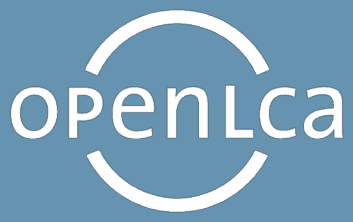


openLCA Tutorial

Basic Modelling in openLCA

Software Version: 1.10

Manual Version: 1.3 (June 2020)

GreenDELTA

2 Basic Modelling

In this text, we will introduce basic modelling steps in openLCA using an example of plastic bottles for packaged drinking water. We will explore the environmental impact of producing a PET bottle as opposed to a PC bottle. The life cycle to be modelled is shown in Figure 1.

The database elements needed for modelling and comparison of product systems in openLCA are:

- Projects 
- Product systems 
- Processes 
- Flows 

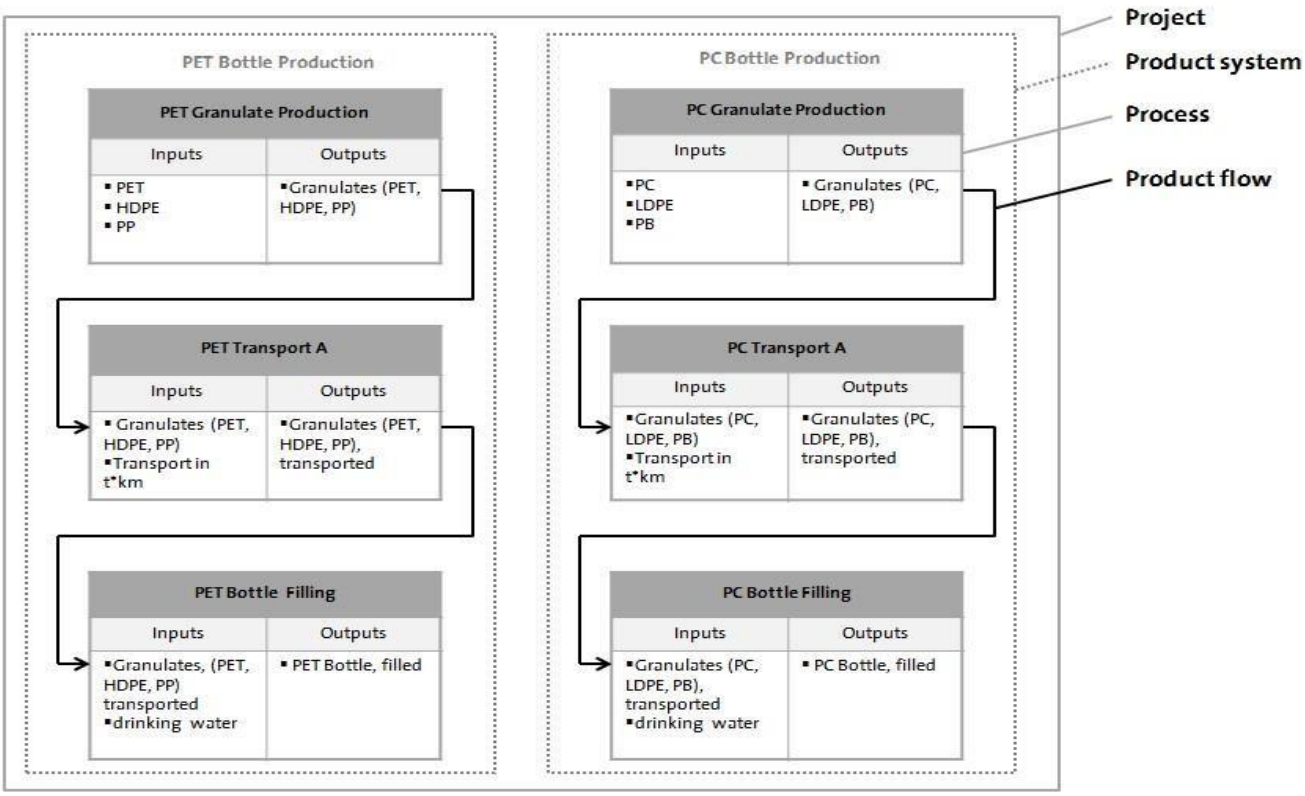


Figure 1: Example of a project with two product systems

3 Flows

Flows are all product, material or energy inputs and outputs of processes in the product system under study.

A flow is defined by the name, flow type, and reference flow property. openLCA distinguishes three flow types:

- elementary flows: material or energy of the environment entering or leaving directly the product system under study (e.g. crude oil from the ground, or emissions to air)
- product flows: material or energy exchanged between the processes of the product system under study
- waste flows: material or energy leaving the product system

Each flow created must be defined by a reference flow property such as mass, volume, area, etc. It is also possible to define several flow properties for the same flow, but only one flow property must be selected as reference flow property.

3.1 Create a new flow

- Create the flows *Granulates (PET, HDPE, PP)*; *Granulates (PET, HDPE, PP)*, transported; and *PET Bottle, filled* in the folder *A Water Bottle*
- Create the flows *Granulates (PC, LDPE, PB)*; *Granulates (PC, LDPE,* PB), transported; and *PC Bottle, filled* in the folder *A Water Bottle*

To create a folder in the element folder *Flows*, right-click next to the elements folder *Flows*, select A*dd new child category* and name it *A Water Bottle*. To create a new flow, right-click next to the folder *A Water Bottle* and select *New flow*. Name the new flow *Granulates (PET, HDPE, PP)*, select the flow type *product*, choose the reference flow property *Mass* and click *Finish*.

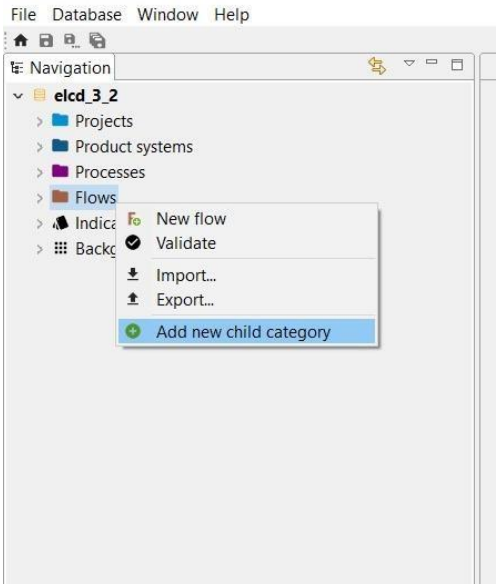


Figure 2: Create a new folder

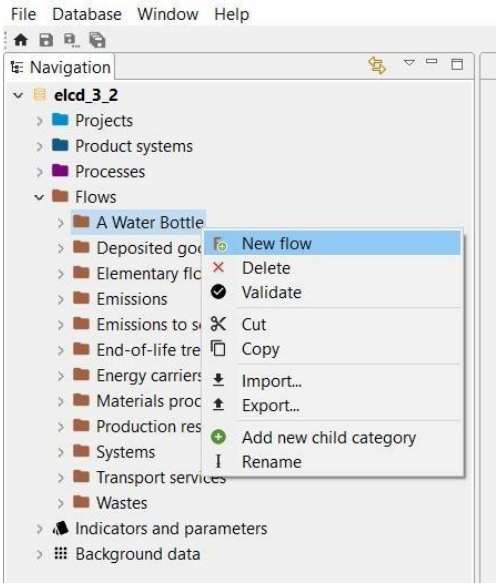


Figure 3: Create a new flow

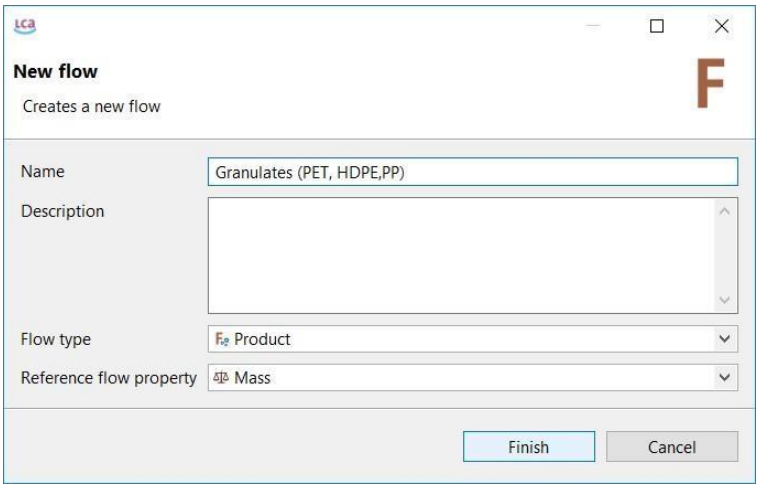


Figure 4: Name, flow type and reference flow property of a new flow

The flow *Granulates (PET, HD, PP)* should now appear in the folder *A Water Bottle* in the Navigation windows as well as in the Editor window.

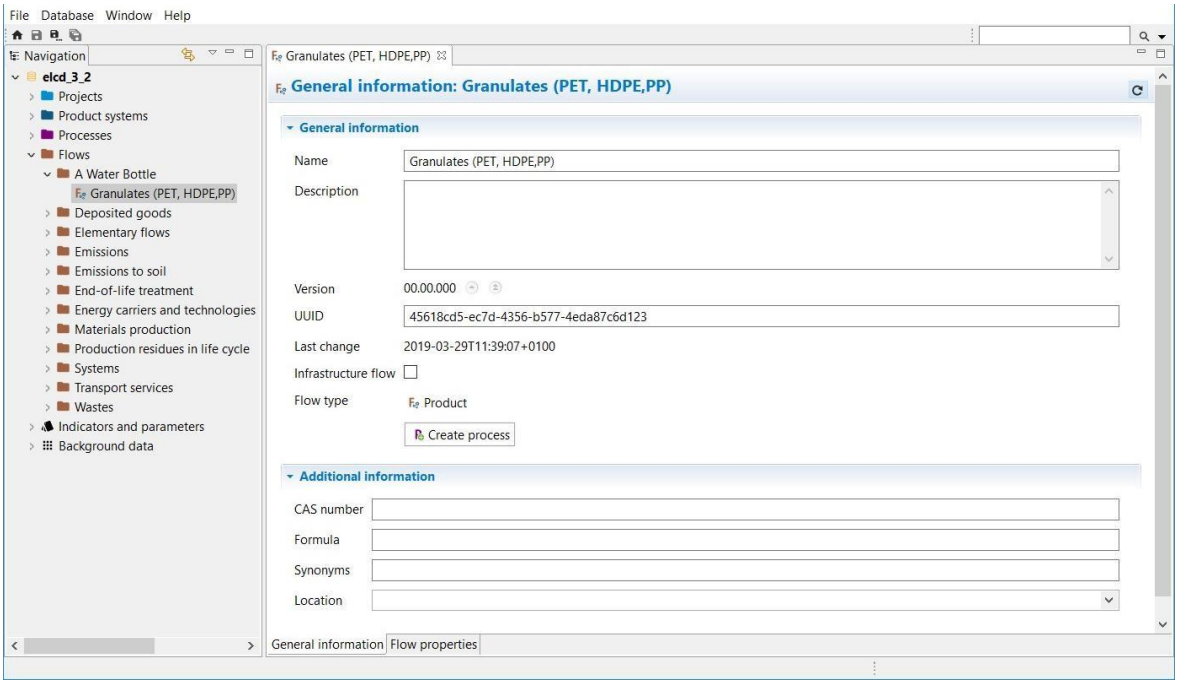


Figure 5: New flow in the Navigation and Editor window

Now create more flows according to Table 1.

