OpenLCA 1.4 case study

of a beer bottle: Aluminium can vs PET bottle

Version: 1.4

Date: October 2014

Content

1 Tutorial Goal

This tutorial aims at explaining a typical Life Cycle Assessment example, while using and discovering openLCA software. Please consider that this is not a real LCA. Through personal research, the figures in this paper are given as example and are not meant to be accurate.

This example is based on the "U.S. Life Cycle Inventory Database". This database is free to use and can be downloaded using this link. It combines the latest ecoinvent assessment; however, there are some data limitations.

Using a step-by-step method, this tutorial gives you an understanding of working with openLCA. If you need more information, see the Learn more section of the openLCA where you can find the latest user manual, links to instructional videos and info pdf files for specific topics. Otherwise, consider using the forum to ask your question.

2 Goal , Scope and limitation of this Assessment

2.1 Goal definition

The goal of this case study is to compare environmental impact between two different materials of a typical 500ml beer bottle packaging in the US. The packaging can be made of aluminum or of PET (Polyethylene Terephthalate).

2.2 Scope definition

When designing a life cycle analysis you always start by defining your functional unit. In this case, both the PET and aluminum packaging options have the same function: contain and protect the valuable beverage. So, the functional unit can be defined as **500ml beer container**. The first option will be called 'PET bottle' and the other one 'ALU can'. To avoid too complicated models in this case study, the sealing and cap options will not be considered, but only the core body of the packaging. **The system boundary of this assessment includes production, consumption and disposal of the bottle within the US.**

2.3 Limitations

In creating a life cycle analysis, one should always be aware of its capabilities. In this case study we do not have exact data from a producer, and we are using a limited database. Therefore, some data cannot be found in the database and a number of approximations and assumptions have to be made. The exact weight of the can and bottle, the origin of aluminum, current recycling rates, transport and energy needed and some other processes can only be guessed or

estimated. Nevertheless we are able to get a good impression about potential environmental impacts. This study does not intend to take part in the debate between two industries. It has a rather exemplary character, showing the functions and capabilities of the software and sharing a typical case of eco-design.

3 Build and compare systems

3.1 Information on the database

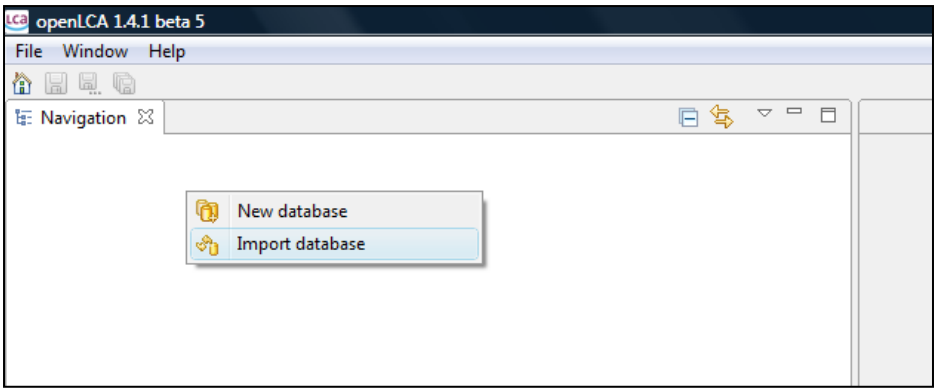
When starting a life cycle assessment, it is necessary to gain access to an inventory database or compile own data. This case study will be based on the database created by the NREL laboratory (www.nrel.gov/lci). As mentioned above, you can download this database using the link provided on the case study page. We have formatted the database to work in openLCA, classified flows and processes, inserted the ecoinvent impact assessment methods and linked the NREL flows to the impact assessment methods and included processes necessary for this case study. All you have to do is download the file and import it to openLCA and you can begin.

Attention: Please consider that the improved database also contains some approximations (NREL and ecoinvent flows may not be always exactly the same) and gaps (some NREL flows cannot be compared and thus have no environmental impacts). This database must be rather used only in this case study or very cautiously for other intended purpose (it is at your own risk and we cannot be held responsible for it).

