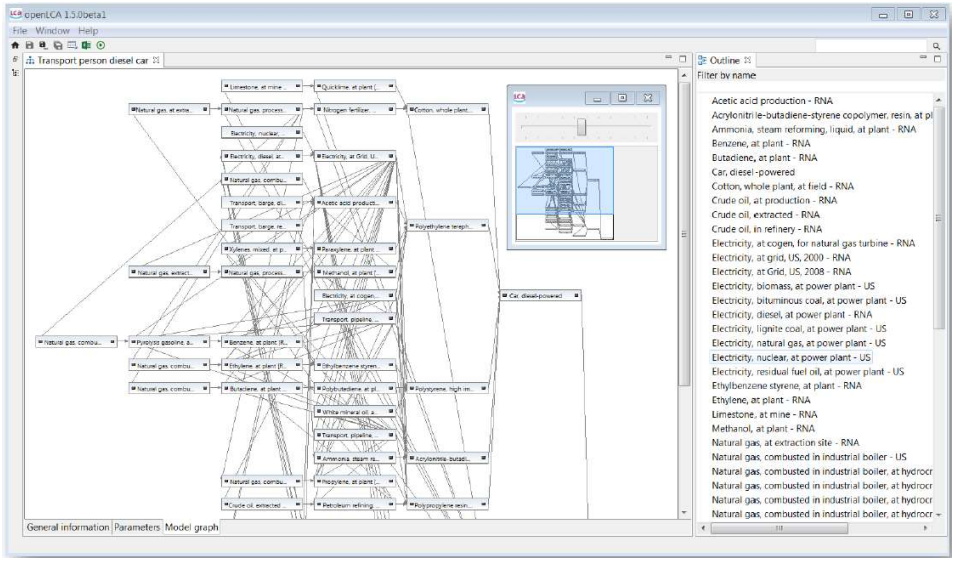


104

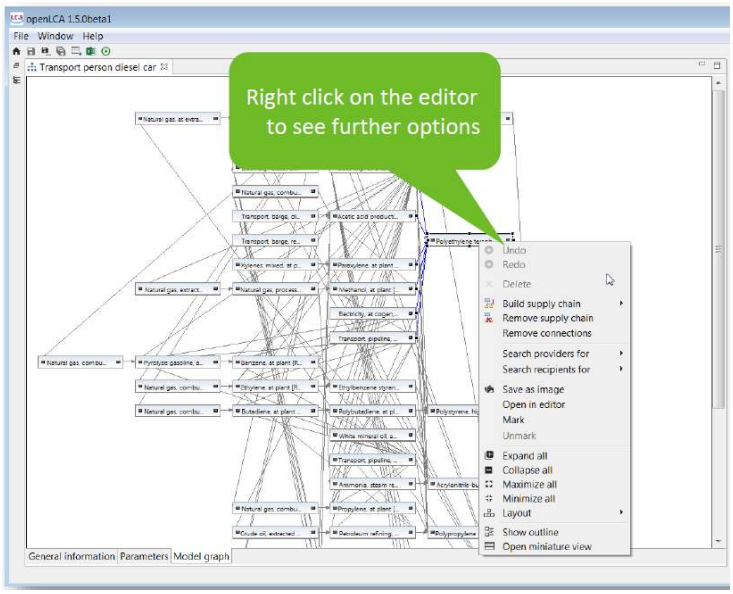
Product system: General Information



Product system: Model Graph

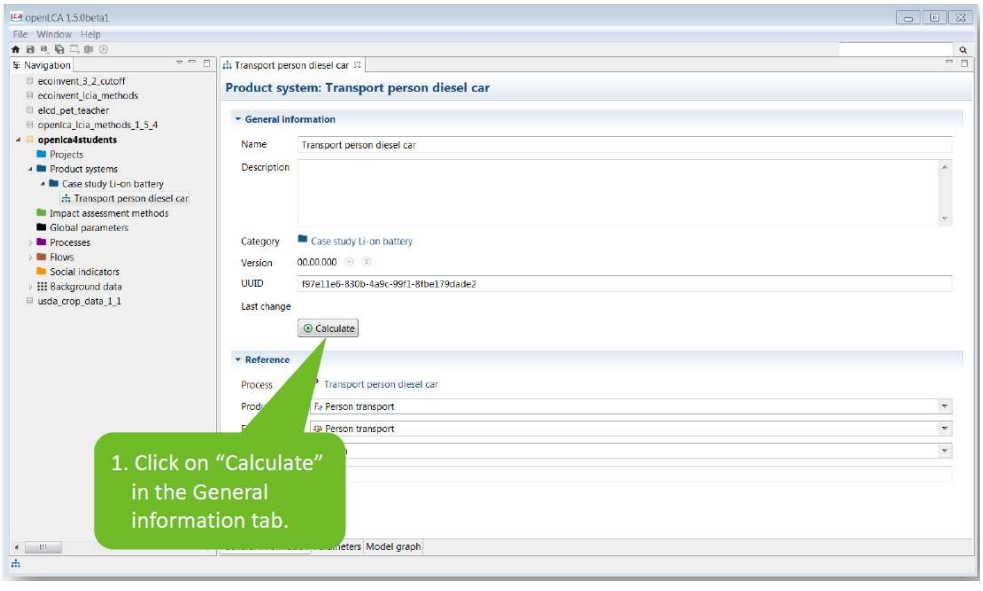


Product system: Model Graph (II)



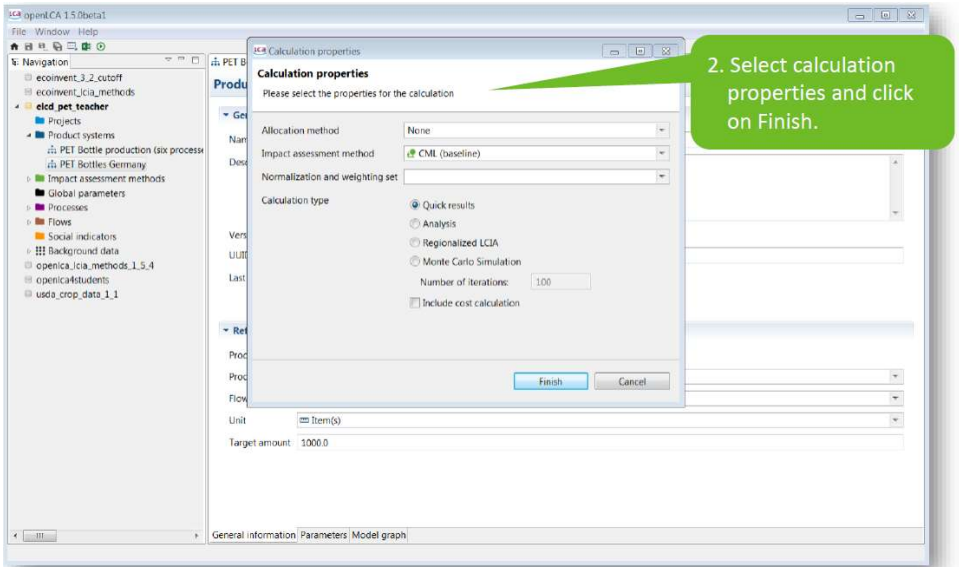
107

Product system: Calculation

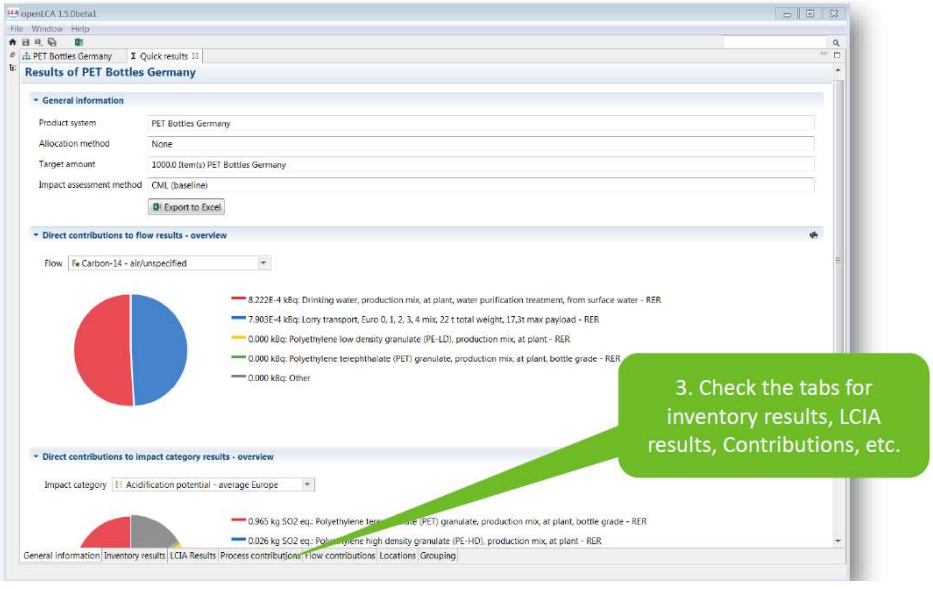


108

Product system: Calculation (II)