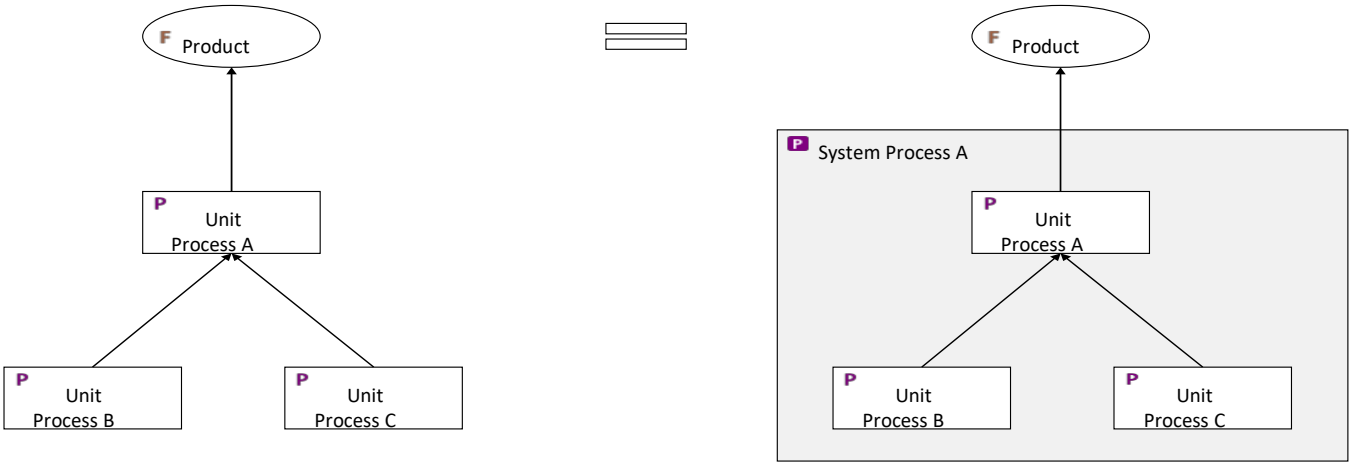
Table 1: Inputs for creating new flows

Flow name	Flow type	Reference flow property
Granulates (PET, HDPE, PP), transported	Product	Number of items
PET Bottle, filled	Product	Mass
Granulates (PC, LDPE, PB)	Product	Mass
Granulates (PC, LDPE, PB), transported	Product	Number of items
PC Bottle, filled	Product	Mass

4 Processes

Processes are sets of interacting activities that transform inputs into outputs. Every process is defined by an output flow as a quantitative reference with the flow type product flow, which is either selected or created when creating a project. openLCA distinguishes two types of processes:

- Unit Processes: smallest unit analysed for which input and output data are quantified
- System Processes: unit for which input and output data are aggregated



Unit Process System Process

Figure 6: Unit and system processes

4.1 Create a new process

- Create the processes *PET Granulate Production*, *PET Transport A*, and *PET Bottle Production* of the product system *PET Bottle Production*
- Create the processes *PC Granulate Production*, *PC Transport A*, and *PC Bottle Production* of the product system *PC Bottle Production*

To create a folder in the element folder Processes, right-click next to the elements folder *Processes*, select *Add new child category* and name it *A Water Bottle*. To create a new process, right-click next to the folder *A Water Bottle* and select *New process*. Name the new process *PET Granulate Production*, select the quantitative reference *Granulates (PET, HDPE, PP)* and click *Finish*.

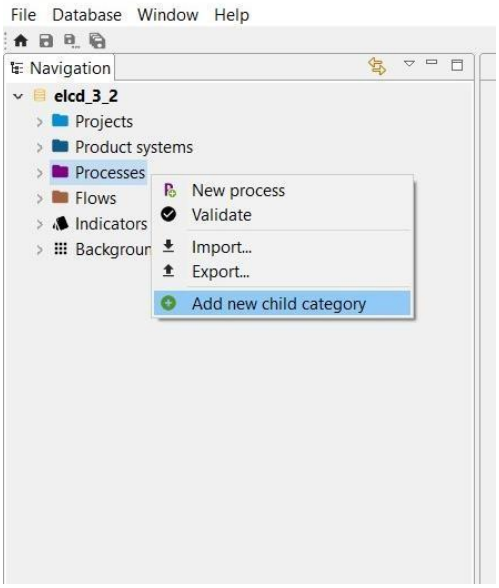


Figure 7: Create a new folder

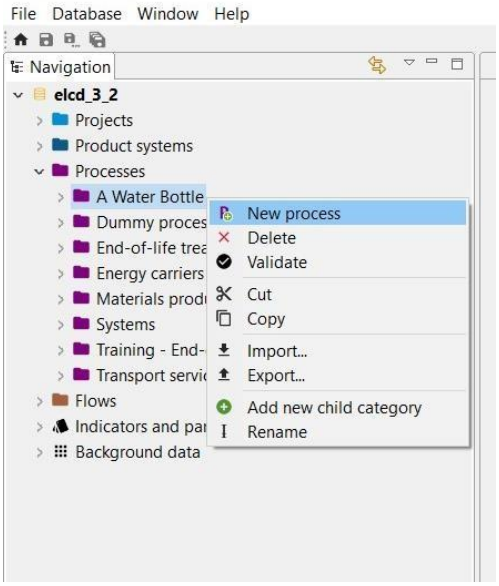


Figure 8: Create a new process

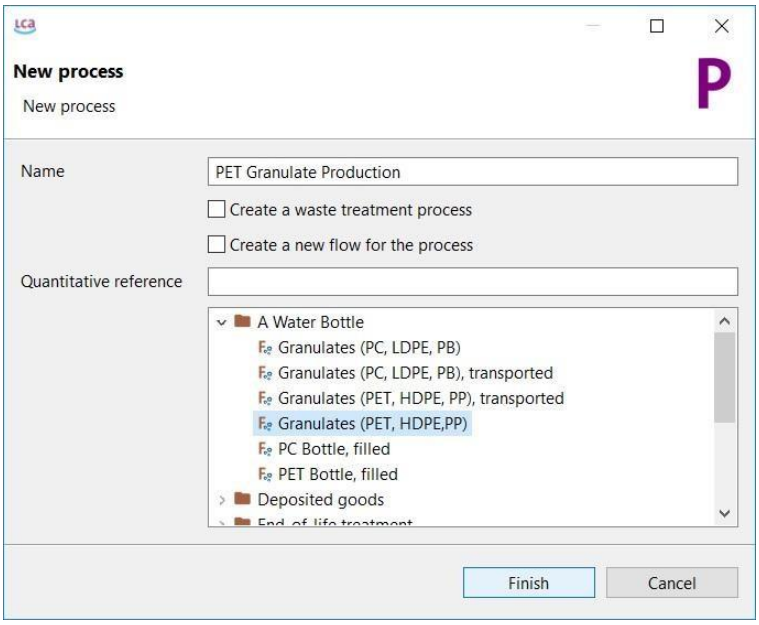


Figure 9: Name and quantitative reference of a new process

The process *PET Granulate Production* created should now appear in the folder *A Water Bottle* in the Navigation windows as well as open in the Editor Window.

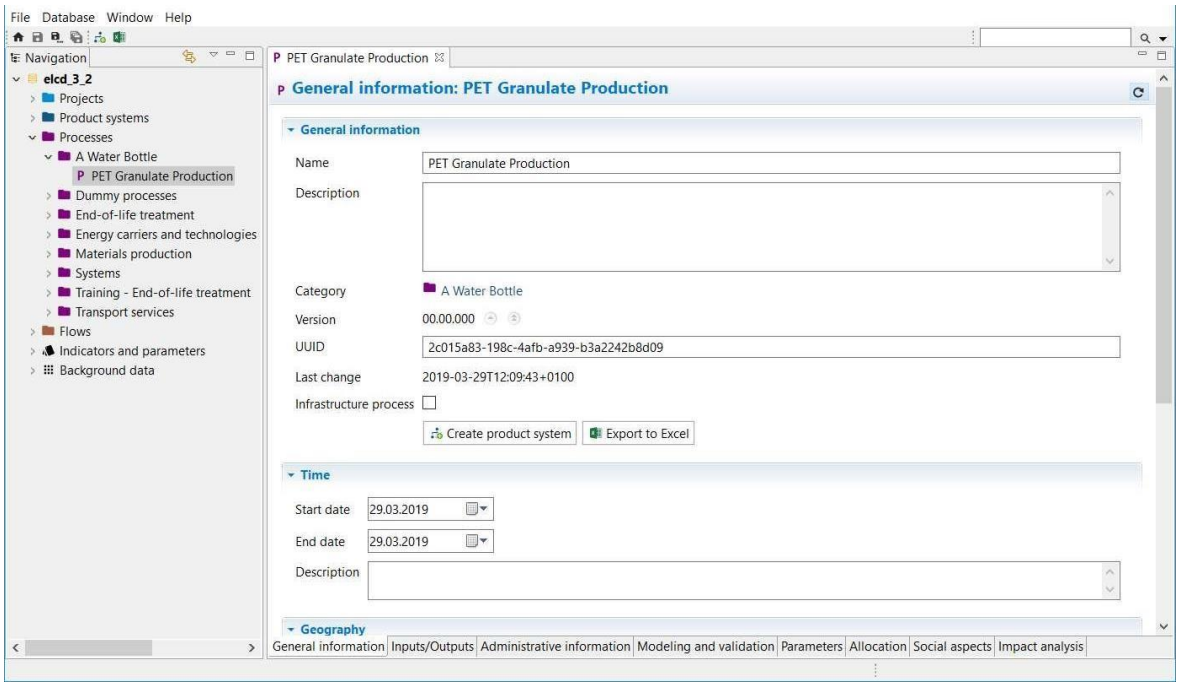


Figure 10: New Process in the Navigation and Editor window

The Process Editor window is structured in several tabs at the bottom of each Editor window. In the Input/Output tab you can see that the quantitative reference flow *Granulates (PET, HDPE, PP)* selected appears as the output flow for the process *PET Granulate Production*.

Add the input flows in the Inputs section of the Inputs/ Outputs tab as described in Table 2 by using the

flow filter: Press the green + button on the top right corner, or double- click in the column Flow of the Inputs Section.