3.2 Install the database

To install the database, follow these steps:

- Download the database CaseStudy_PETvsALU_empty.zolca from the openLCA-website.
- To add it to your openLCA 1.4 database, right click in the window of “Navigation” and select ‘Import database’.
- Select the downloaded zolca-database, rename and import it.



- You can start with the case study now.

3.3 Build the 'PET bottle' model

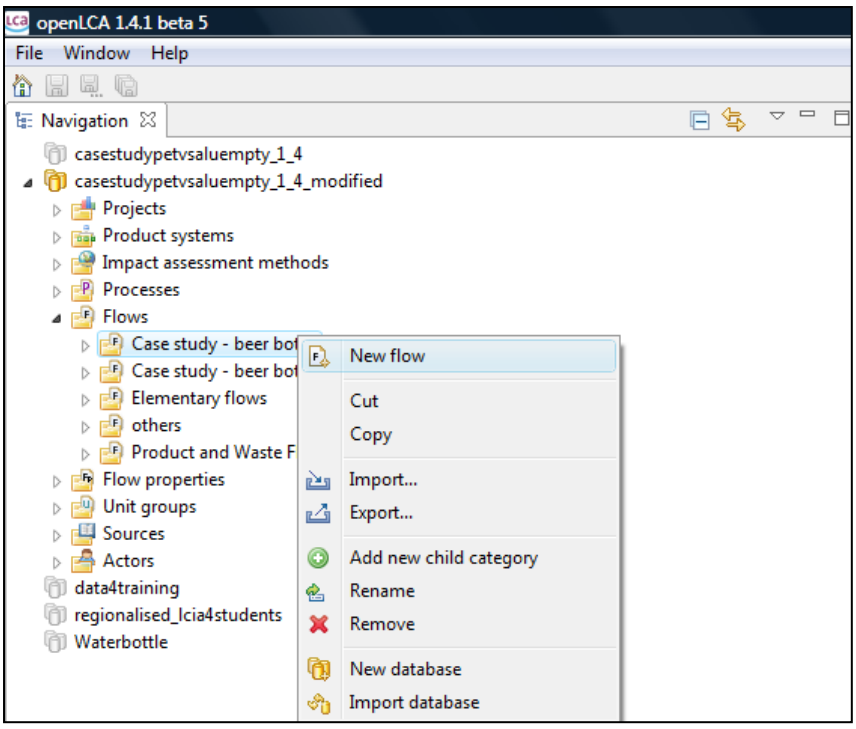
First , we will create the whole life cycle of the PET bottle. In order to ease your first experience with openLCA, some flows and processes have already been createdo.5.

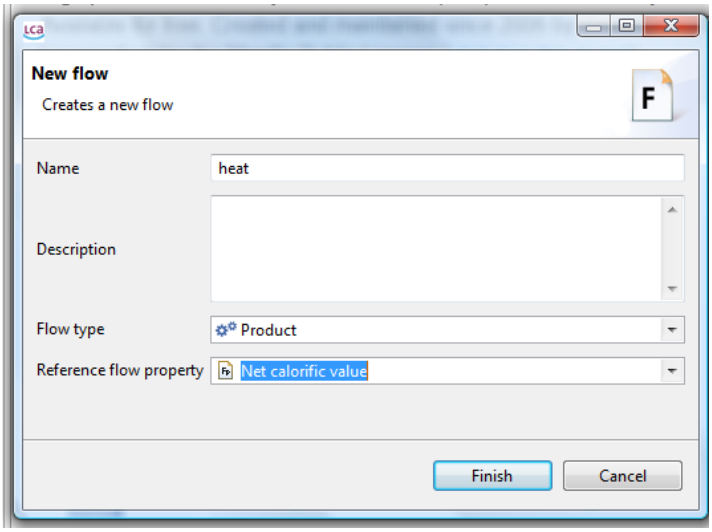
We assumed the PET bottle is composed of Polyethylene Terephthalate, and method of disposal is recycling by burning natural gas to melt the PET, but we do not reuse the melted PET in this production system.