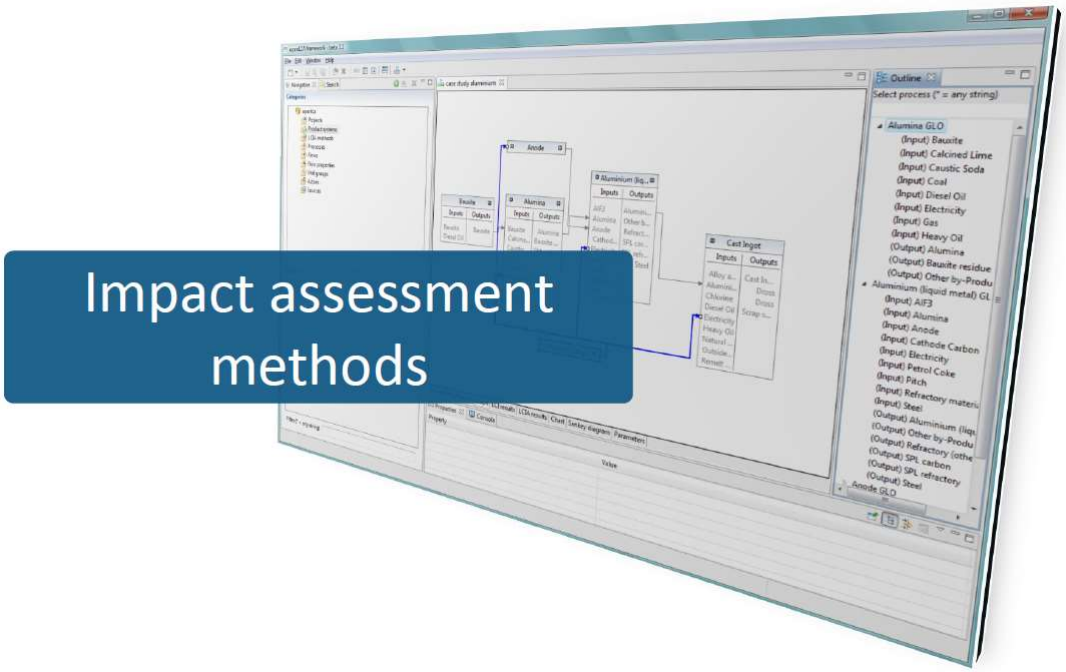
Product system: Calculation (III)



Task #6: Creation of product system

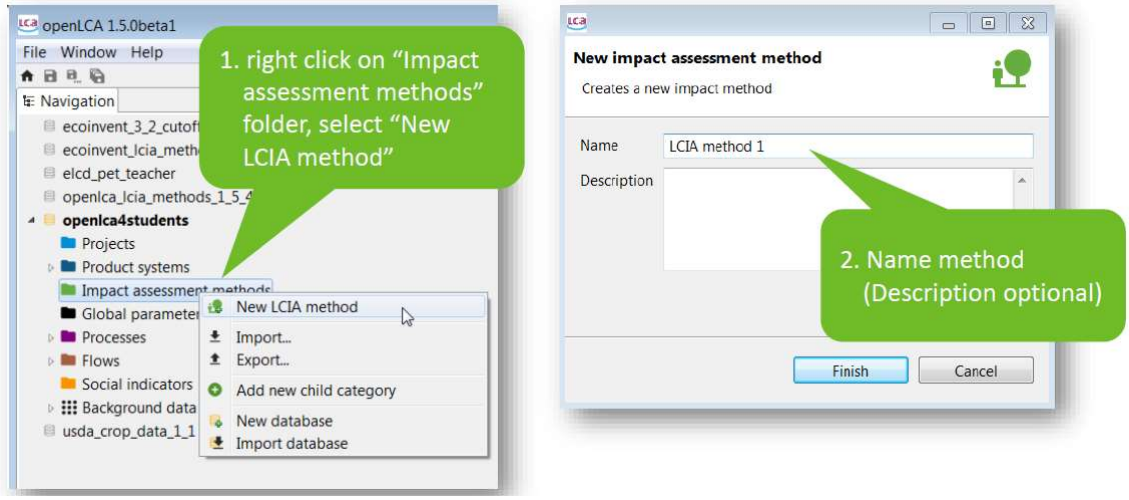
- Create the product system called “PET full bottle” with reference product “PET full bottle”
  - Select “only link default providers”
  - Check the different views of the model graph. What can be observed in the graph?
  - Calculate the inventory of the product system
  - Which information can you derive from the inventory?

111

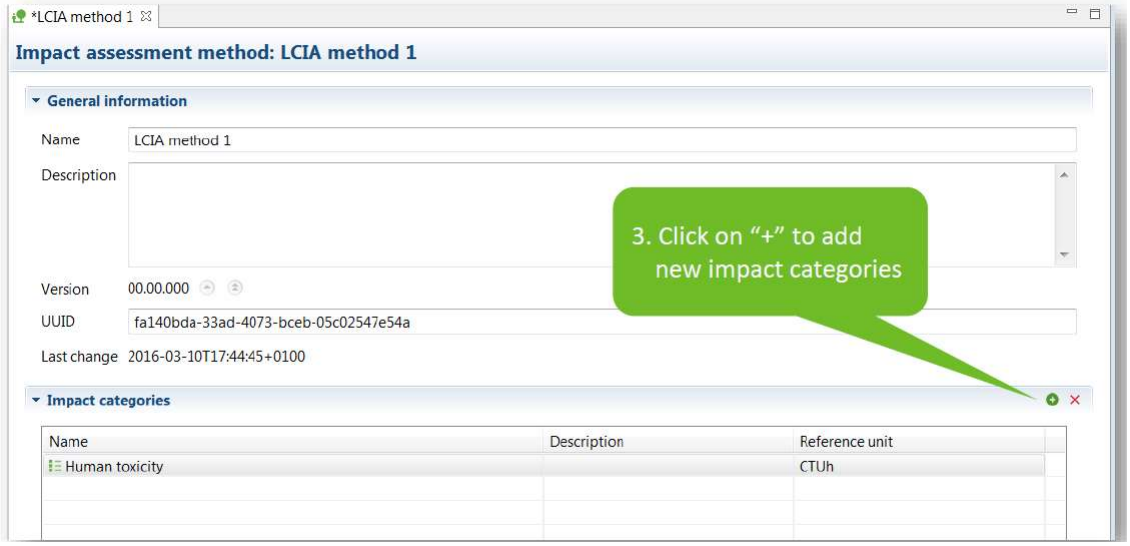


112

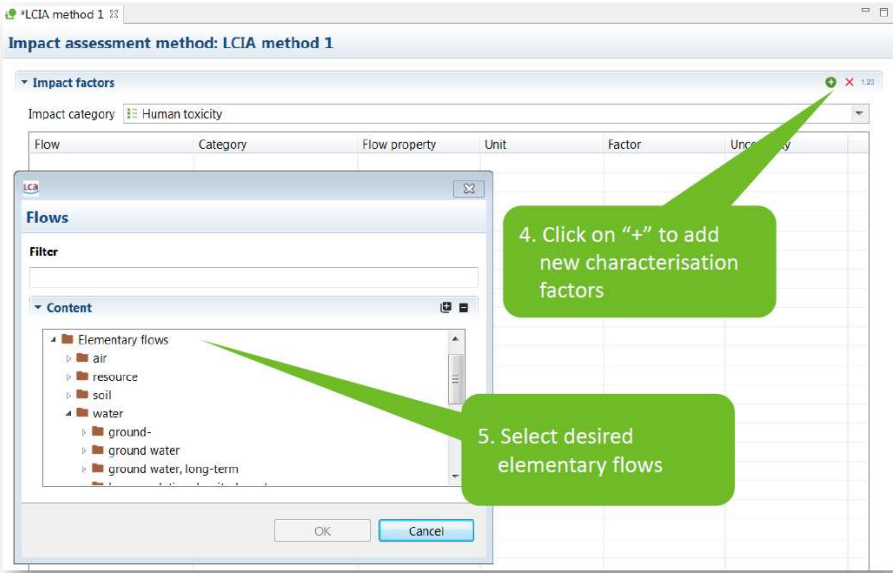
Impact assessment method: Creation



Impact assessment method: Creation (II)

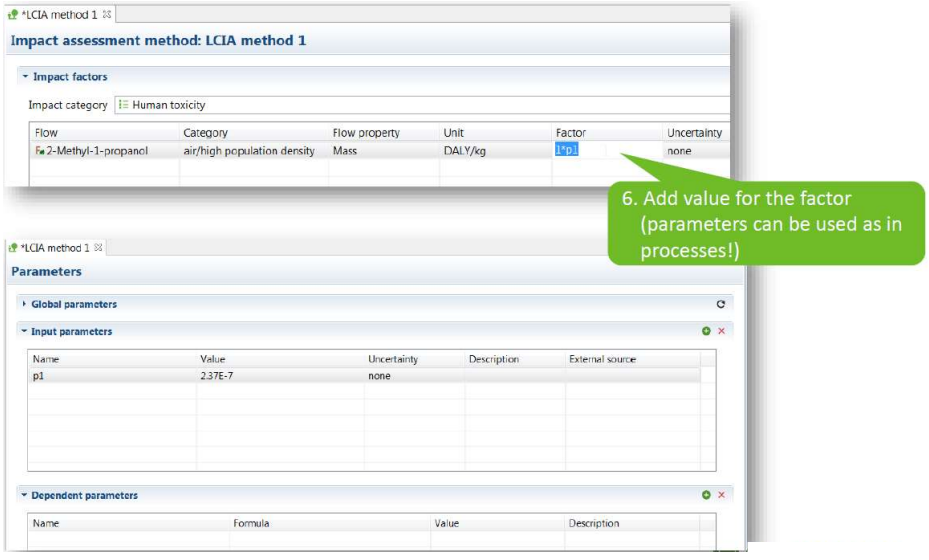


Impact assessment method: Creation (III)



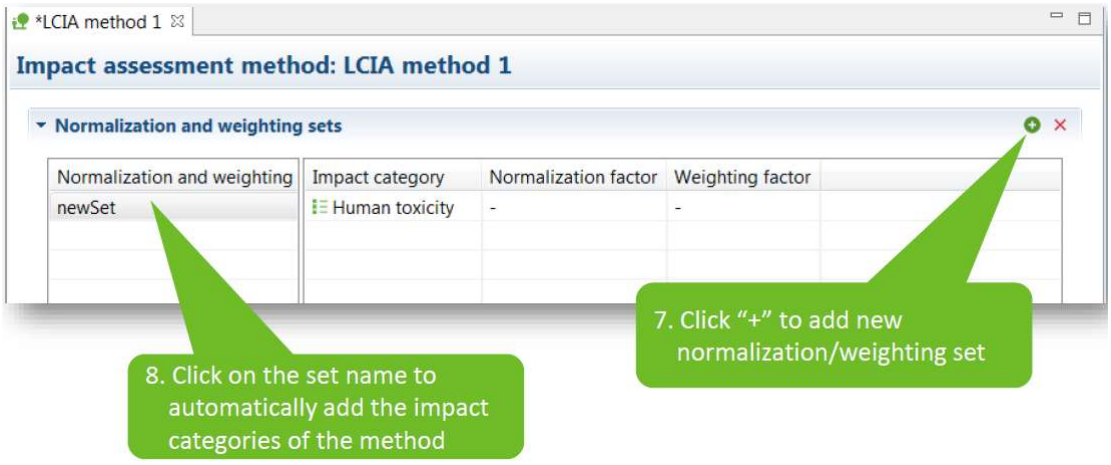
115

Impact assessment method: Creation (IV)