Table 2: Inputs for the processes of the product system *PET Bottle Production*

Process	Quantitative reference	Input Flows	Amount
PET Granulate Production	Granulates (PET, HDPE, PP)	polyethylene terephthalate (PET) granulate	60 g
		polyethylene high density granulate (PE-HD)	4 g
		polypropylene granulate (PP)	1 g
PET Transport A	Granulates (PET, HDPE, PP) transported	Granulates (PET, HDPE, PP)	0.065 kg
		Transport in t*km	0.065 kg*500 km
PET Bottle Filling	PET Bottle, filled	Granulates (PET, HDPE, PP), transported	1 item
		Drinking water	1 kg

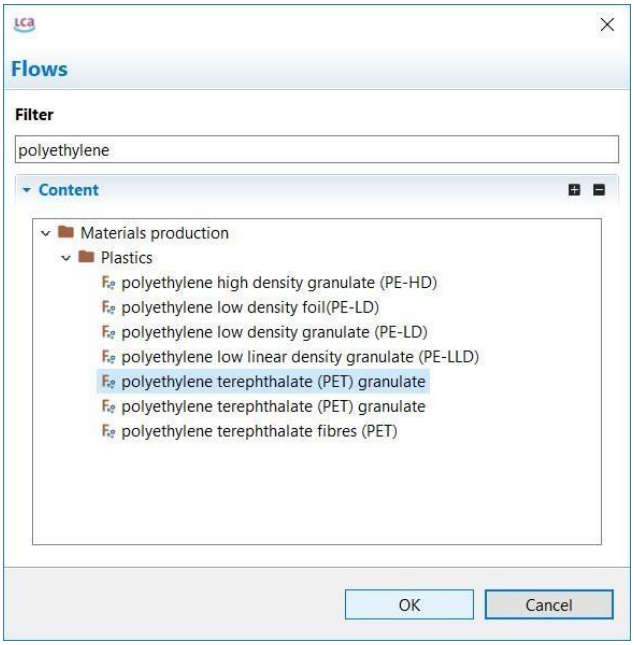


Figure 11: Adding input flows by using the flow filter

Note! When you search for flows by using the flow filter, only folders containing the keywords you have entered will be shown in the content section. The flow *polyethylene terephthalate (PET) granulate* appears twice because these flows are output flows of different production processes. Select the flow, which has the provider *Polyethylene terephthalate (PET) granulate, production mix, at plant, amorphous - RER*. In case of doubt add both flows and check their provider to select the right process.

It is also possible to use the search function at the top right corner to search any element within the active database. To search in different types of database elements use the arrow icon next to the search bar.

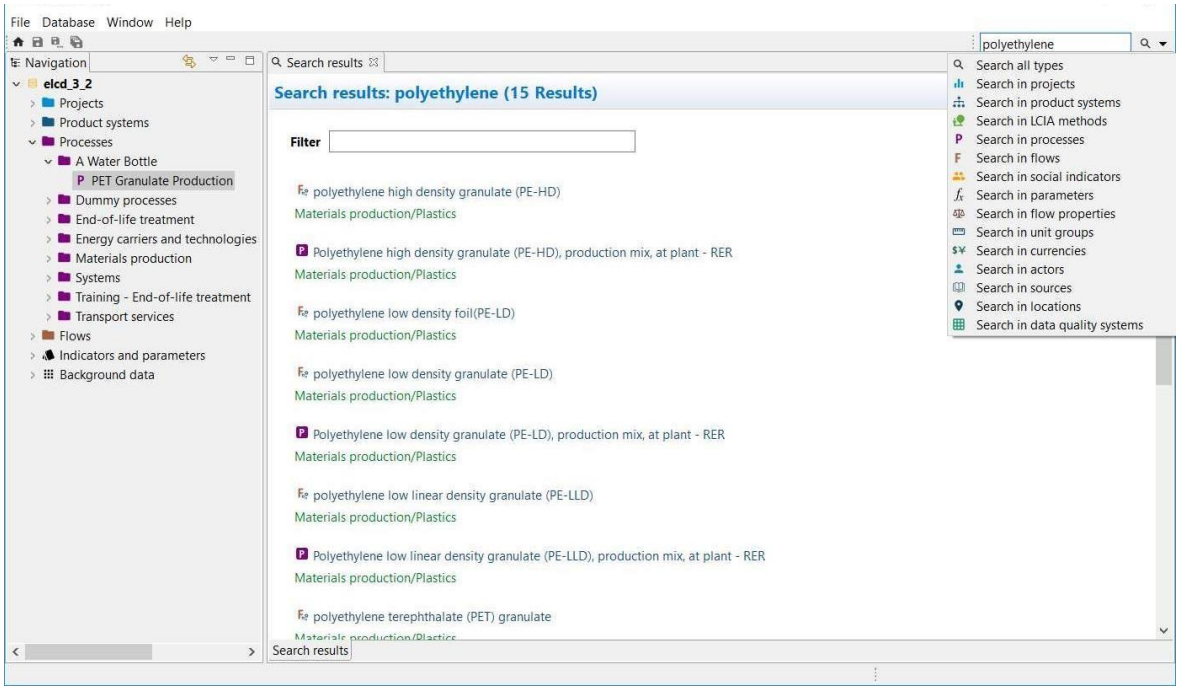


Figure 12: Search function

It is also possible to search the flows in the Navigator window and add them as inputs for the process by using drag and drop.

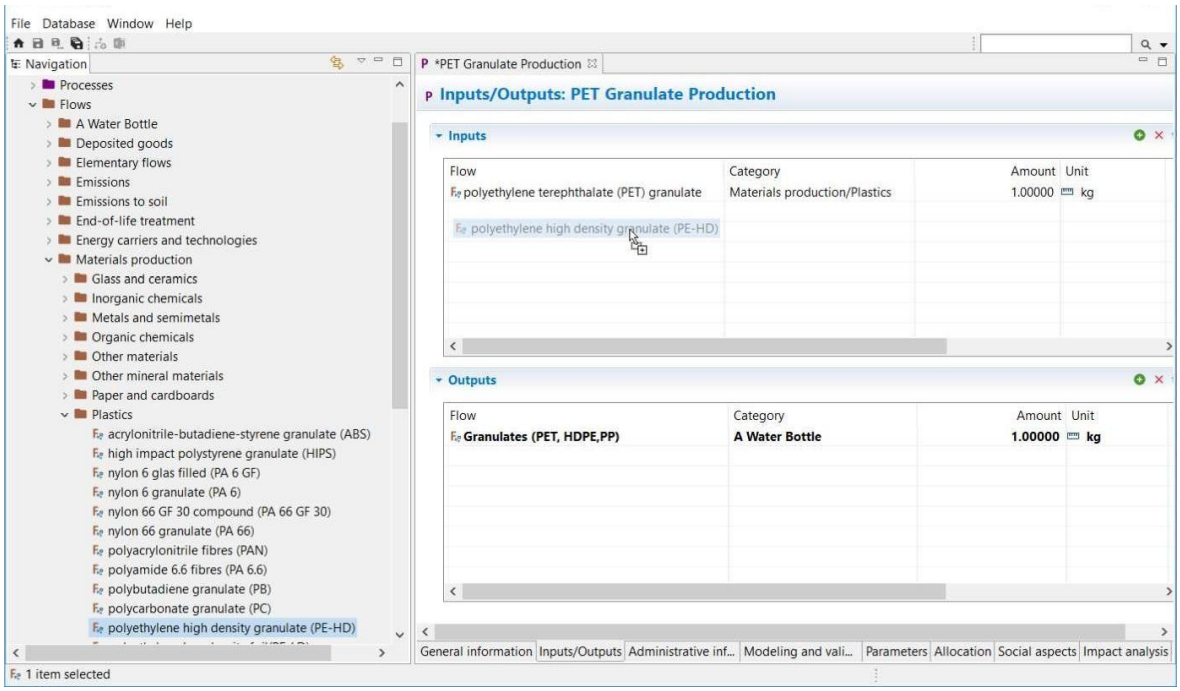


Figure 13: Adding input flows from the Navigation window by using drag and drop

Once you have found the flows you can adjust the amounts needed for each input and output flow according to Table 2. Double-click in the column Provider to connect the input flows with their respective upstream supply chain and save your changes.

Note! Number format: Use a decimal point instead of a decimal comma.

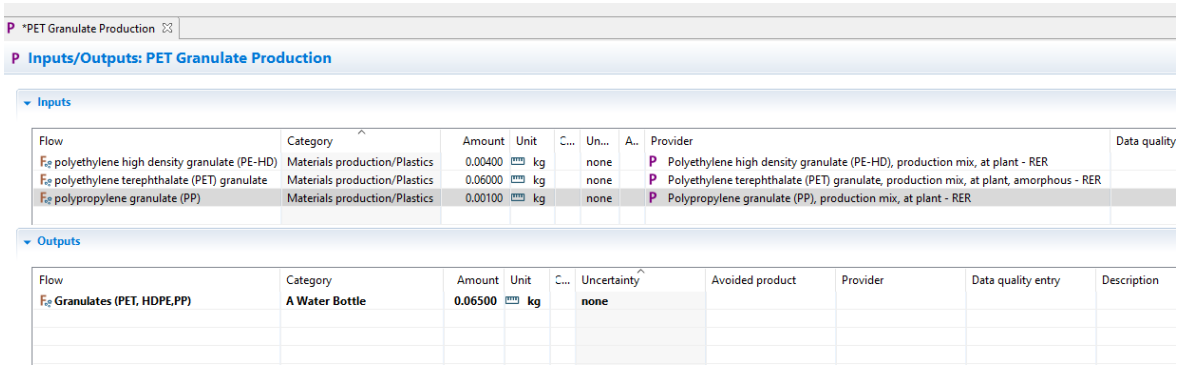


Figure 14: Inputs/Outputs tab of the process editor for the process *PET Granulate Production*

Note! Unsaved Changes in the Editor are indicated with an *. Save your changes by clicking the Save button under the Main Menu or use command Ctrl + S.

Now create a second process *PET Transport A* with the quantitative reference *Granulates (PET, HDPE, PP), transported.* To connect the first process with the second process of the production chain, the output flow *Granulates (PET, HDPE, PP)* of the first process (*PET Granulate Production*) must be used as an input flow of the second process (*PET Transport A*). Add the respective amounts for each flow (table 2) and

define the provider. Select the provider *Lorry transport, Euro 0, 1, 2, 3, 4 mix, 22 t total weight, 17,3t max payload - RER* for the input flow *transport in t*km*.

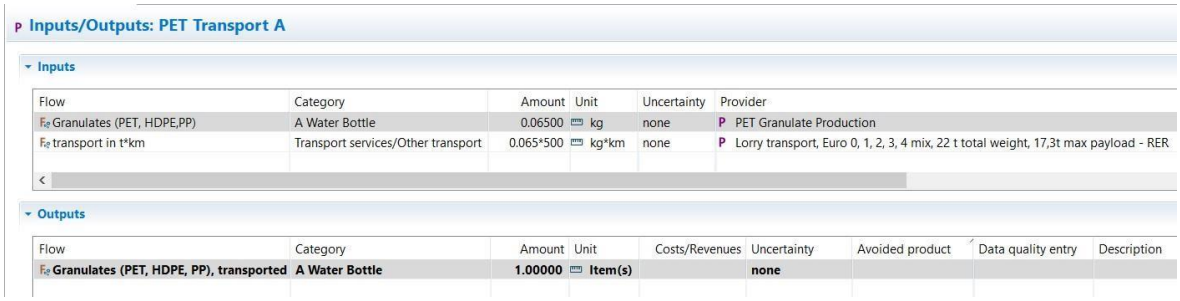


Figure 15: Inputs/Outputs tab of the process editor for the process *PET Transport A*

Create the third process PET Bottle Filling according to Table 2.