In order to practice and improve your understanding, there are a few things you need to do. You will create the disposal phase of the PET. First, transport the empty bottles to the recycle site and use the natural gas to melt the bottle, so the only output flow will interact with the environment will be the heat,

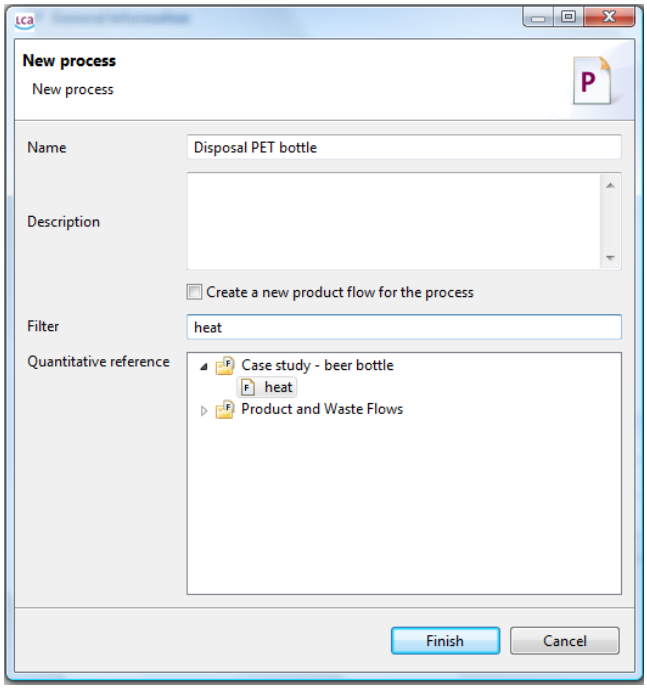
- First, Go to **Flows** and right click on "Case study – beer bottle" to create a new flow:
  - Name: Heat
  - Description: Case study - beer bottle
  - Flow type: Product
  - Reference flow property : Net calorific value

Tip 1:
Use point (.) instead of comma (,) for the decimal numbers. Otherwise OpenLCA will not accept it