116

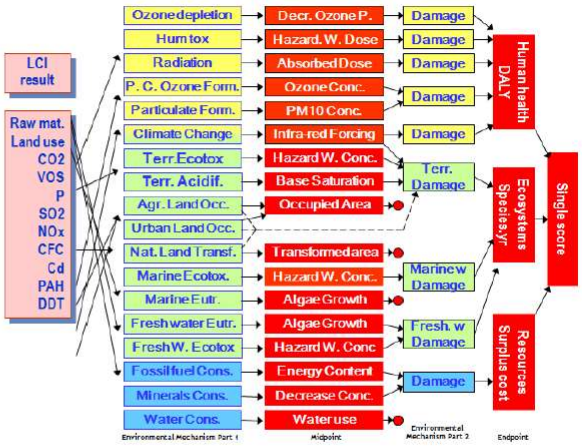
Impact assessment method: Creation (V)



117

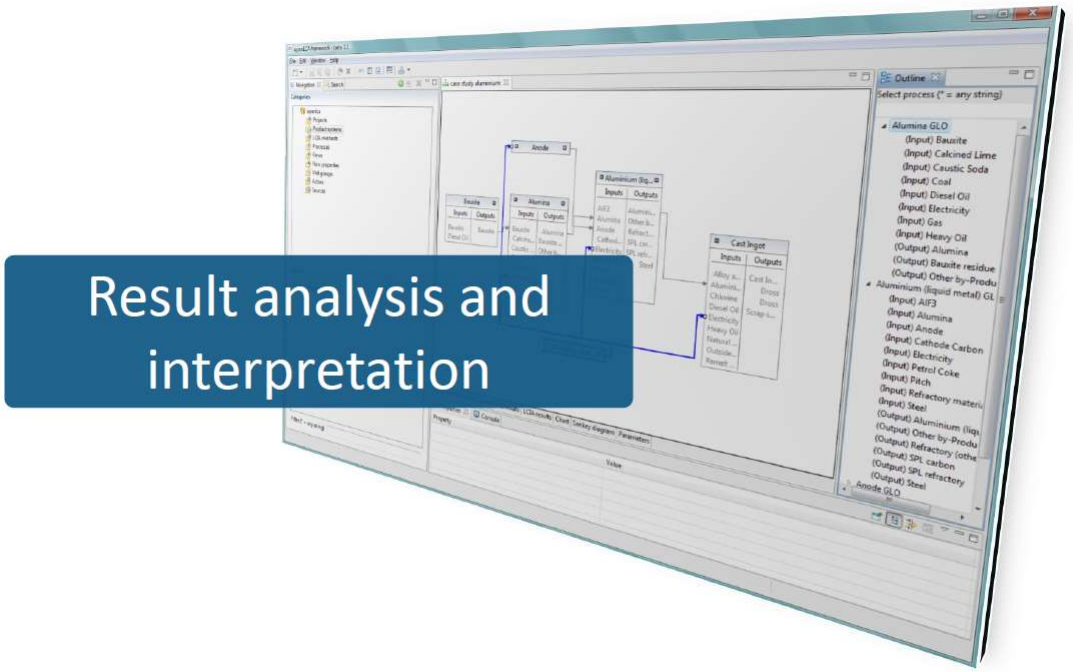
LCIA methods

- LCIA methods convert inventory results into specific environmental impact categories (LCI results to associated environmental impacts, summarised in impact categories)
- CML baseline
- ReCiPe
- PEF (supposed to replace ILCD method)



Source: http://www.lcia-recipe.net/project-definition

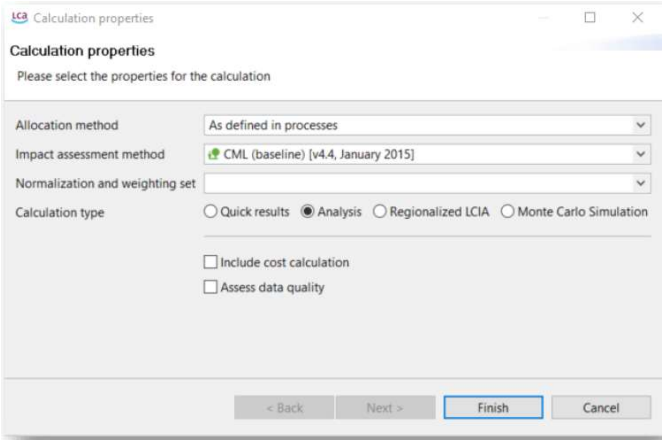
118



119

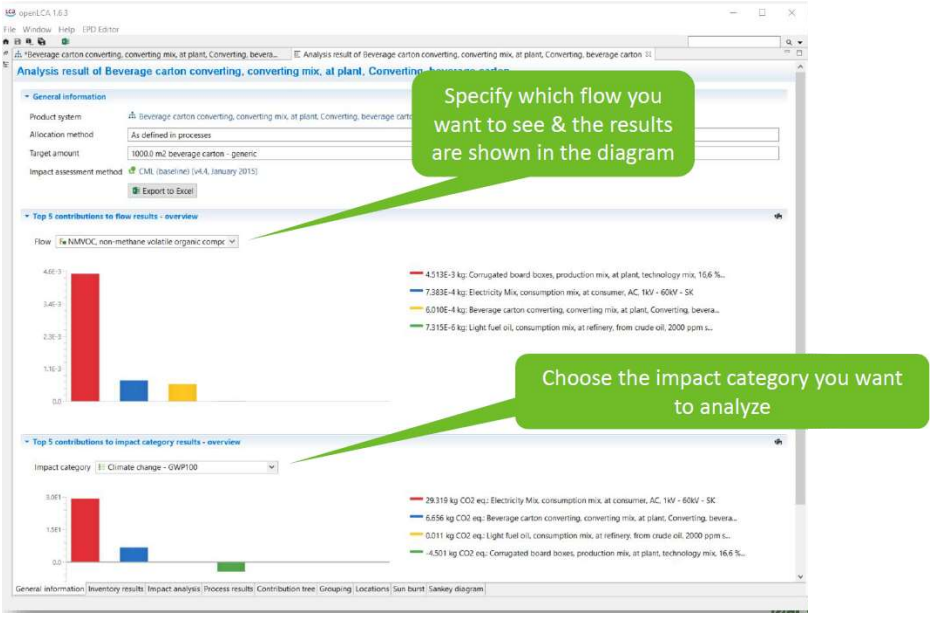
Analysis functions

- To run the analysis functions the product system needs to be recalculated
- Click the calculation button in the General Information tab of the Product System, select an LCIA method and check “Analysis”