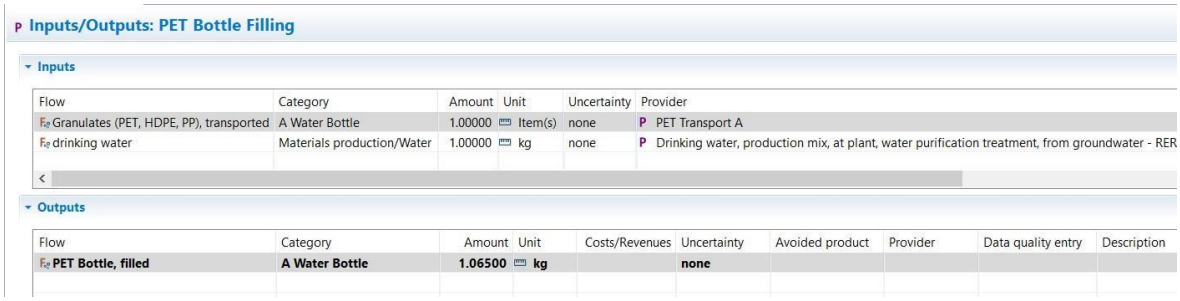


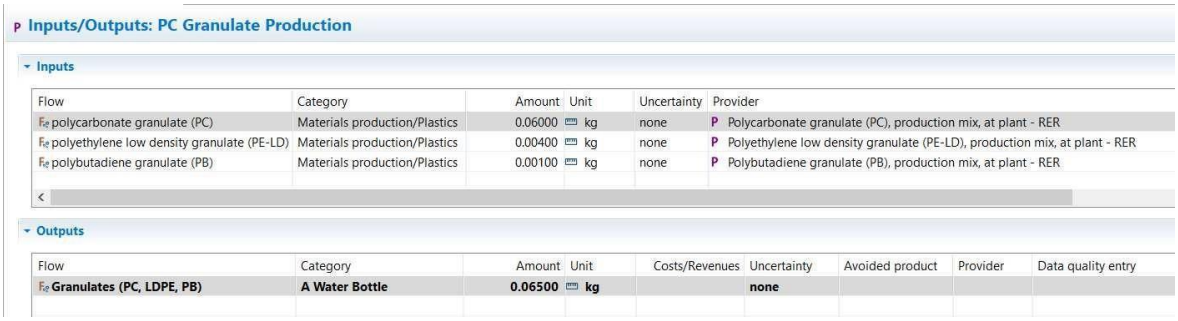
Figure 16: Inputs/Outputs tab of the process editor for the process *PET Bottle Filling*

When you have finished creating all processes of the product system *PET Bottle Production*, you create the processes of the product system *PC Bottle Production* according to Table 3.

Table 3: Inputs for the processes of the product system *PC Bottle Production*

Process	Quantitative Reference	Input Flows	Amount
PC Granulate Production	Granulates (PC, LDPE, PB)	polycarbonate granulate (PC)	60 g
		polyethylene low density granulate (PE- LD)	4 g
		polybutadiene granulate (PB)	1 g
PC Transport A	Granulates (PC, LDPE, PB), transported	Granulates (PC, LDPE, PB)	0.065 kg
		Transport in t*km	00065 kg*500 km

PC Bottle Filling	PC Bottle, filled	Granulates (PC, LDPE, PB), transported	1 item
		Drinking water	1 kg



Inputs/Outputs: PC Granulate Production

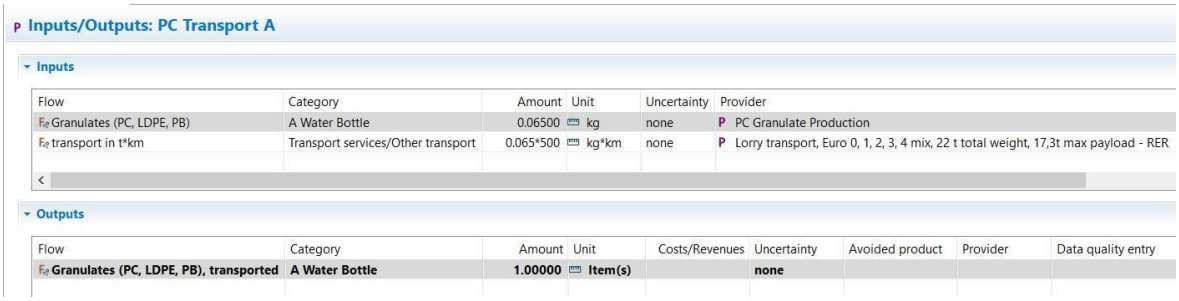
Inputs

Flow	Category	Amount	Unit	Uncertainty	Provider
polycarbonate granulate (PC)	Materials production/Plastics	0.06000	kg	none	Polycarbonate granulate (PC), production mix, at plant - RER
polyethylene low density granulate (PE-LD)	Materials production/Plastics	0.00400	kg	none	Polyethylene low density granulate (PE-LD), production mix, at plant - RER
polybutadiene granulate (PB)	Materials production/Plastics	0.00100	kg	none	Polybutadiene granulate (PB), production mix, at plant - RER

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality entry
Granulates (PC, LDPE, PB)	**A Water Bottle**	**0.06500**	**kg**		**none**			

Figure 17: Inputs/Outputs tab of the process editor for the process *PC Granulate Production*



Inputs/Outputs: PC Transport A

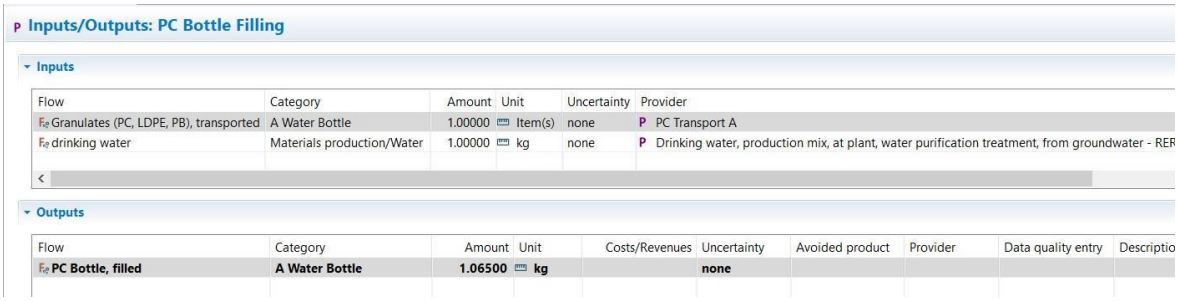
Inputs

Flow	Category	Amount	Unit	Uncertainty	Provider
Granulates (PC, LDPE, PB)	A Water Bottle	0.06500	kg	none	PC Granulate Production
transport in t*km	Transport services/Other transport	0.065*500	kg*km	none	Lorry transport, Euro 0, 1, 2, 3, 4 mix, 22 t total weight, 17,3t max payload - RER

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality entry
Granulates (PC, LDPE, PB), transported	**A Water Bottle**	**1.00000**	**Item(s)**		**none**			

Figure 18: Inputs/Outputs tab of the process editor for the process *PC Transport A*



Inputs/Outputs: PC Bottle Filling

Inputs

Flow	Category	Amount	Unit	Uncertainty	Provider
Granulates (PC, LDPE, PB), transported	A Water Bottle	1.00000	Item(s)	none	PC Transport A
drinking water	Materials production/Water	1.00000	kg	none	Drinking water, production mix, at plant, water purification treatment, from groundwater - RER

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality entry	Descriptio
PC Bottle, filled	**A Water Bottle**	**1.06500**	**kg**		**none**				

Figure 19: Inputs/Outputs tab of the process editor for the process *PC Bottle Filling*

5 Product systems

A product system contains all processes under study. The product system can consist of one process only or a network of multiple processes and is defined by the reference process.

In openLCA, the impacts can be calculated for a product system. The reference process of the product system is used to calculate the impacts for all connected upstream processes of the product system.

In openLCA, product systems can be created automatically or manually. For illustrative purposes, we will exemplary create a product system with automatic linking of processes and one with manual linking. However, if the ELCD or GaBi database is used, the product systems should always be created manually.

5.1 Create a product system

- Create the product system *PET Bottle Production* with automatic linking of processes
- Create the product system *PC Bottle Production* with manual linking of processes

When you have finished creating all processes of the production chain you can create the product system based on the last process as the reference process of the product system.

Go to the *General Information* tab of the *PET Bottle Filling* process editor and press the button *Create product system* or use *Create product system* icon in the main menu.

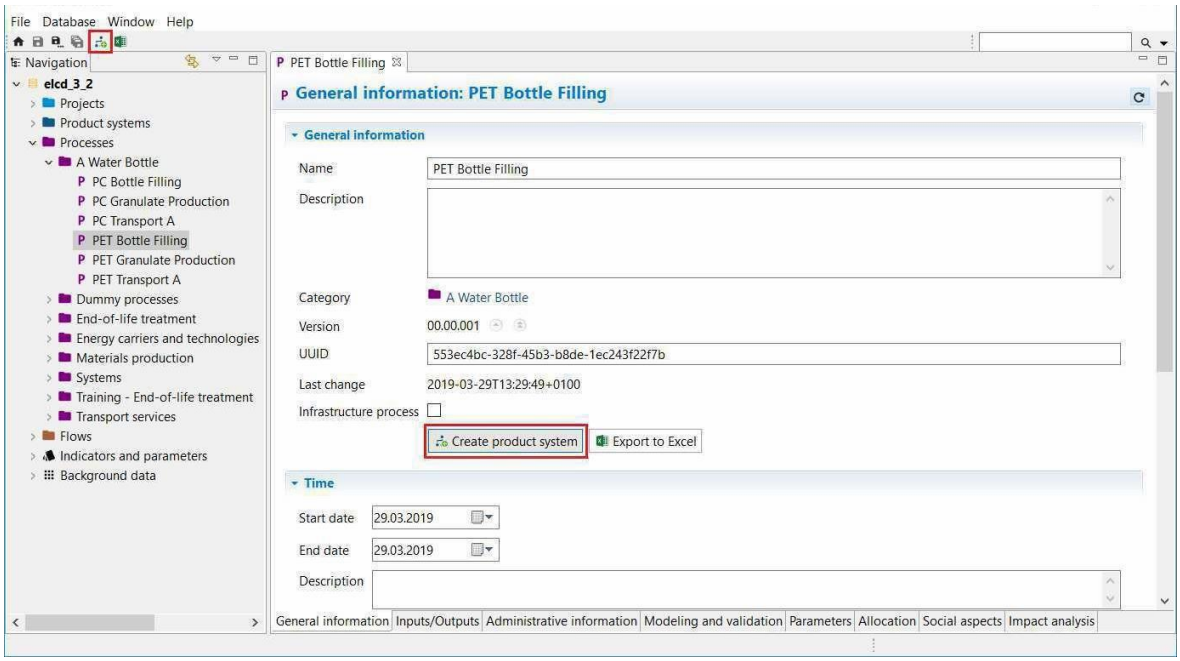


Figure 20: Create a product system in the process editor

Name the product system *PET Bottle Production*, select *PET Bottle Filling* as the reference process, select *Auto-link processes*, for provider linking select *only link default providers*, as preferred process type select *System process* and click *Finish*. In this way, all connections between the processes are established.