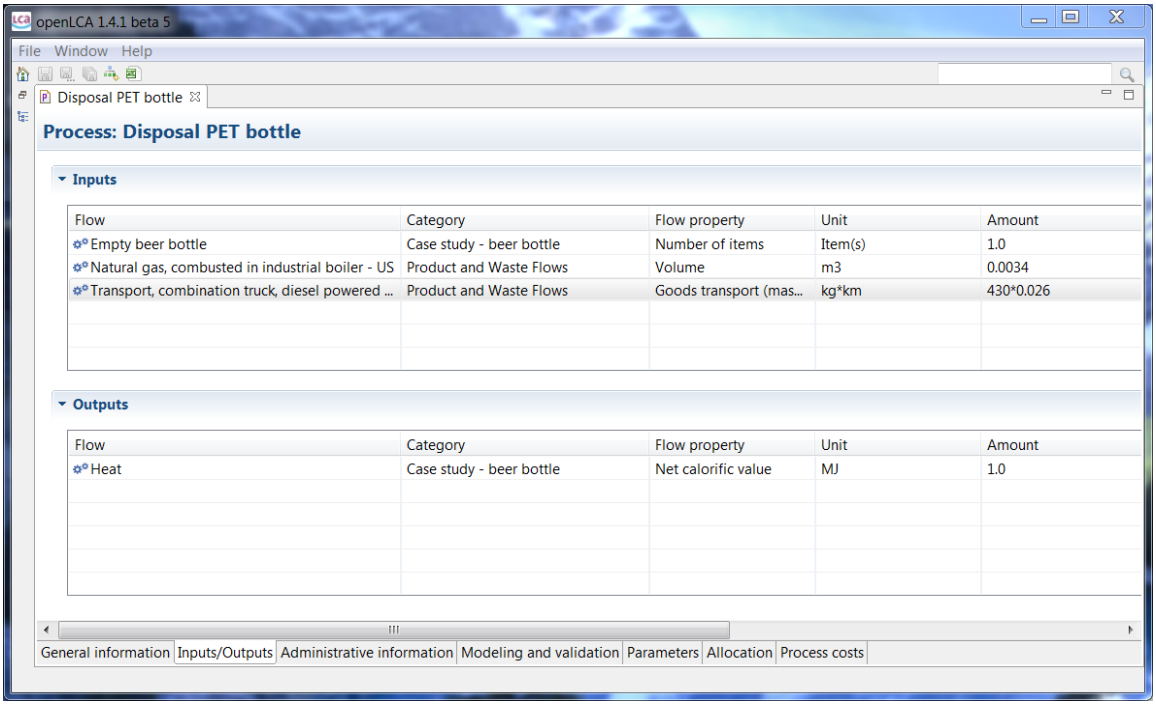


- Go to **Processes** and right click on 'Case study – beer bottle' to create a new process:
  - Name: Disposal PET bottle
  - Description: Case study – beer bottle
  - Quantitative reference: Heat
  - Click Finish.



  - Add inputs in the inputs tab of the process editor as described below in the table 1; press the green "+" button on the upper right side, and use the filter to find these flows. We assumed the distance of transporting the empty bottles from the gathering site to the disposal site is 430km, and one empty bottle weighted 