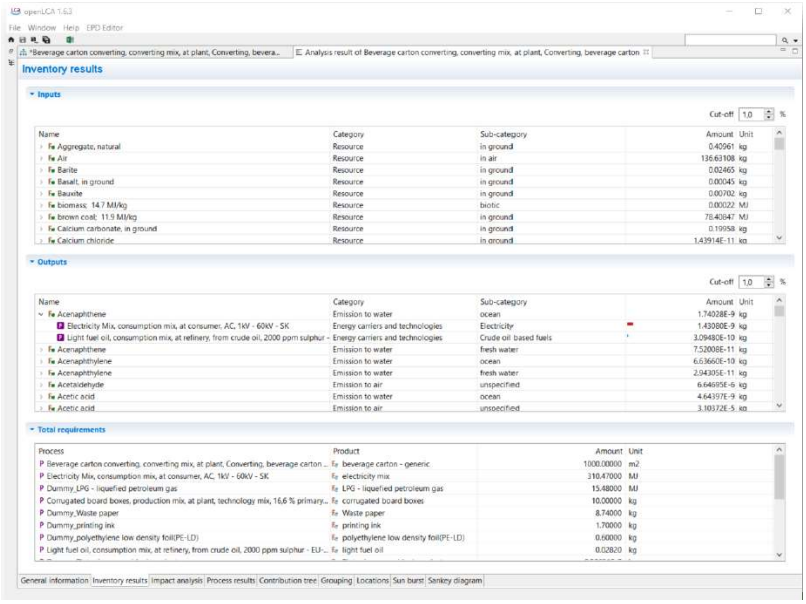
120

Analysis: Flow & Impact contributions



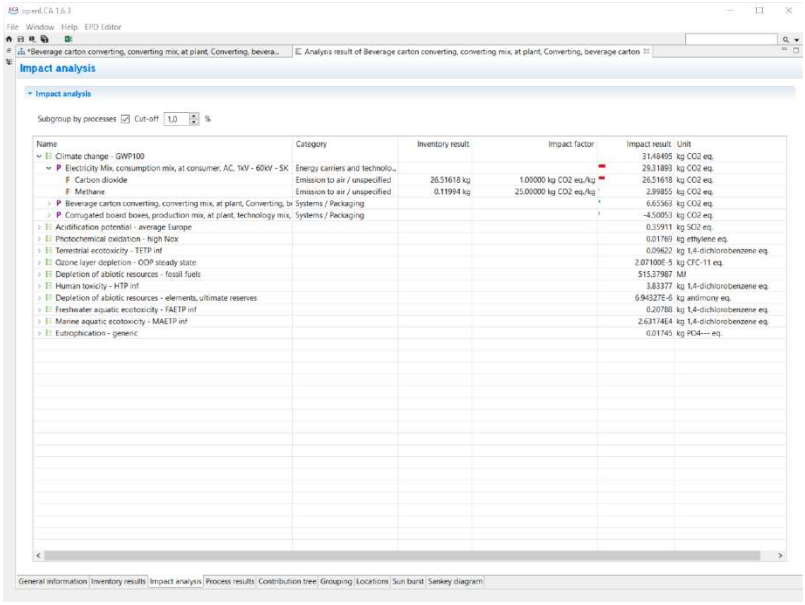
121

Analysis: Inventory Results

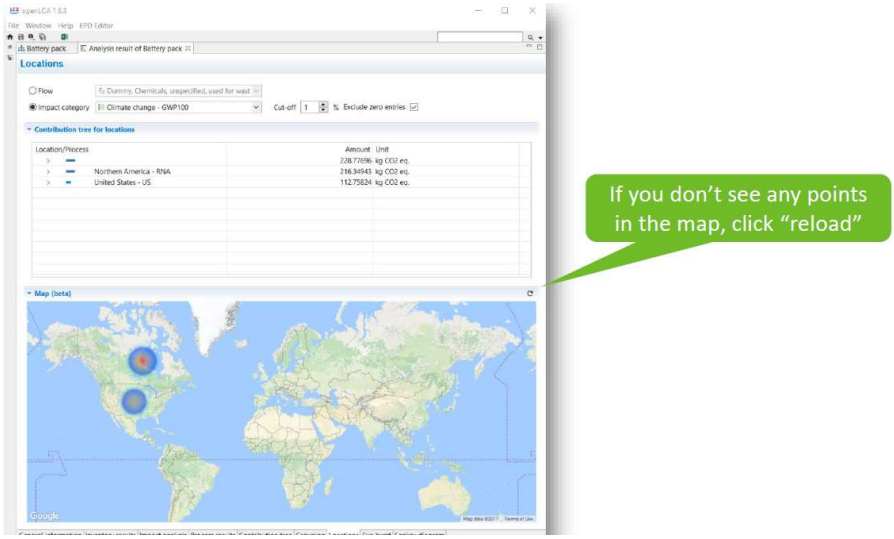


122

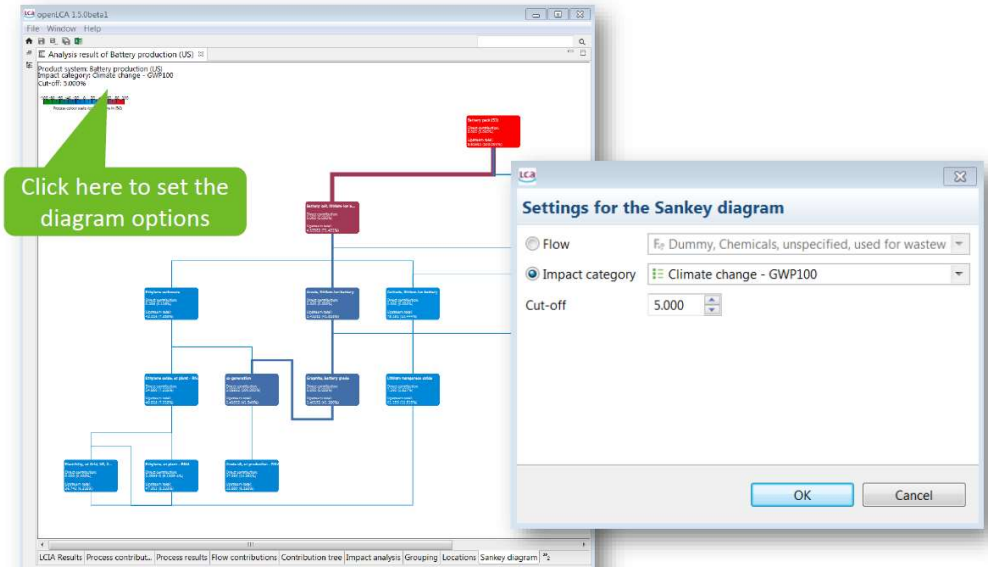
Analysis: Impact Analysis (LCIA Results)



Analysis: Locations



Analysis: Sankey Diagram

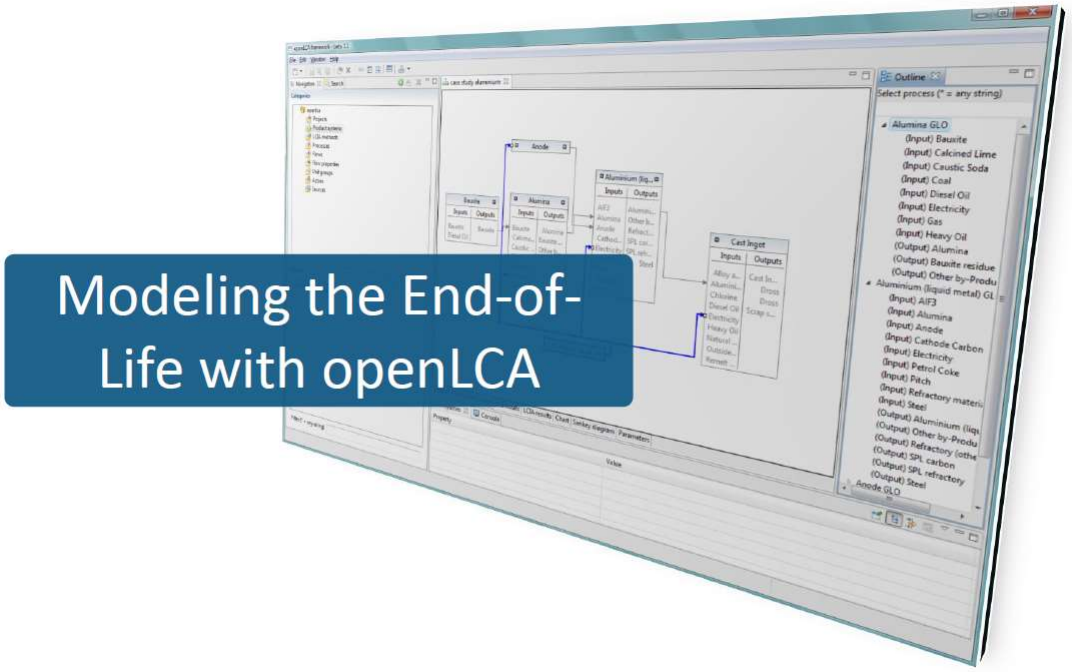


125

Task #7: Calculation of impacts

- Calculate the environmental impacts caused by the production of 1 PET bottle filled with water using the LCIA method CML(baseline) and interpret the results.
  - Which process contribute most to the impact category “Global Warming Potential”?
  - Which is the direct contribution of the flow “Carbon dioxide” to the same impact category?
  - Do the raw materials contribute more than electricity to the final GWP value?
  - Where does the emissions of “VOC, volatile organic compounds” come from?

126



127

Modeling waste

- ISO 14044: “substances or objects which the older intends or is required to dispose of”
- By-products with no market value

Life Cycle Stage 2 - Processing / Manufacturing - Pulp and paper production (Inter...

Inputs	Outputs
Additives (paper production)	Bark
Electricity	Tall oil (raw product)
Electricity	Virgin materials for paper production
Heat	Water (waste water, treated)
Packaging materials and cores	Water-turpentine mix
RER: integrated paper mill	Wood pellets (0% H2O content)
RER: Market pulp for paper production	
Thermal energy (MJ)	
Unspecified industrial waste treatment	
Water (process water)	
Wood for paper production	

Product: Water (waste water, treated)

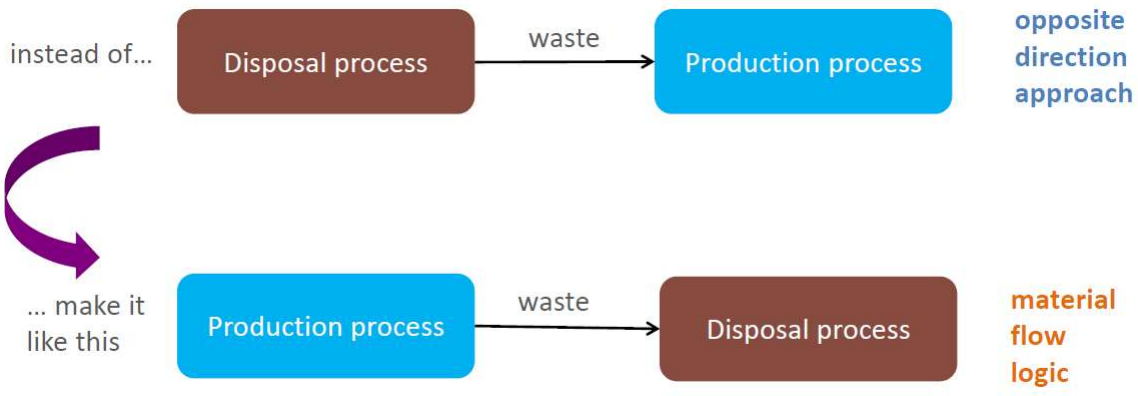
128

Possible approaches

- Presently there are two possible approaches when modelling wastes and waste treatment:
- opposite direction approach (ecoinvent)
  - interpret the waste treatment as a service and add it as an input or add waste as a negative input, which mathematically means it is an output
- material flow logic (openLCA)
  - It follows the natural direction of the flow, where something is produced and the waste is an output from the production or use phase

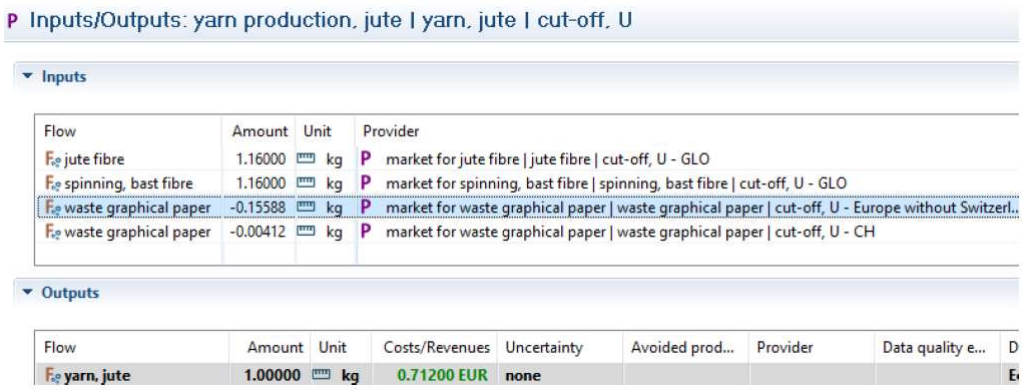
129

Modeling of waste (II)