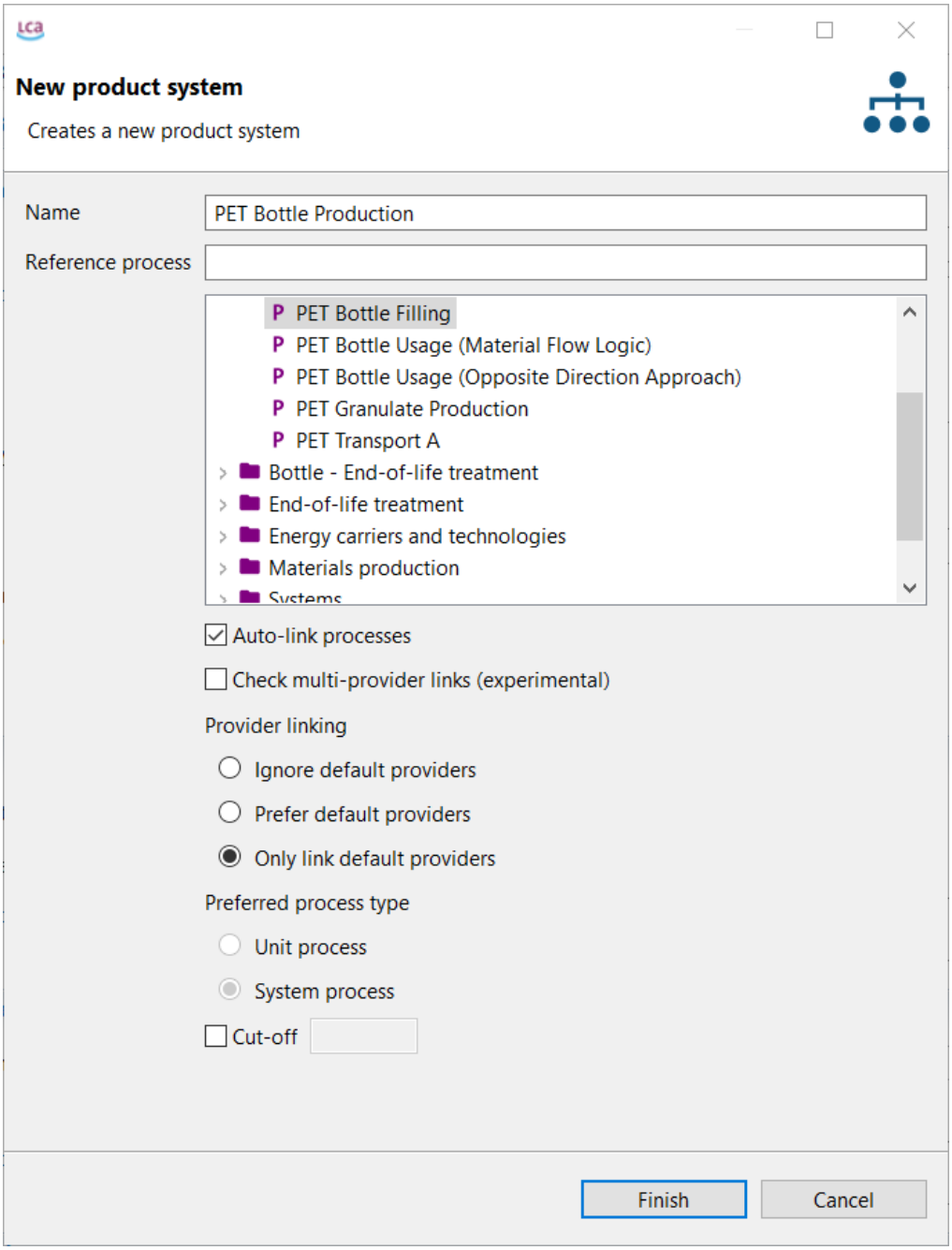


Figure 21: Create the product system *PET Bottle Production*

The product system *PET Bottle Production* will open in the Editor window with the *General information* tab. Go to the *Model graph* tab to see the product system created.

If *Auto-link processes* is selected, the upstream processes for input flow will automatically be considered, indicated by a + in the top left corner of each process. Double click on the processes to maximise the view and see the input and output product flows, click on the + button to expand the view and see the providers for the input flows of the unit processes you have modelled.

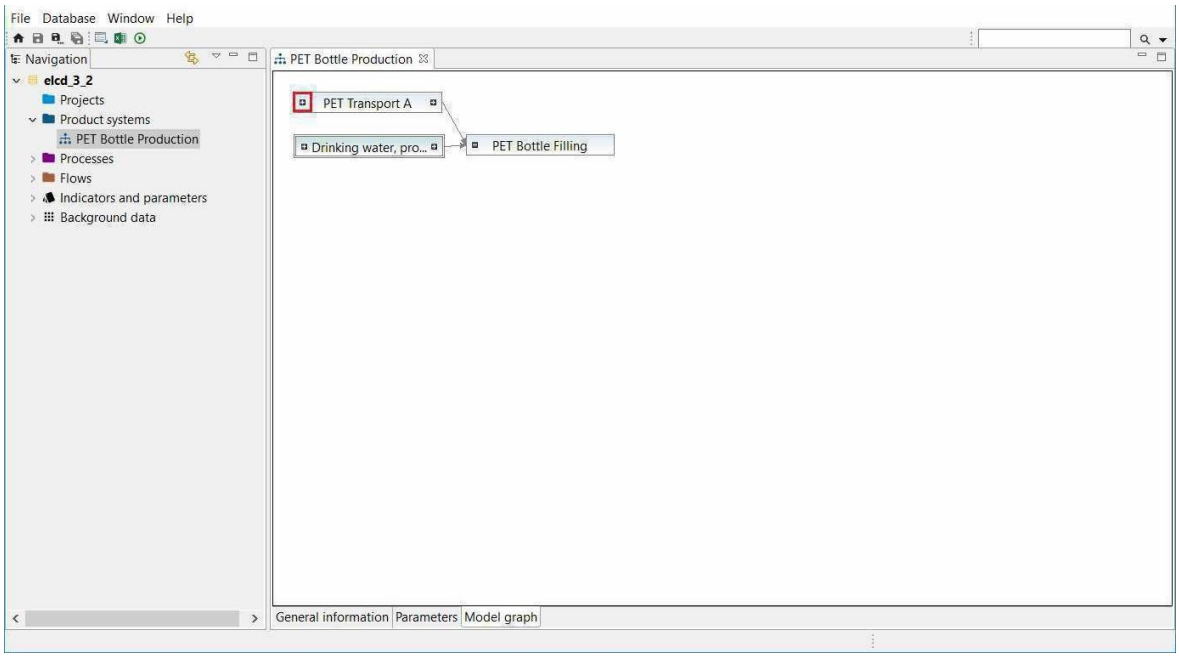


Figure 22: *Model graph* of the product system *PET Bottle Production*

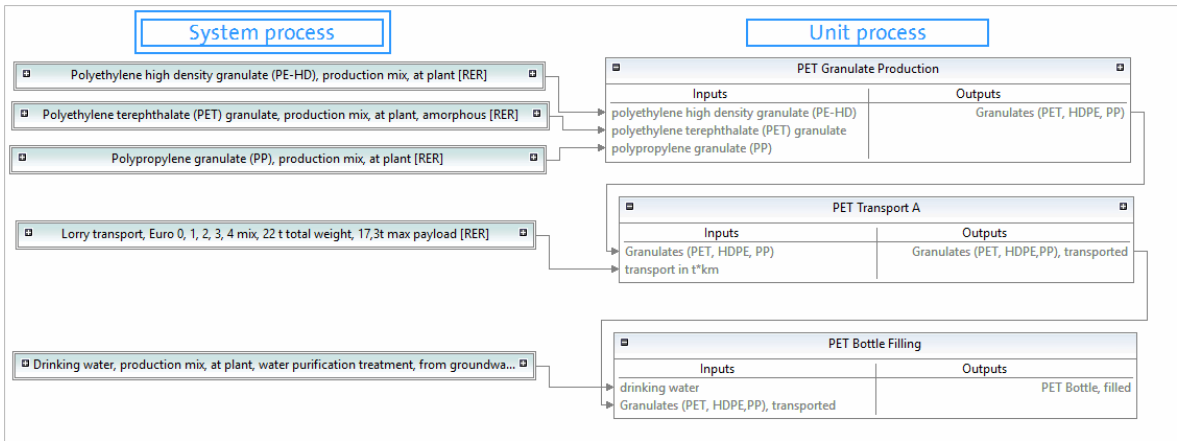


Figure 23: System and unit processes of the product system *PET Bottle Production*

Note! System processes in the model graph are framed with a double line, unit processes are framed with one line. Only product flows are shown as inputs and outputs for each process in the model graph, elementary flows are not shown.

To quantify the environmental impacts of the product system created, see section 7.1.

Create the second product system *PC Bottle Production* with the reference process *PC Bottle Filling*, but do not select *Auto-link processes*. The input flows of the process *PC Bottle Filling* are not connected to their respective providers and thus, the + at the top left of the process in the model graph is missing. To connect the input flows with their respective providers manually, select the process *PC Bottle Filling* by clicking on it, then right-click and select *Search providers for*. Click *Add* and *Connect* in the *Select Provider* window. Search, add and connect the providers for all input flows of each unit process created.