0.026kg. Melting one bottle requires 0.0034 m^3 natural gas and output as 1MJ of heat (see Tip 1).

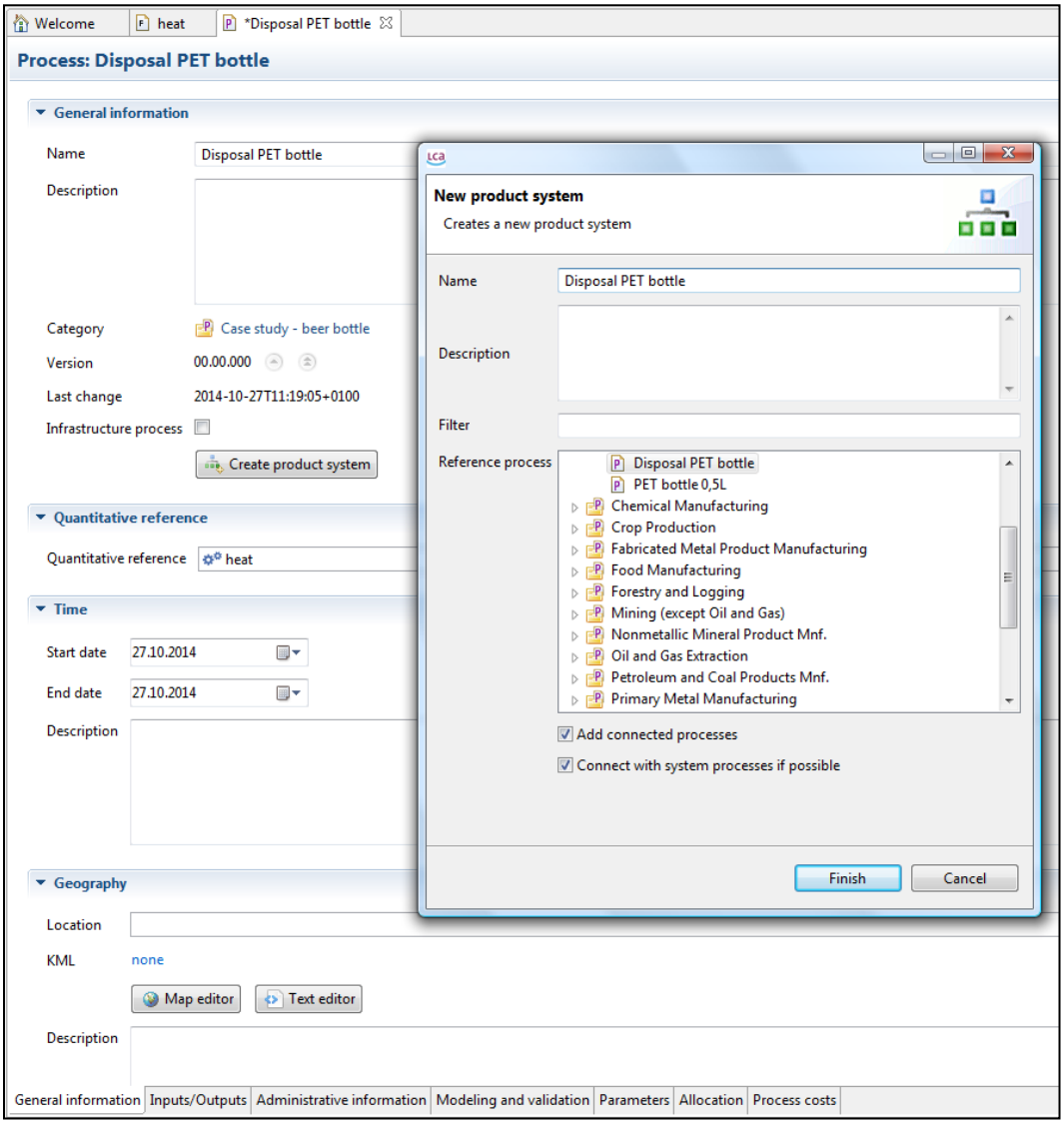
Table 1.				
Input Flow	**Category**	**Flow type**	**Amount**	**Unit**
Empty beer bottle	Case study – beer bottle	Product	1	Item
Natural gas, combusted in industrial boiler - US	Product and waste flows	Product	m^3	0.0034
Transport, combination truck, diesel powered - US	Product and waste flows	Product	kg*km	430*0.026
Output Flow	**Category**	**Flow type**	**Amount**	**Unit**
Heat (the one you just created.)	Case study – beer bottle	Product	1	MJ