130

Waste treatment in ecoinvent



131

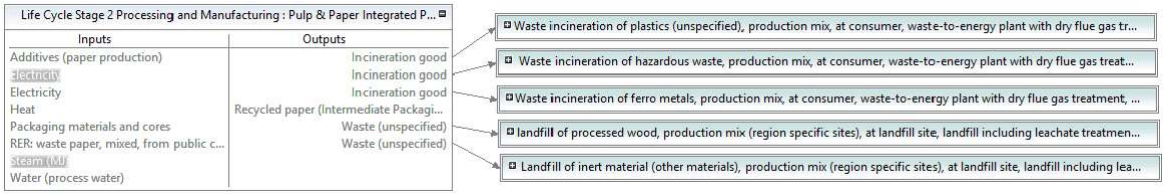
Waste treatment modeling in openLCA

- openLCA can handle both ways of modelling waste but it is necessary to pay attention to the flows used
- Product flows:
  - on the input side are considered input materials
  - on the output side are considered by products and can be allocated or marked as avoided product
- Waste flows:
  - On the output side are considered waste and can be connected to the waste treatment process
  - On the input side are the raw material for a waste treatment process and do not allow a connection with a provider

132

Material flow logic

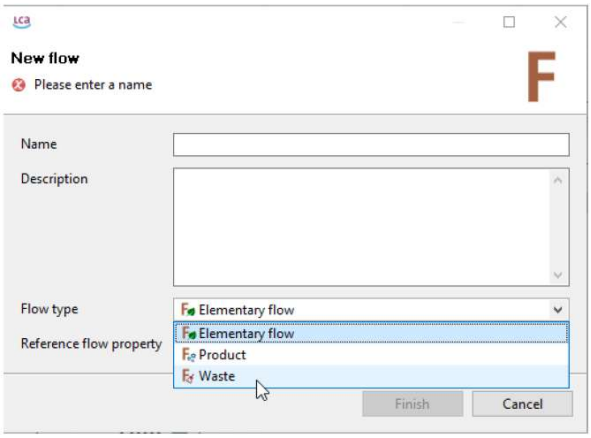
- When you select the waste flow type, openLCA recognizes it and allow you to specify default providers for them on the output side of your process
- This means that this flow will be treated in the following process



133

Waste treatment flows in openLCA

- The waste flows are marked with the symbol of a brush
- One can create them normally using the flow editor



134

Waste treatment modeling in openLCA

Inputs

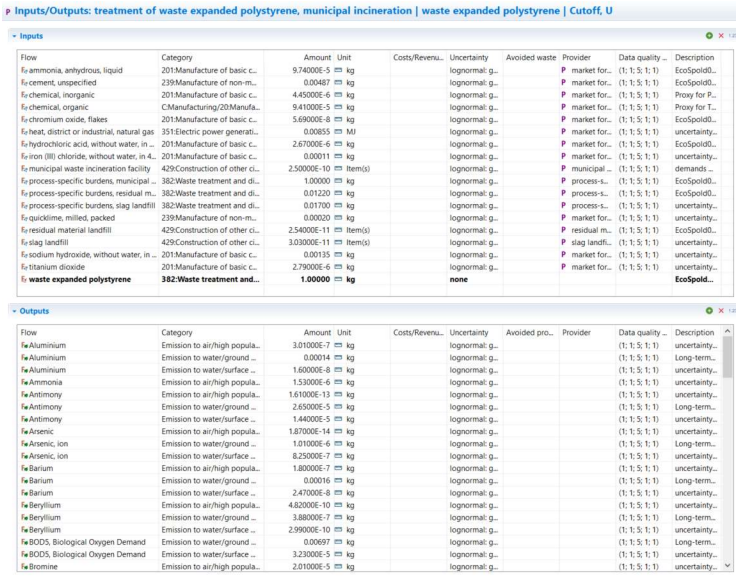
Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided waste	Provider
Additives (paper production)	Valuable substances/Intermedi...	44.50535	kg		none		Life Cy
Electricity	Energy carriers and technologi...	413.15446	MJ		none		Electric
Heat	Energy carrier/Thermal energy	7347.37000	MJ		none		CREDIT
Packaging materials and cores	Materials/Packaging	2.43062	kg		none		Life Cy
RER: waste paper, mixed, from public co...	Materials production/Paper an...	1075.28408	kg		none		Life Cy
Water (process water)	Materials/Operating materials	5951.39022	kg		none		Life Cy

Outputs

Flow	Amount	Unit	A..	Provider	Description
Incineration good	32.90000	kg		Waste incineration of plastics (unspecified), pro...	incineration of plastics (PE, PS, PP, PB)
Incineration good	1.20000	kg		Waste incineration of hazardous waste, producti...	disposal of bilge oil to hazardous waste incineration
Incineration good	11.00000	kg		Waste incineration of ferro metals, production ...	steel to incineration
Recycled paper (Intermediate Packaging)	**1000.00000**	**kg**			**Functional Unit 1 tonn paper**
Steam (MJ)	107.00000	MJ	☑	Process steam from biomass (solid) 90%, produ...	
Electricity	393.00000	MJ	☑	Electricity grid mix 1kV-60kV , consumption mix,...	

135

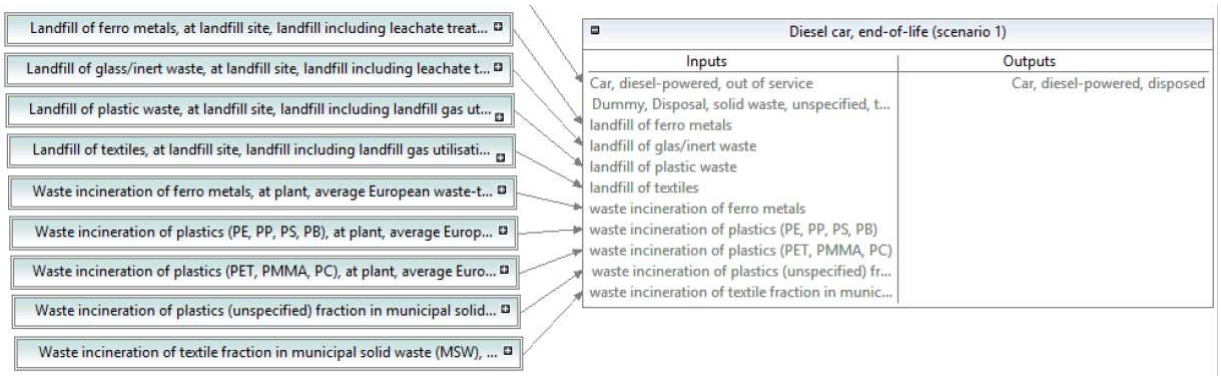
Waste treatment processes in openLCA



136

Opposite direction approach

- The waste is modeled using a product flow at the input side with a negative amount depending on whether the approach used was the 2nd or 3rd version of ecoinvent
- A default provider of waste treatment can be set



137

Task #8: model the EoL with the two approaches

- To model the use phase, create a process called “PET full bottle, transported” and add a transport of 50km by lorry to the shop.

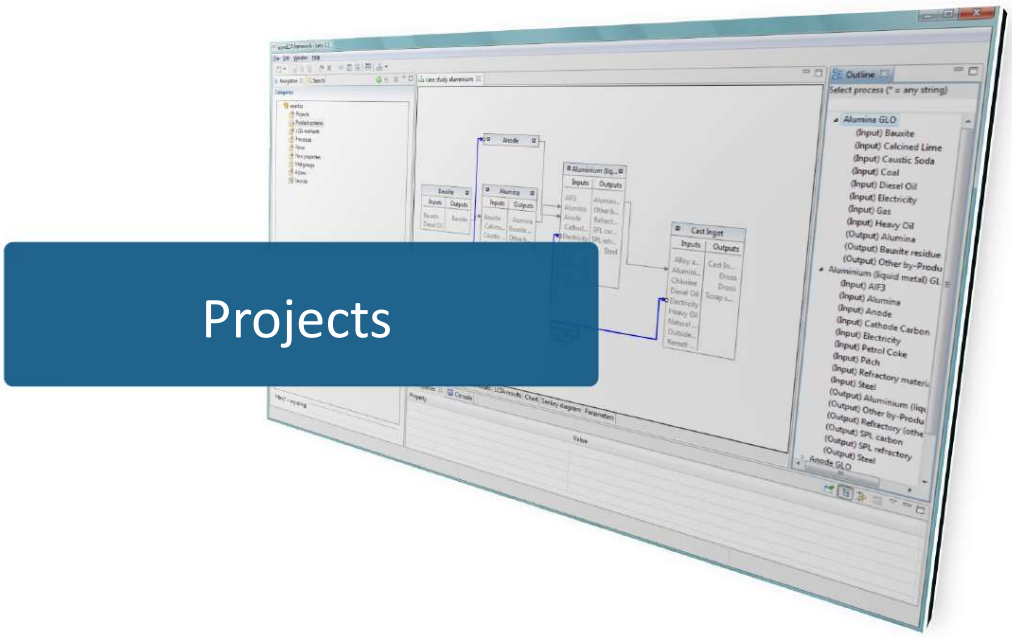
- Create two copies of “Waste incineration of plastics (PET, PMMA, PC), at plant, average European waste-to-energy plant, without collection, transport and pre-treatment” within the folder of your processes (use copy/paste). Before doing that, check that the input of the process is 1 kg of plastic.
  - Rename the two process “Waste incineration of plastics (Material Flow)” and “Waste incineration of plastics (Opposite Direction)”
  - Which approach is adopted in this process by default?