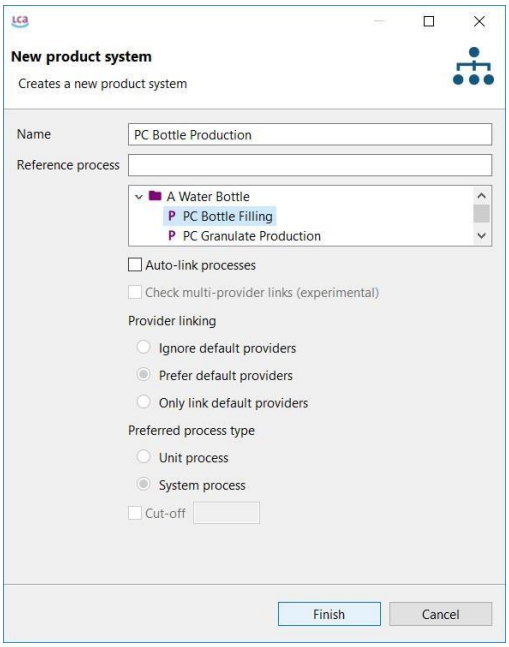


Figure 24: Create the product system *PC Bottle Production*

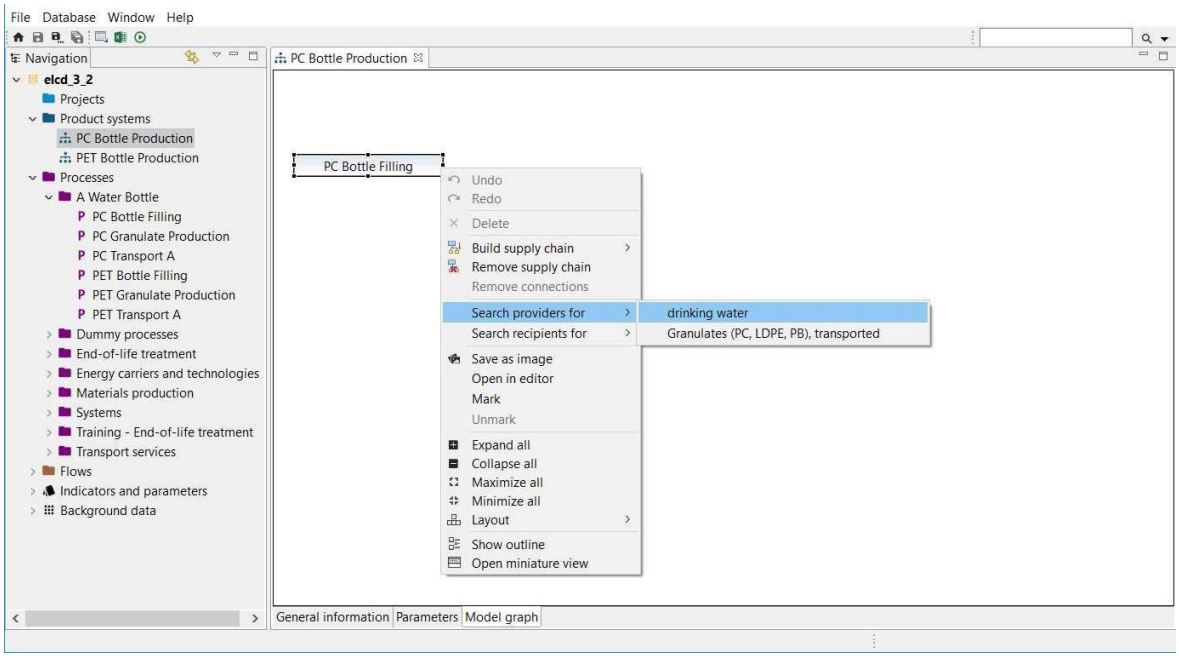


Figure 25: Model graph of the product system *PC Bottle Production*

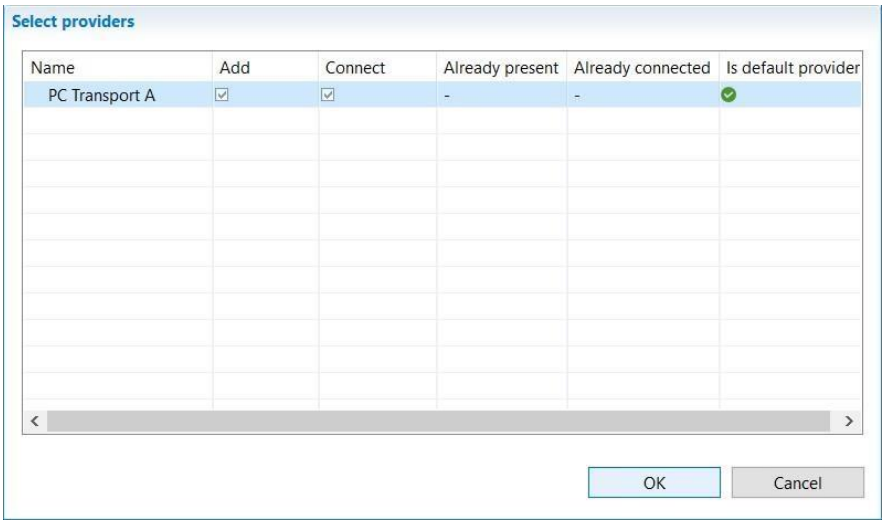


Figure 26: Select providers of the product system *PC Bottle Production*

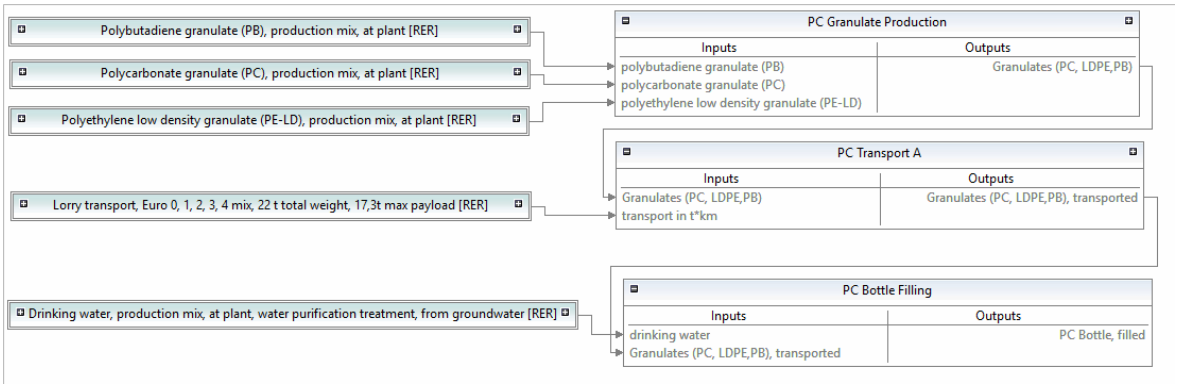


Figure 27: System and unit processes of the product system *PC Bottle Production*

Note! openLCA offers multiple ways to link providers. To find out if and how you should link the providers, click on Check linking properties in the menu item Database and you will see a recommendation for the database you are currently using. In this case, the *ELCD database* is used, which has processes without default providers as well as product flows with multiple providers. In Figure 24, the options *Ignore default providers* and *Prefer default providers* are ambiguous and the option *Only default providers* is incomplete. So, none of the provider linking options is recommended. Therefore, the checkmark *Auto-link processes* should not be activated when creating a product system and all providers should be set manually, as otherwise links that are not intended could also be set.

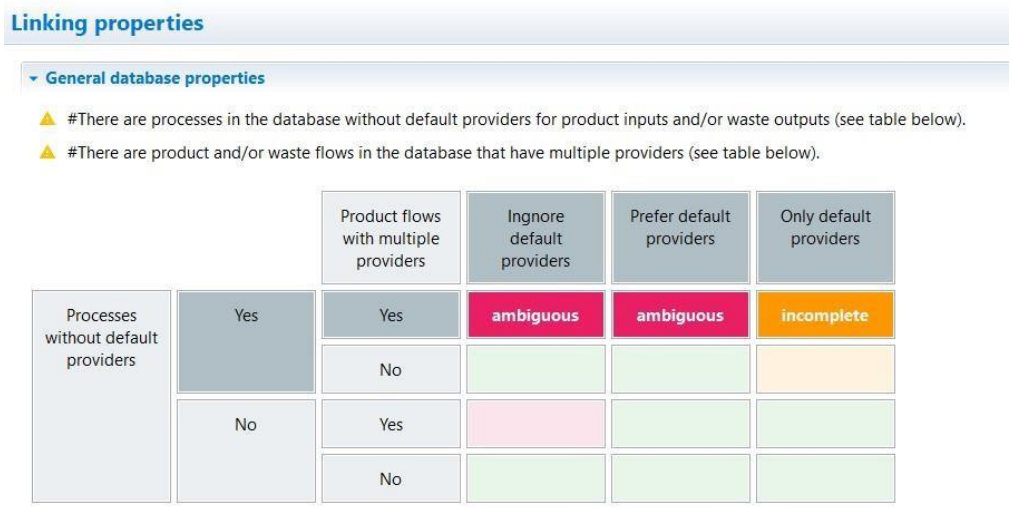


Figure 28: Linking properties

5.2 Cut-off

The use of cut-off reduces the required memory of openLCA and the calculation time. Unfortunately, this goes along with a loss of detail in the results.

- Build the product system *PET Bottle Production (cut-off)* with a cut-off 1E-1

Create a new product system and name it *PET Bottle Production (cut-off)*, select the reference process *PET Bottle Filling* activate *Cut-off* and enter the value 1e-01.

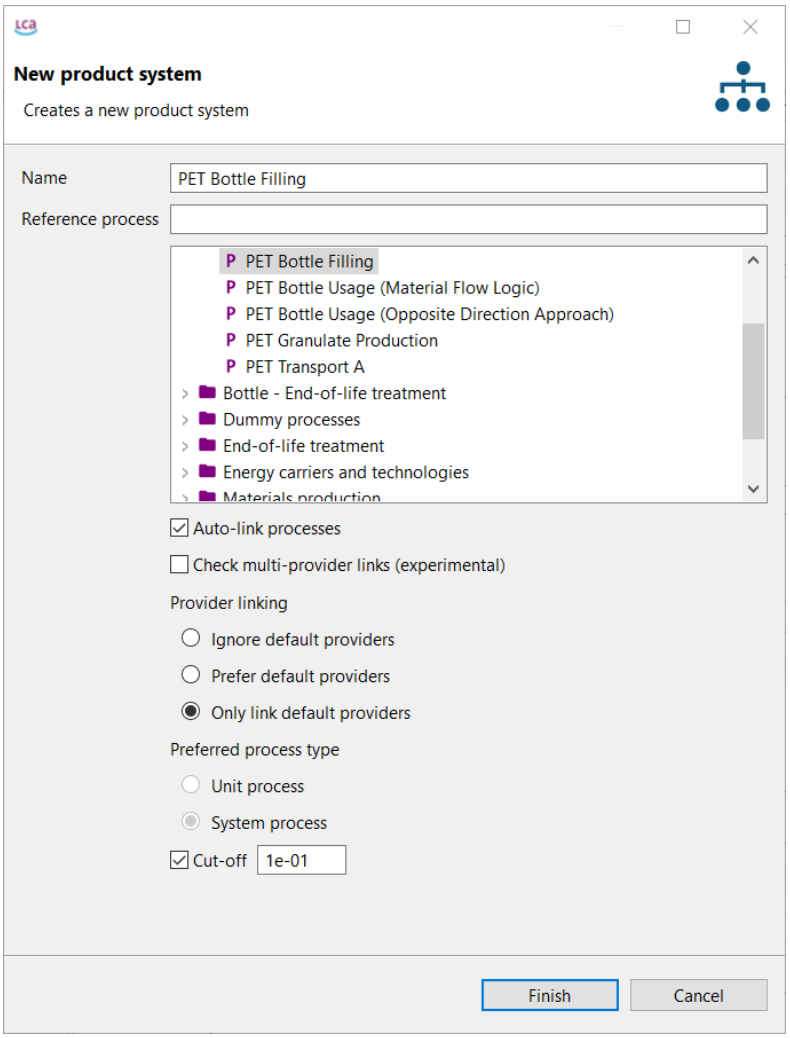


Figure 29: Create the product system PET Bottle Production (cut-off)

Now open the model graph of the resulting product system and compare it with the product system *PET Bottle Production*. The *PET Bottle Production (cut-off)* has fewer upstream chains then *PET Bottle Production*.