- Save and close.

- Before adding a new Product system, right click on **Product systems** and create a new child category called 'Case study – beer bottle'. Open the process "Disposal PET bottle" and click on "Create Product System " it to create a new product system:
  - Name: PET bottle
  - Description: Case study – beer bottle
  - Reference process: Disposal PET bottle

- To connect the upstream chain, ensure ‘Add connected processes’ and ‘Connect with system processes if possible’ are checked
- Click the 'Finish' button



- You will get the similar graph like Figure 1: (see Tip2)

Tip2: How to open the whole Model Graph?
In each product system, there is a “Model graph” tab, you can open all the chain by right click on the boxes and “build supply chain” to see the whole processes.

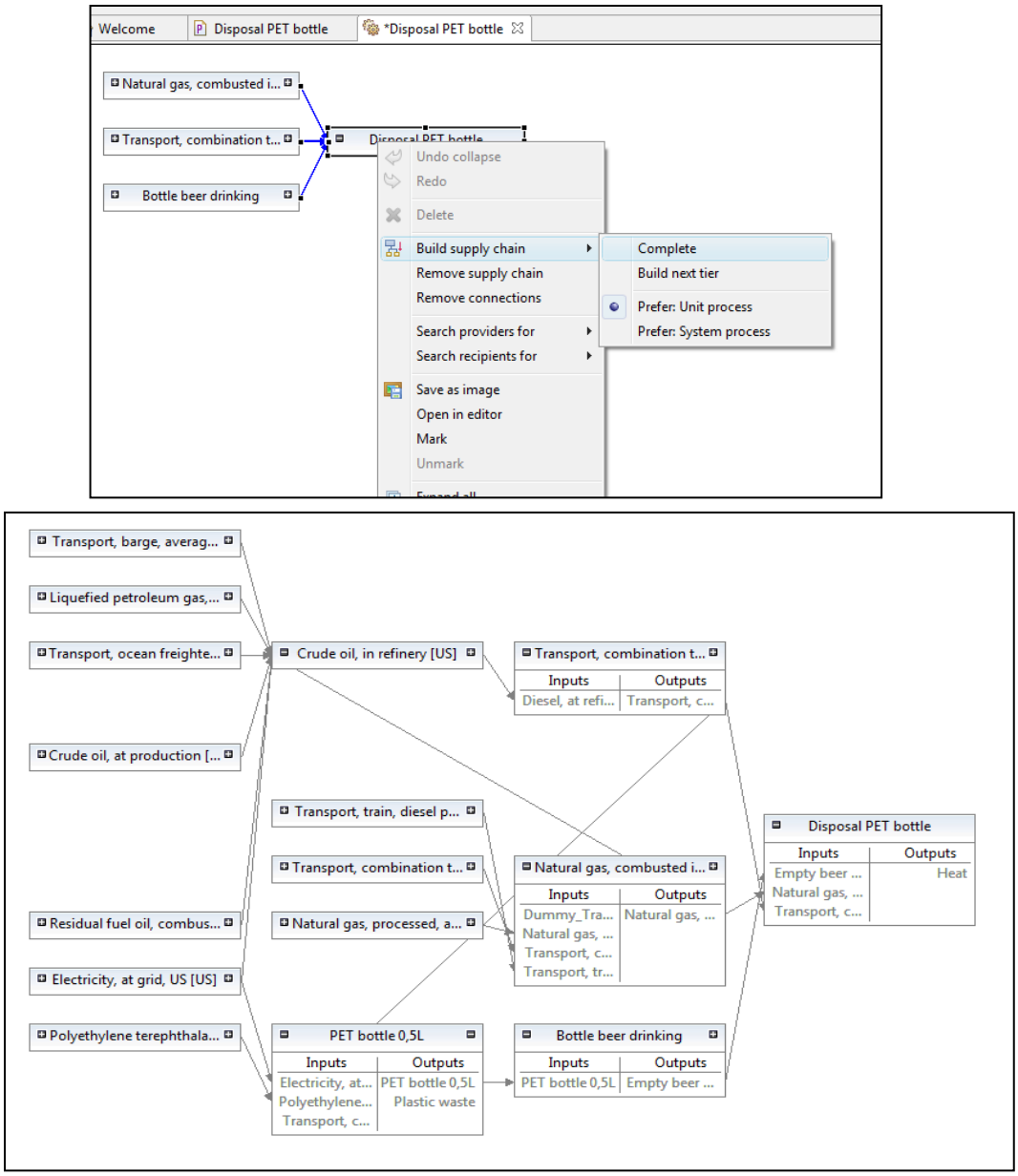
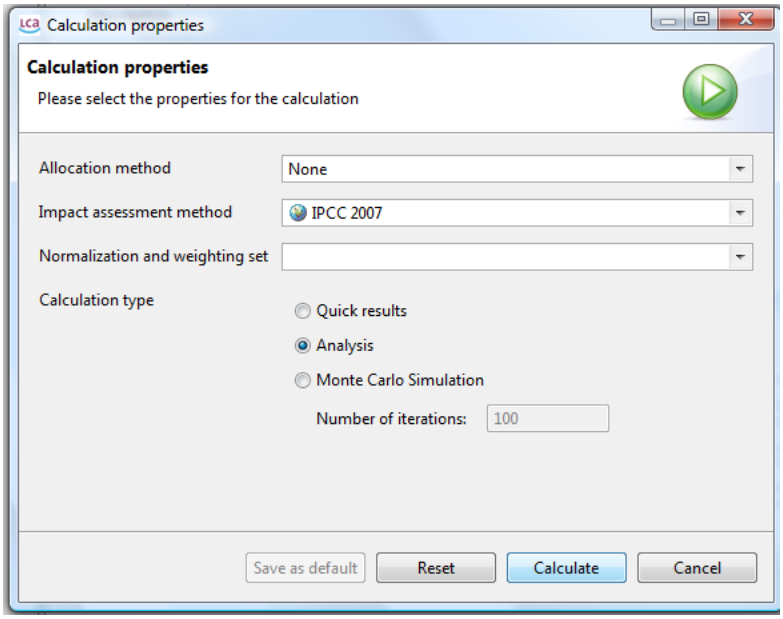


Figure 1, Product System "PET bottle" model graph

To assess the impact of this system:

- Click on the " Calculate" button (in the "General Information" of the product system tab),
- select the LCIA-method 'IPCC2007', you can choose "Quick result", or "Analysis" if you want to see Sankey diagram.



- and click calculate.
- Now, you can have a look at the full impact assessment data of this model.