138

Task #8: model the EoL with the two approaches (II)

- Opposite direction approach
  - Create a process called “PET bottle EoL (OD)” with a new mass reference flow called “PET bottle used”
  - Add the transported bottle and the treatment process as a negative service in input. Pay attention to the mass involved!
- Material Flow logic
  - Create a new mass-based waste flow called “PET bottle used, waste”
  - Add the new flow as an input for “Waste incineration of plastics (Material Flow)”, set this new flow as reference flow (right click) and remove the previous reference output. Is the mass correct? (Yes, it is. You removed 1kg from output, adding 1 kg to input)
  - Create a process called “PET bottle EoL (MF)” with the flow “PET bottle used” as reference flow. Use the correct amount
  - Add the transported bottle in input and the treatment process as a positive output. Pay attention to the mass involved!
- Now, check the model graph! Is it different?

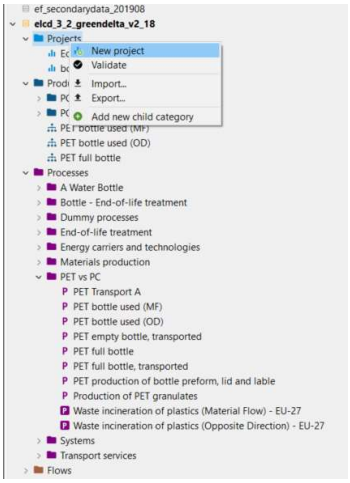
139



140

Projects: Creation

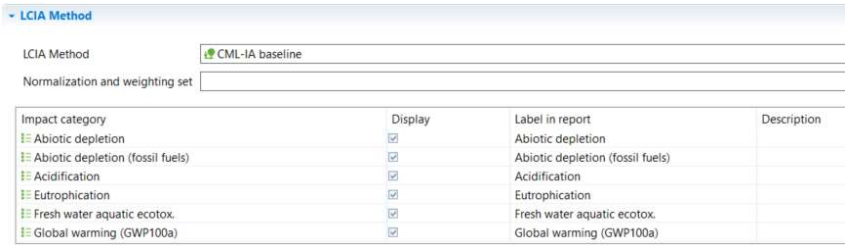
- Projects are created to compare different product systems
- To create a new project, right-click on Projects and select “new”



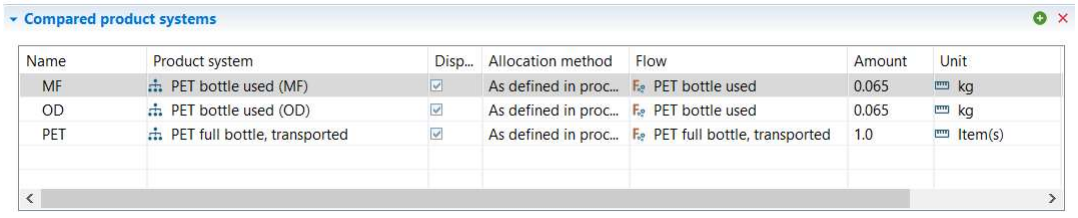
141

Projects: Creation (II)

- Select the LCIA methodology to perform the comparison



- Add the product systems to be compared and specify the quantity for each one



142

Projects: Creation (III)

- It is possible to specify the values of any parameter used in the product systems

Parameters

Parameter	Context	Label in report	Description	MF	OD

- If specifies, any contributions of the selected processes in the project setup to the variant results of the selected LCIA category will be shown

Process contributions

Process	Label in report	Description
P PET full bottle	PET full bottle	

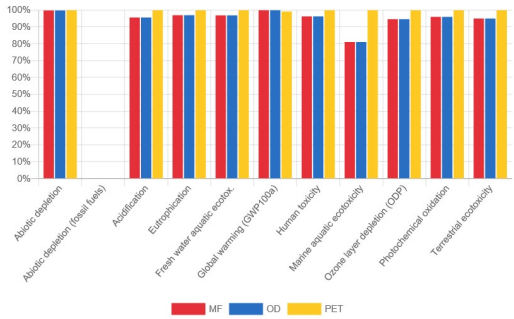
143

Projects: Report

- The comparison will be performed clicking on the “Report” button

- The report sections can be modified before calculation on the dedicated tab at the bottom of the screen
- The results will be shown in terms of tables and graphs

Indicator	MF	OD	PET	Unit
Abiotic depletion	4.40991e-9	4.40991e-9	4.42033e-9	kg Sb eq
Abiotic depletion (fossil fuels)	0	0	0	MJ
Acidification	1.51223e-2	1.51223e-2	1.58239e-2	kg SO2 eq
Eutrophication	1.03368e-3	1.03368e-3	1.06648e-3	kg PO4--- eq
Fresh water aquatic ecotox.	4.87685e-3	4.87685e-3	5.03611e-3	kg 1,4-DB eq
Global warming (GWP100a)	3.44847e+0	3.44847e+0	3.42001e+0	kg CO2 eq
Human toxicity	2.79593e-1	2.79593e-1	2.90501e-1	kg 1,4-DB eq
Marine aquatic ecotoxicity	3.23604e+2	3.23604e+2	3.99503e+2	kg 1,4-DB eq
Ozone layer depletion (ODP)	1.83928e-7	1.83928e-7	1.94477e-7	kg CFC-11 eq
Photochemical oxidation	8.47388e-4	8.47388e-4	8.83074e-4	kg C2H4 eq
Terrestrial ecotoxicity	1.33859e-3	1.33859e-3	1.40919e-3	kg 1,4-DB eq

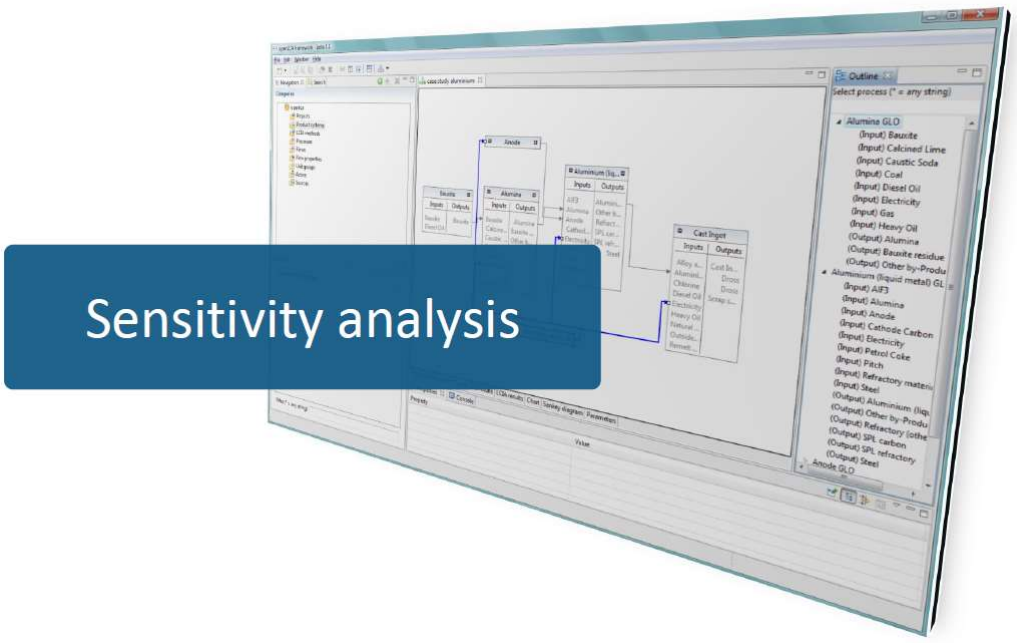


144

Task #9: Create a project

- Create a project and compare the two product systems modelled using different approaches.
- If they are not equal, something is wrong!!

145



146

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?

147

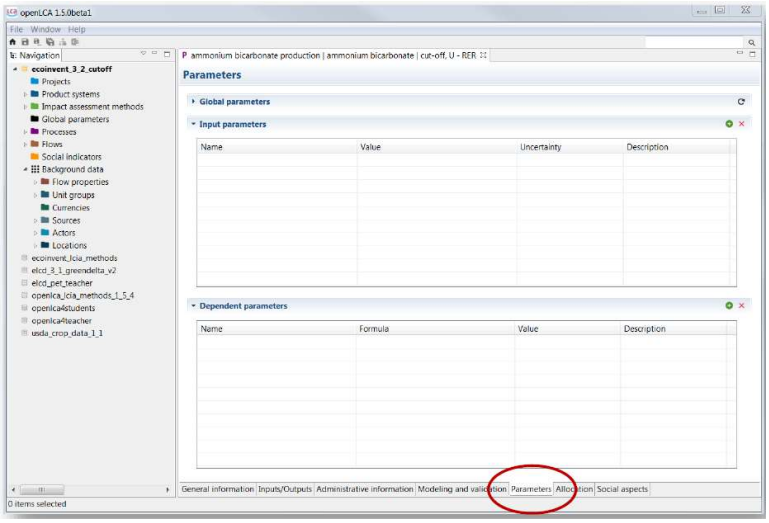
Modeling with parameters

- Useful for sensitivity analyses → What impact does one aspect have when I change its value?
- Useful for preliminary data: data can be changed easily at the end of your study
- Create different versions of your life cycle by changing the input values
- Enter calculation rules instead of concrete values → more flexibility