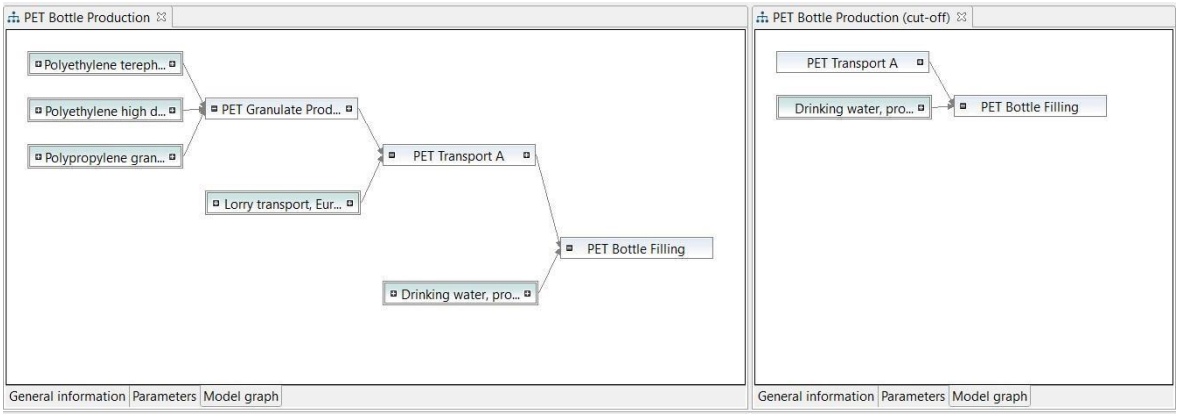


Figure 30: Model graph of the *PET Bottle Production* and the *PET Bottle Production (cut-off)*

6 Projects

In openLCA, projects can be used to compare the impacts of different product systems.

6.1 Create a project

- Create the project *Water Bottle - PET vs PC Production*

To create a new project, right-click the elements folder *Projects* and select *New Project* and name it *A Water Bottle - PET vs PC Production*.

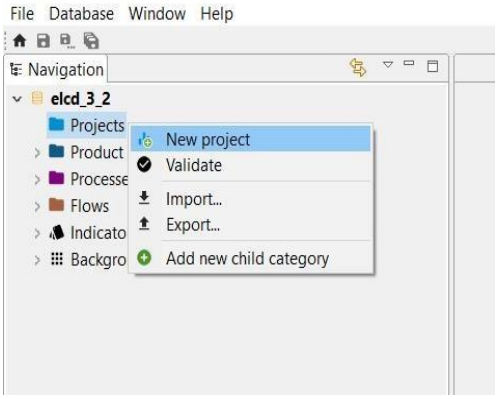


Figure 31: Create a new project

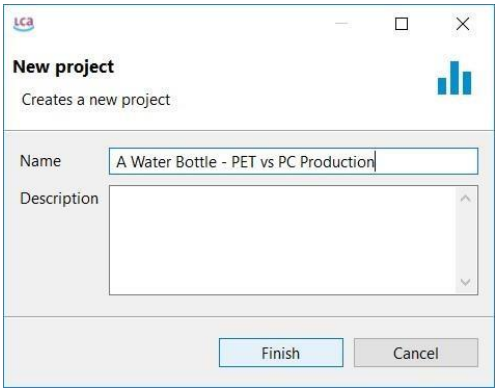


Figure 32: Name of a new project

The Project Editor will open with the Project setup tab. To compare the environmental impacts of the product systems *PET Bottle Production* and *PC Bottle Production*, see section 7.2.

7 Impact assessment

To quantify the environmental impacts of the product system analysed, the Impact Assessment methods must be imported into openLCA. A comprehensive package of environmental impact methods for use with all databases available in the Nexus web repository is provided free of charge by GreenDelta and can be downloaded from the openLCA website.

7.1 Calculate a product system

- Calculate the environmental impacts of the product system *PET Bottle Production* using calculation type *Analysis*

To calculate the environmental impacts of the product system analysed, go to the *General information* tab of the *PET Bottle Production* product system editor and press the button Calculate or use the calculate icon in the main menu. Select the Impact Assessment method *CML-IA baseline* and the calculation type *Analysis*.