3.4 Build the 'ALU can' model

This time, you do not need to create processes or flows because this has already been done. Anyway, you should first have a look at the processes included in "Case study – beer bottle". Find out the quantities and how they are supposed to be connected by right clicking on the boxes to build the whole chain. Figure 2 show the logic of building this model. As for the aluminum can, it is composed of primary and secondary aluminum. The disposal methods are part recycle and part waste, and we reuse the aluminum we have recycled into this production system

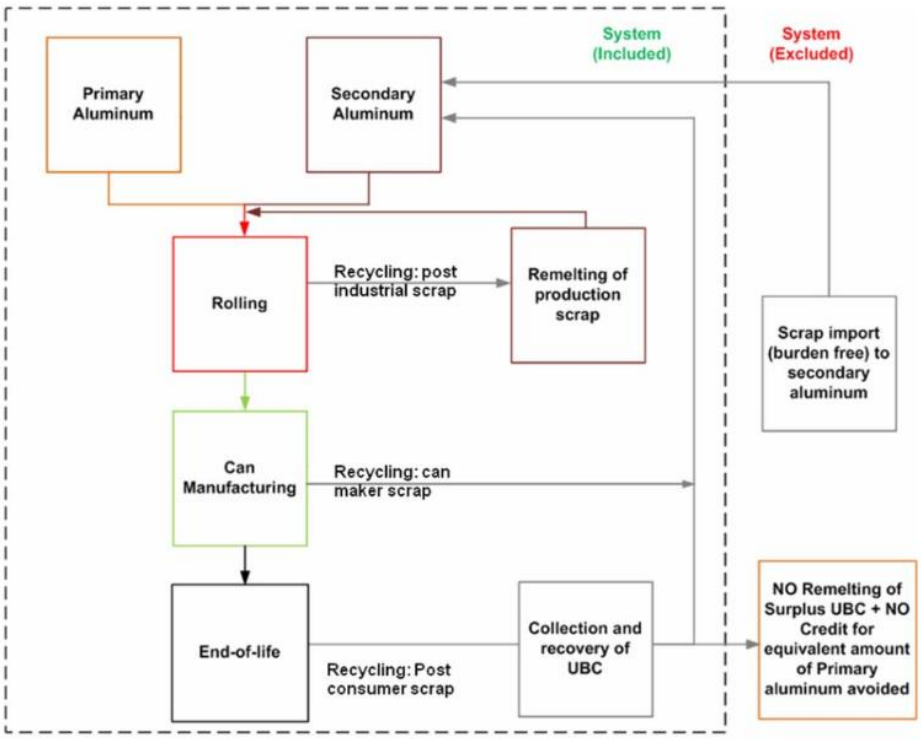
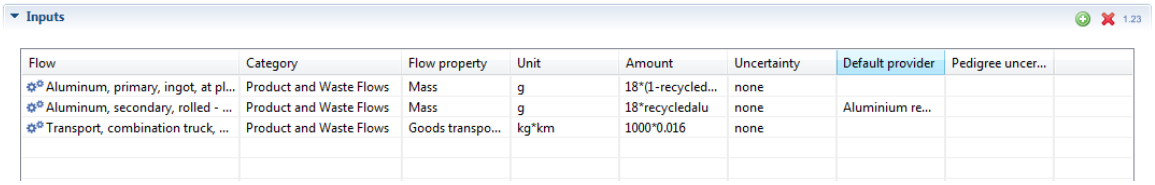


Figure 2, Processes in the life-cycle of Aluminum cans (Recycled content perspective)
Sources: Aluminum Association (2010)