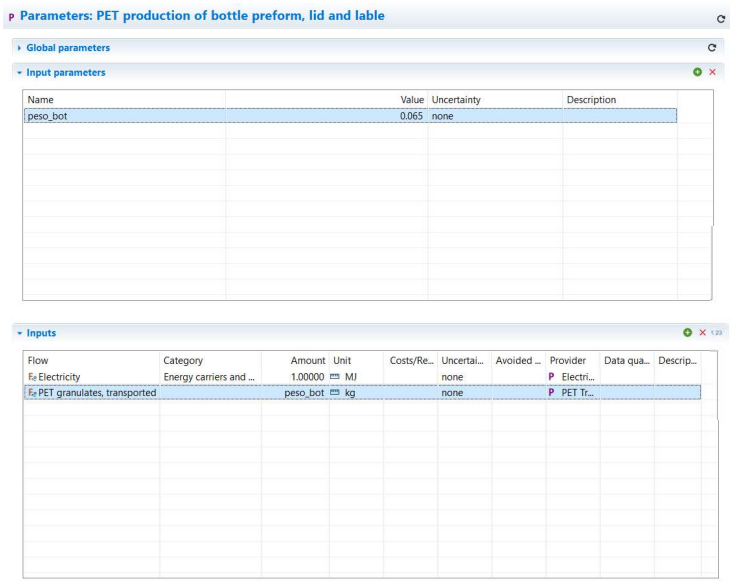
- Available on process, product system, LCIA method, project and database level
- Local and global parameters → parameters can overwrite each other!
- Parameters can be linked to other parameters (i.e. dependent parameters) → Loops are not allowed

148

Process: parameters

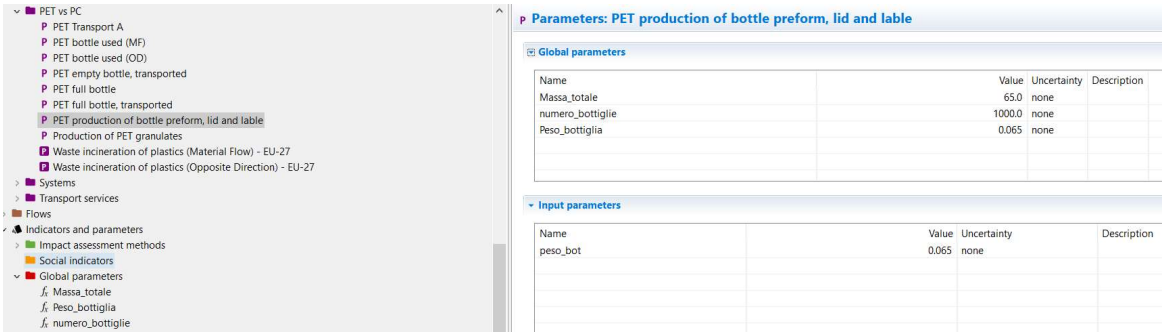


Process: parameters



Process: parameters at Global and Local level

- Global parameters can be used by any process
- Local parameters are process-specific and overwrites global parameters values.
  - Try to use different names to avoid confusion



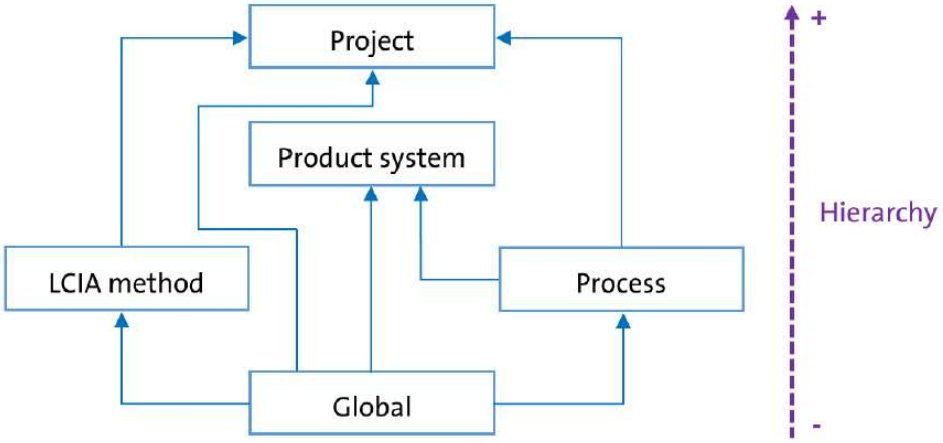
151

Parameter rules

- Parameter names…
  - … must be one word, underscores are allowed.
  - … 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.

152

Parameters: Hierarchy



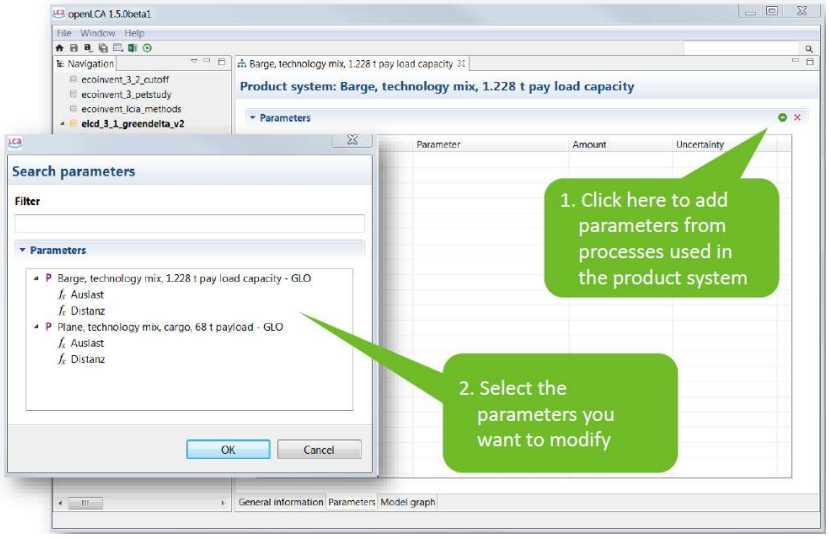
153

Parameter: checking formulas

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

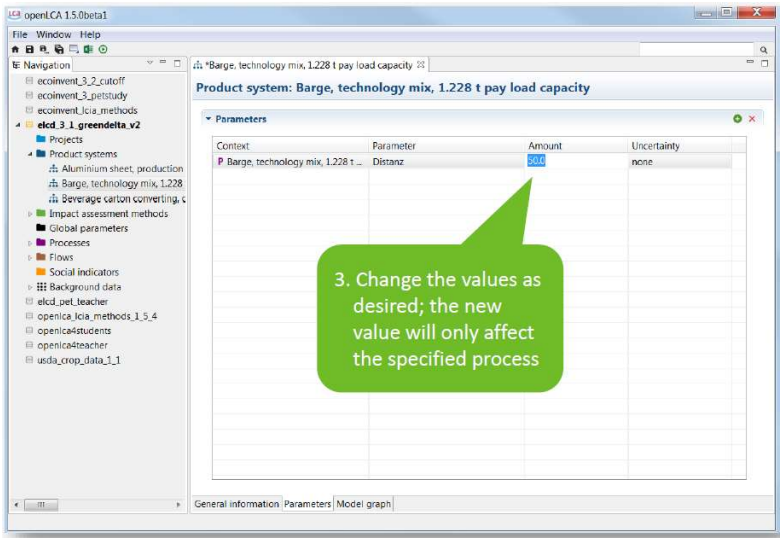
154

Product system: Parameters



155

Product system: Parameters (II)



156

157

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

158

Excel export

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

Other export formats

JSON-LD

- Every element in an openLCA databa

CSV-Matrix

- Graph of a product system

Images

- Diagrams

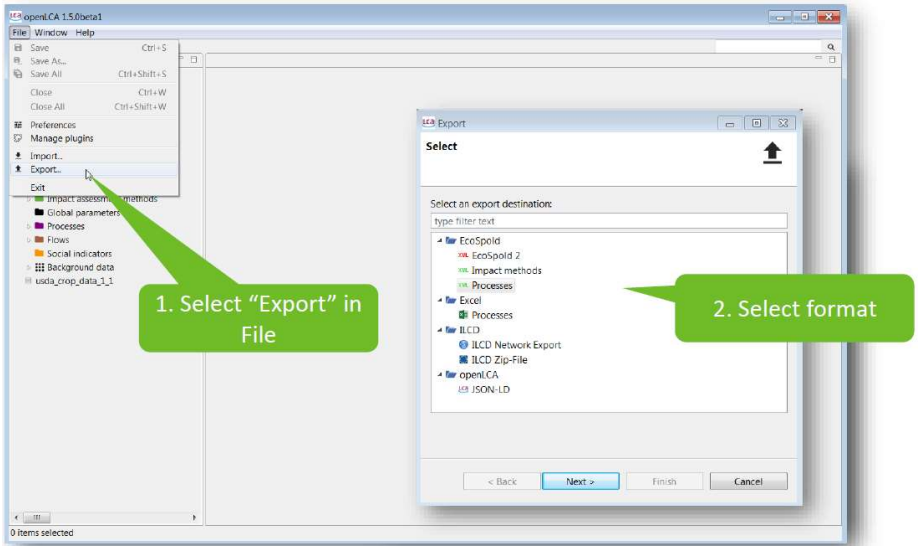
HTML

- Project report

openLCA script (.zolca)