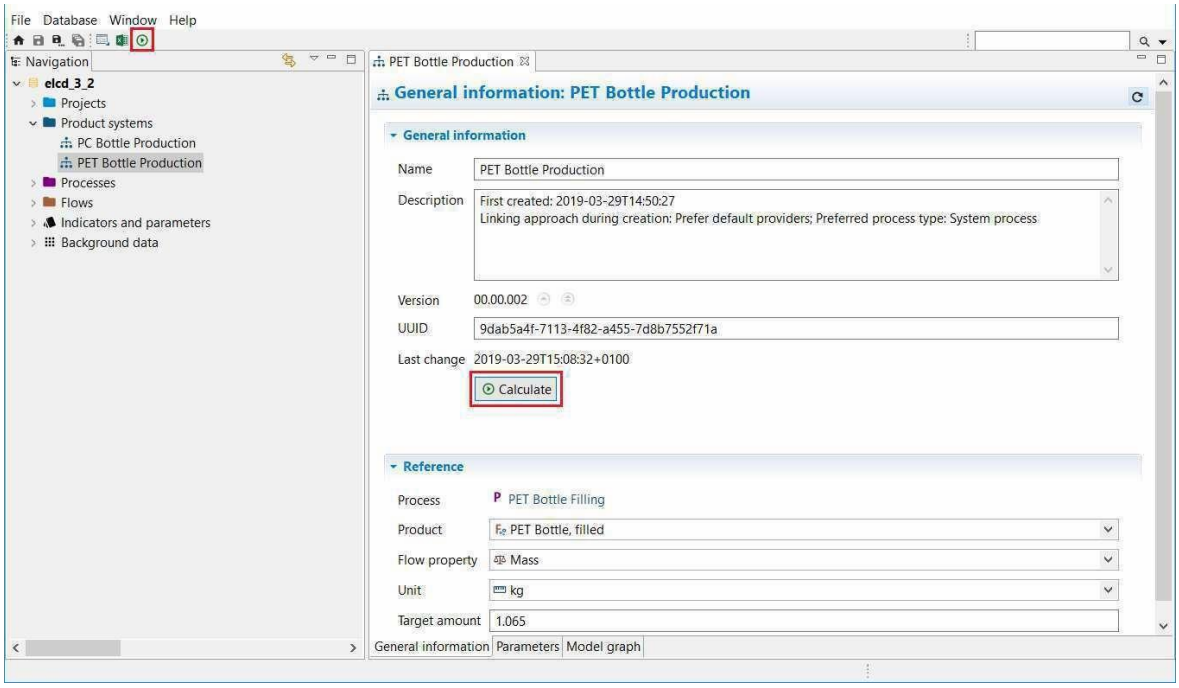


Figure 33: Calculate a product system

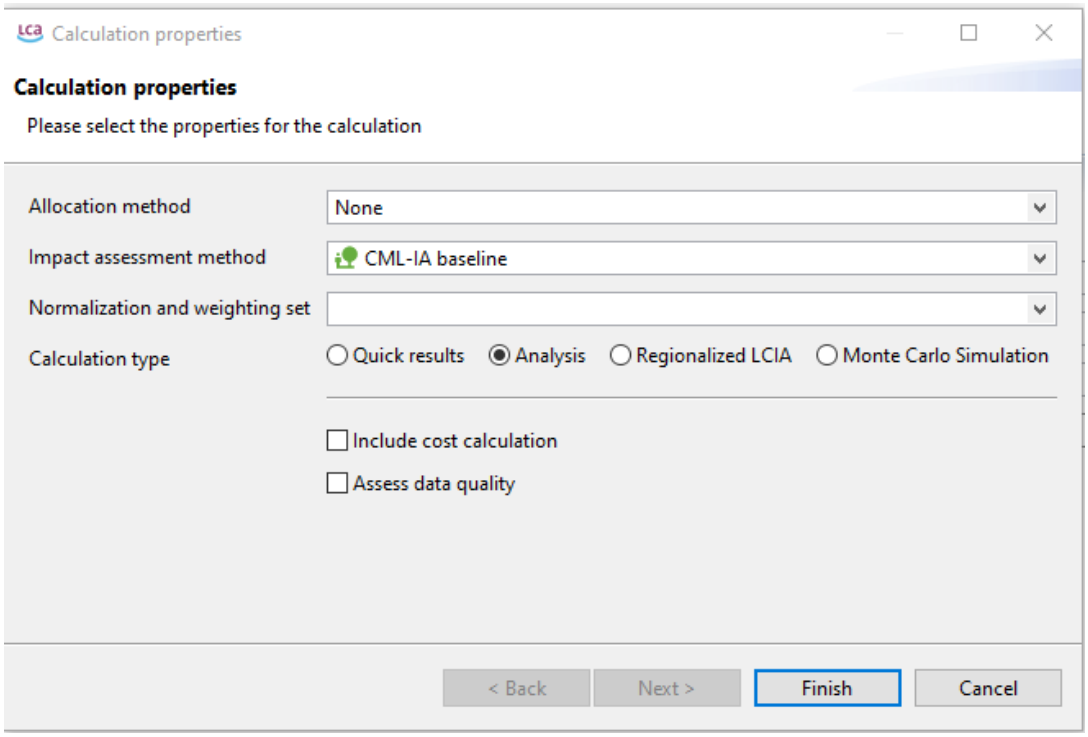


Figure 34: Calculation properties

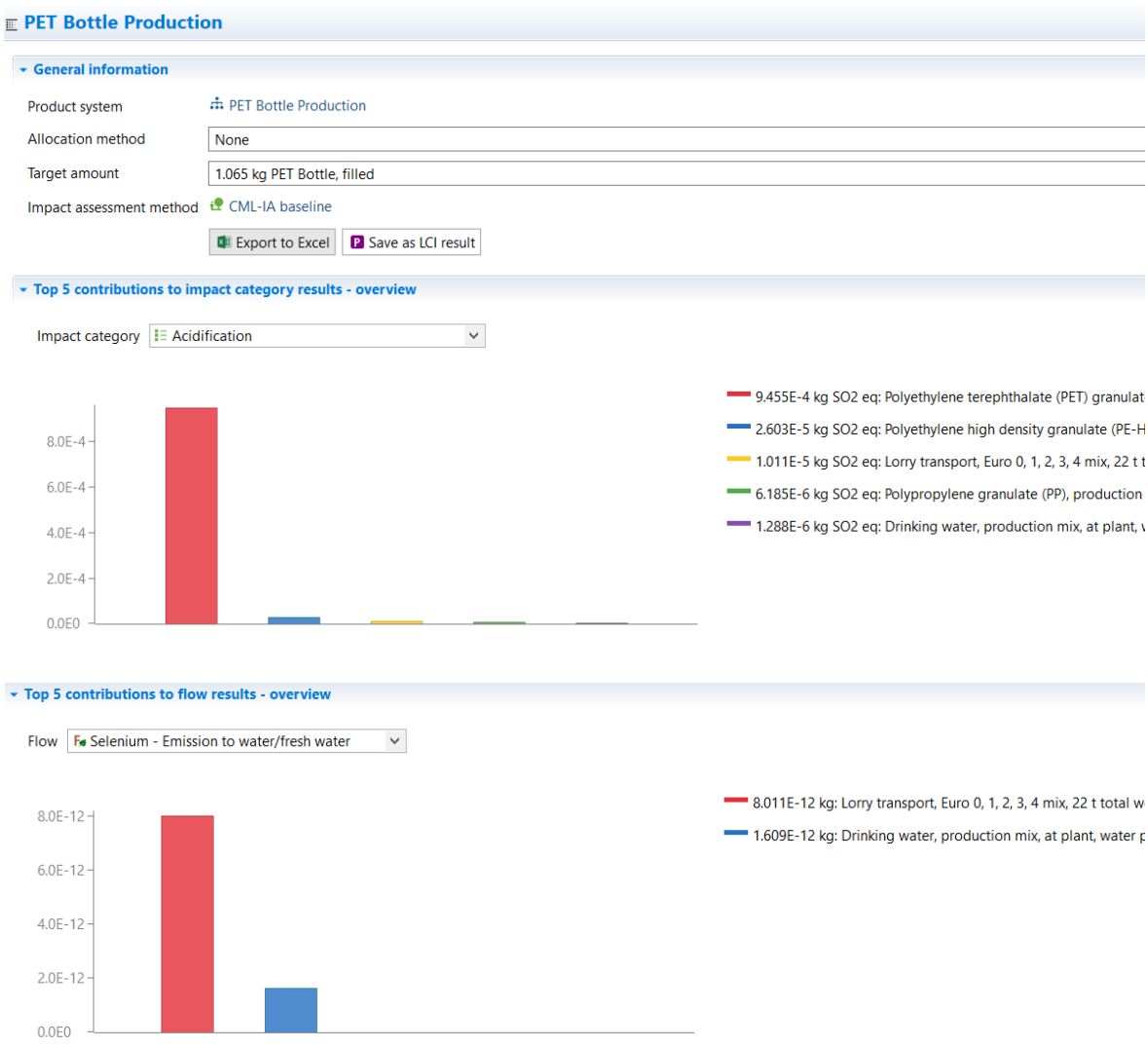
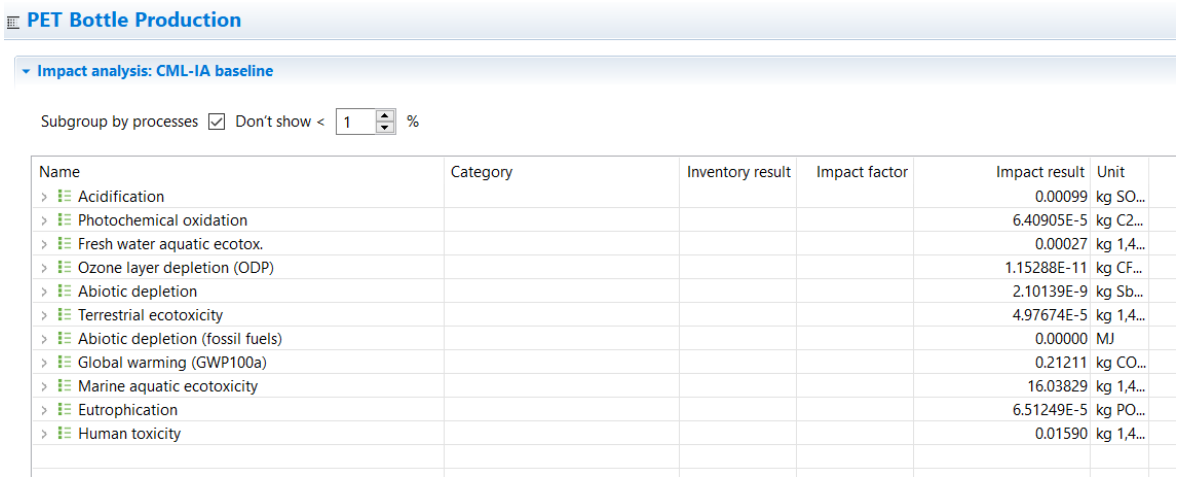


Figure 35: Direct contribution for each flow and each impact category



Name	Category	Inventory result	Impact factor	Impact result	Unit
Acidification				0.00099	kg SO...
Photochemical oxidation				6.40905E-5	kg C2...
Fresh water aquatic ecotox.				0.00027	kg 1,4...
Ozone layer depletion (ODP)				1.15288E-11	kg CF...
Abiotic depletion				2.10139E-9	kg Sb...
Terrestrial ecotoxicity				4.97674E-5	kg 1,4...
Abiotic depletion (fossil fuels)				0.00000	MJ
Global warming (GWP100a)				0.21211	kg CO...
Marine aquatic ecotoxicity				16.03829	kg 1,4...
Eutrophication				6.51249E-5	kg PO...
Human toxicity				0.01590	kg 1,4...

Figure 36: Impact analysis

7.2 Calculate a project

- Compare the environmental impacts of the product systems *PET Bottle Production* and *PC Bottle*

Production

To calculate the environmental impacts of a project, go to the Project setup tab of the *A Water Bottle PET vs PC Production* project editor and enter the information required. Select the LCIA method *CML-IA baseline* and choose the impact categories Impact category *Global warming (GWP100a)* and *Human toxicity* in the LCIA methods section of the *Project setup* tab. Enter the product systems *PC Bottle Production* and *PET Bottle Production* by double-clicking in the product system column of the compared product system section and rename them PC and PET respectively. Once you have finished the project setup, save the changes and press the button Report or use the calculate icon in the main menu.

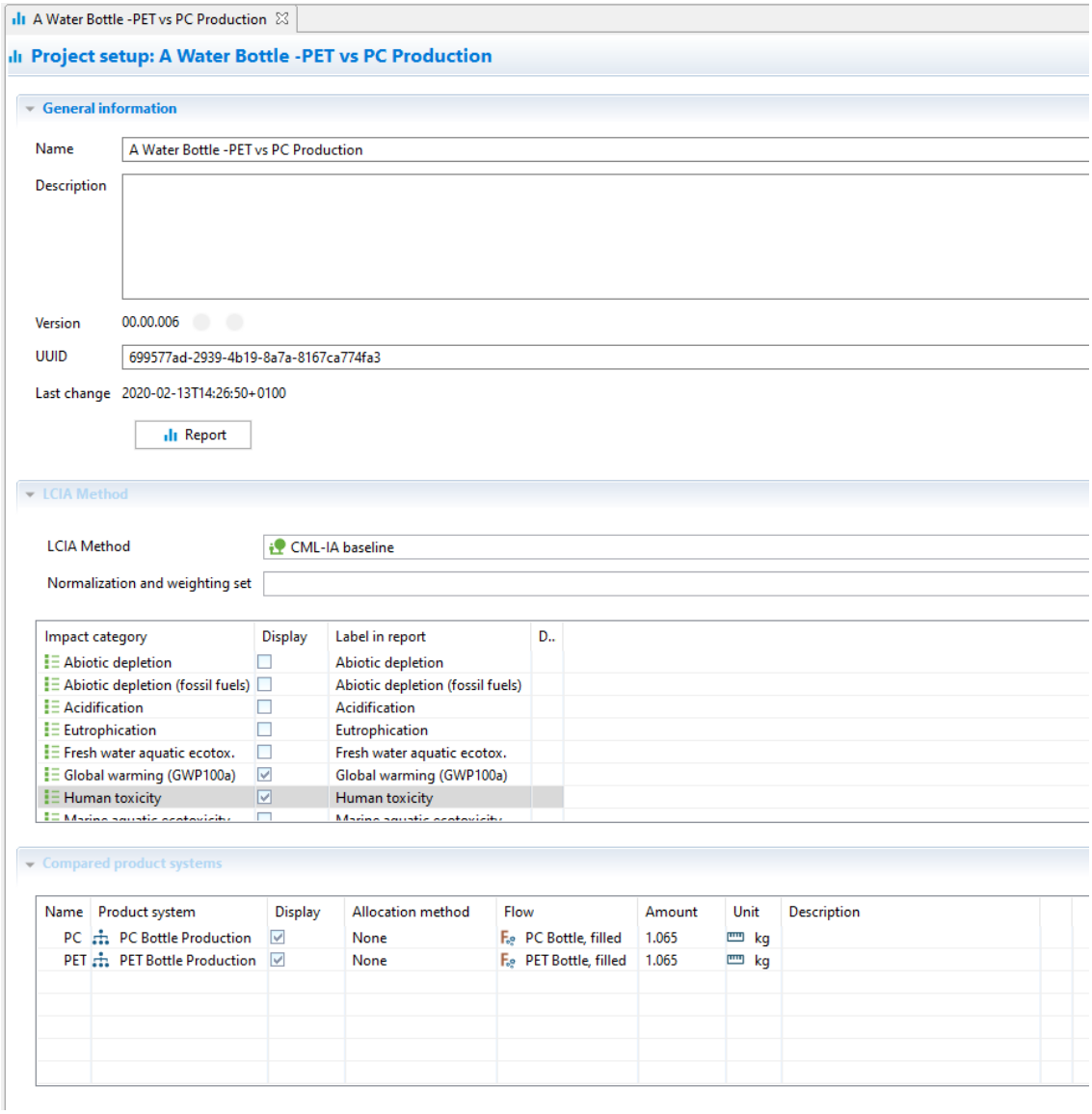


Figure 37: Project setup

Relative Results

The following chart shows the relative indicator results of the respective project variants. For each indicator, the maximum result is set to 100% and the results of the other variants are displayed in relation to this result.

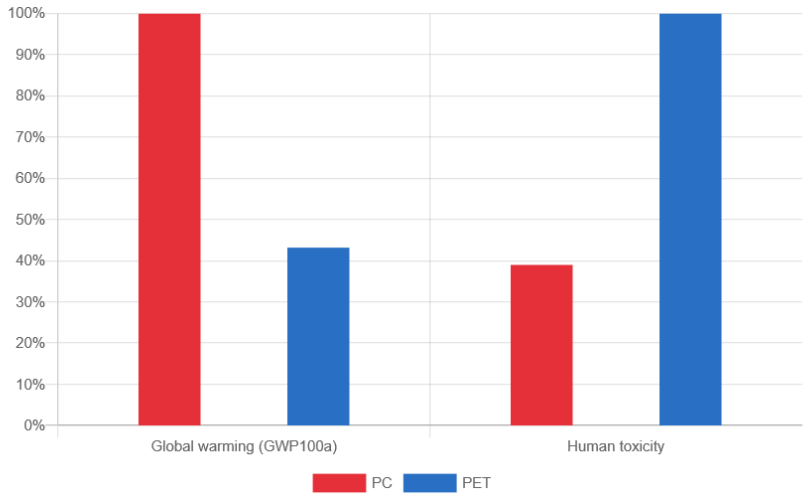


Figure 38: Relative results of the compared product system for the selected impact categories

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