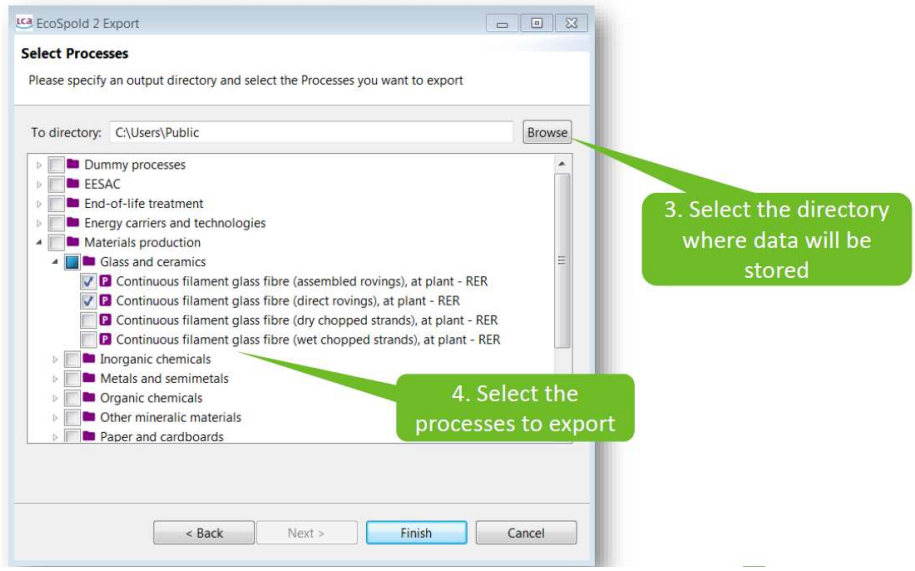
- Complete databases

Process export

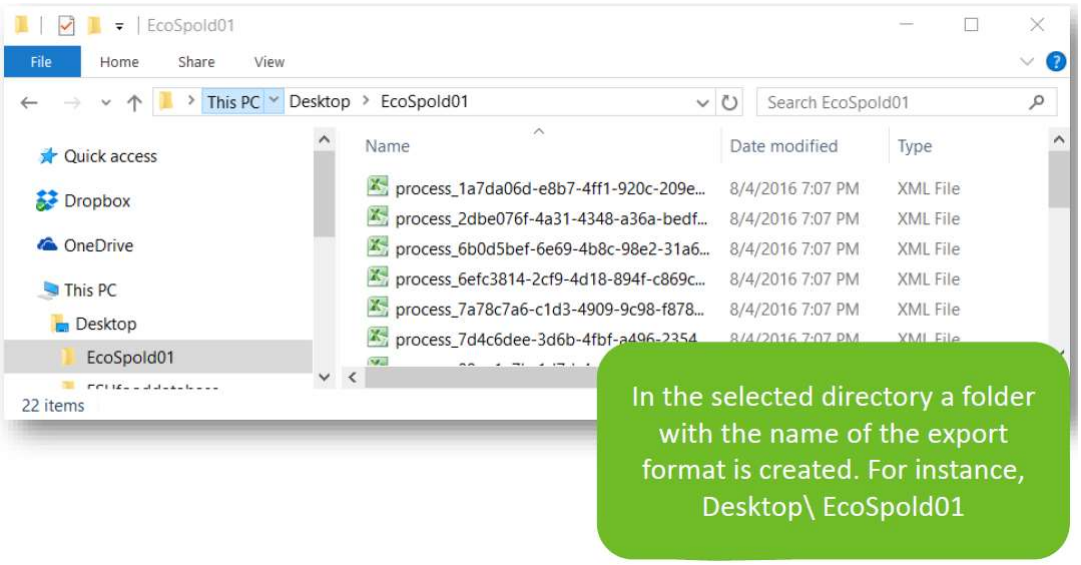


160

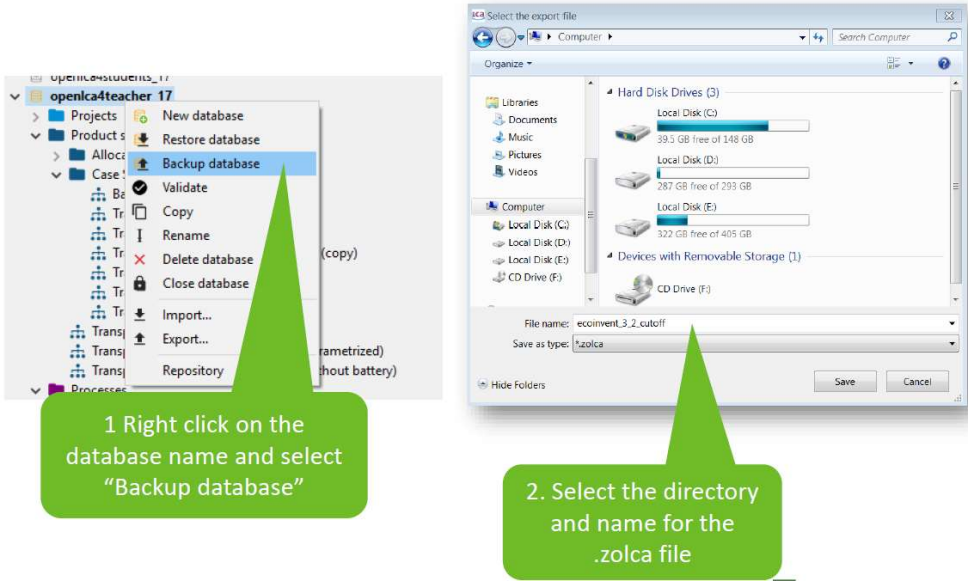
Process export (II)



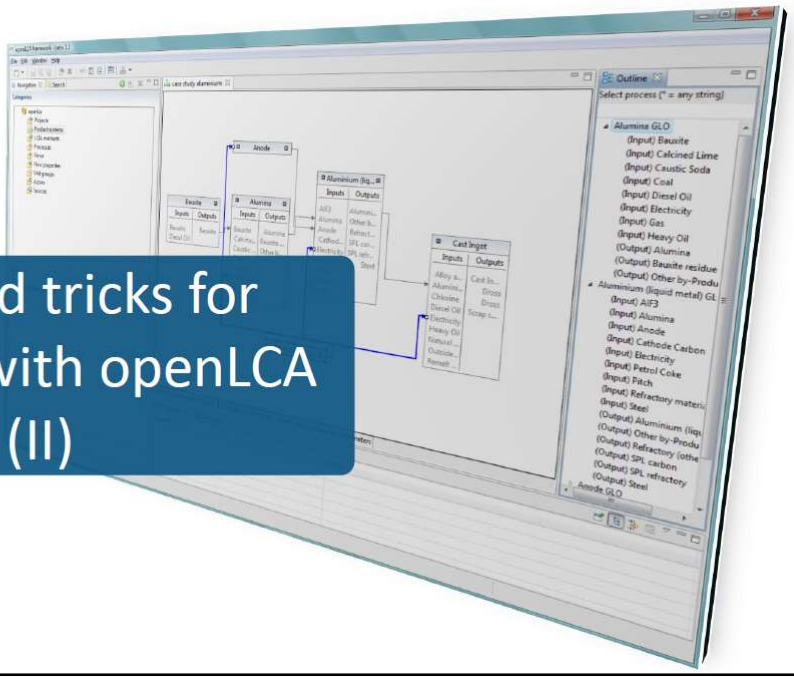
Process export (III)



Export openLCA database

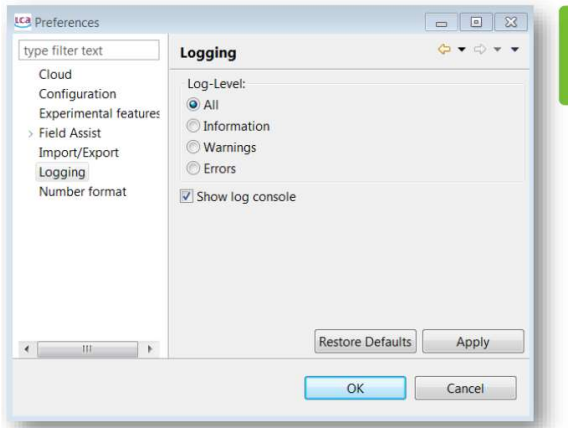


Tips and tricks for working with openLCA (II)



Errors

- It is possible to report all errors in a log file automatically
- To do so go to file/preferences/logging and check “All”

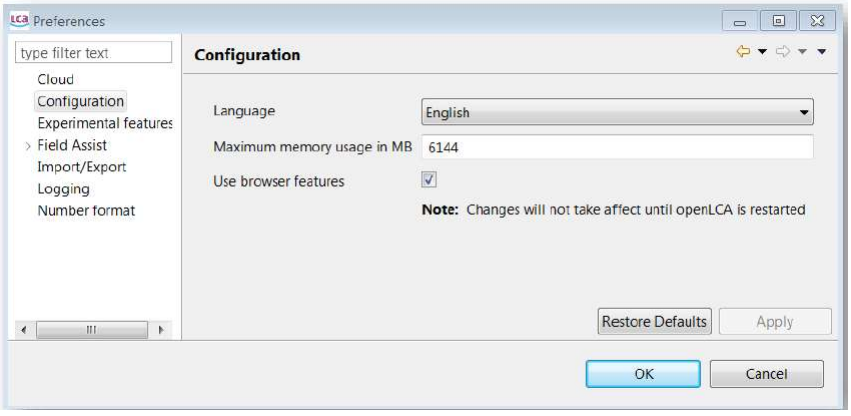


The log file is rewritten every time openLCA is restarted!

165

Language

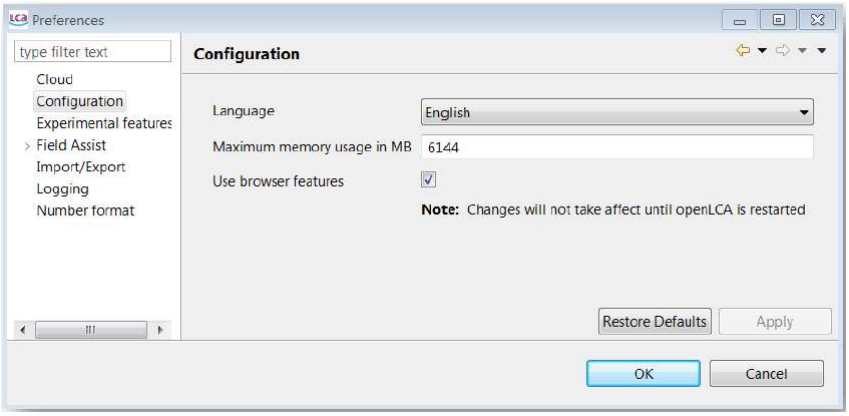
- openLCA is available in Arabic, Bulgarian, Catalan, Chinese, English, French, German, Italian, Portuguese, Spanish and Turkish
- Change it under File/Preferences/Configuration.
- Once you change the language, restart the program to activate it



166

Memory usage

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



167

openLCA-data directory

- The openLCA data folder is automatically created 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 the following way:

```
-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
```

168

Task #10: Create the PC bottle

- Create a new bottle made of PC and compare it with the PET bottle using a new Project
- Everything will be the same, except for the raw materials. They will be:
  - Polycarbonate granulate (PC): 60g
  - Polyethylene low density granulate (PE-LD): 4g
  - Polybutadiene granulate (PB): 1g

169