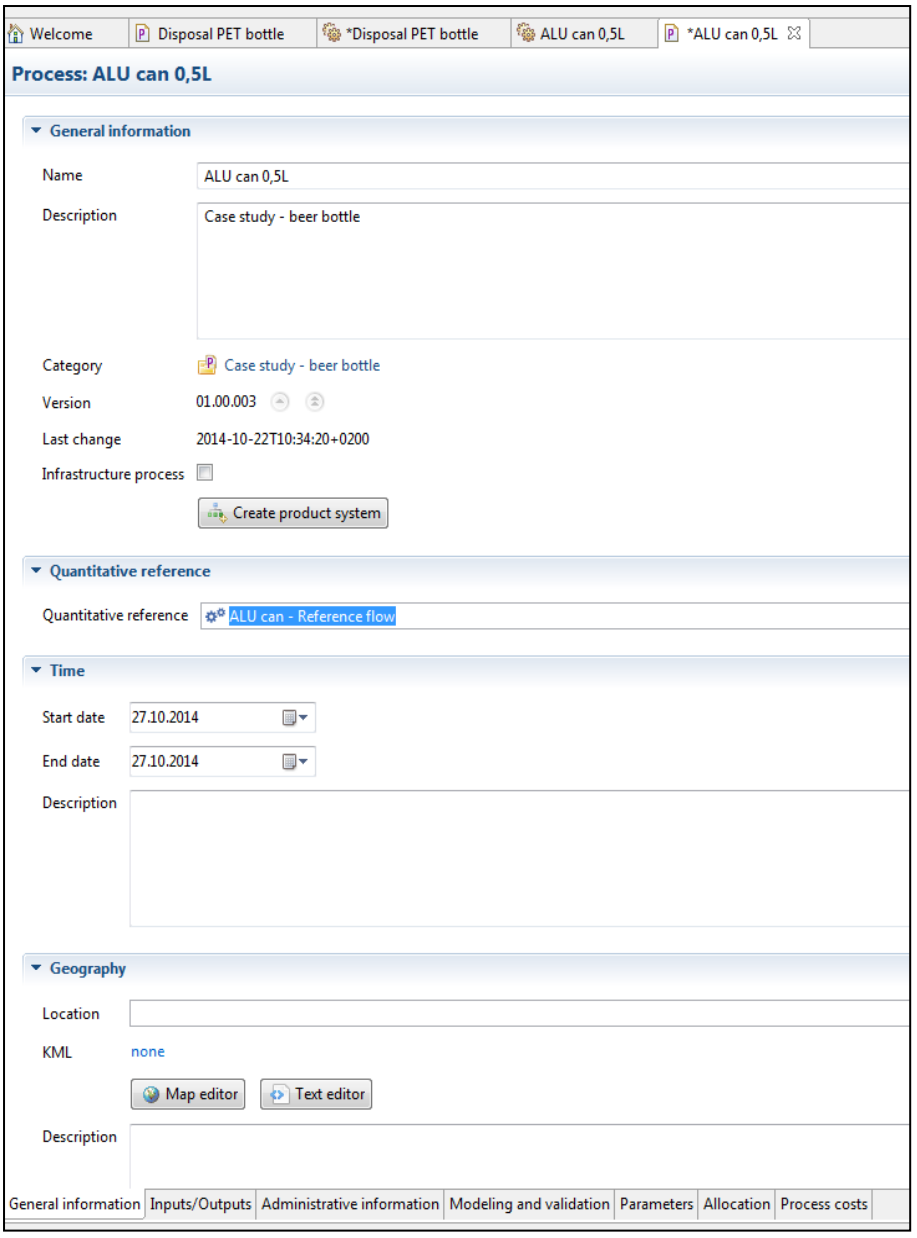
- Go to **Processes**, click on "ALU can 0.5L":
  - Attention: Check the input “Aluminum, secondary, rolled”, you need to choose the “default provider” as the process “Aluminum recycling”, and then they will automatically connect. (See Tip 3)



Flow	Category	Flow property	Unit	Amount	Uncertainty	Default provider	Pedigree uncer...
Aluminum, primary, ingot, at pl...	Product and Waste Flows	Mass	g	18*(1-recycled...	none		
Aluminum, secondary, rolled - ...	Product and Waste Flows	Mass	g	18*recycledalu	none	Aluminium re...	
Transport, combination truck, ...	Product and Waste Flows	Goods transpo...	kg*km	1000*0.016	none		

Tip 3:
Sometimes there are identical flows from different process, in order to choose the correct flow you want, use the “default provider” option to select the correct provider.

  - Go to the "General information" tab and to create a product system, but before you create the product system make sure to set the Quantitative reference to "ALU can - Reference flow" (Why? See Section 3.5)
  - Click on “Create product system”
  - Name: ALU can
  - Description: Case study – beer bottle
  - Reference process : ALU 0.5L



- Ensure “Add connected processes” and “Connect with system processes if possible” are checked
- Click the "Finish" button

- Go to the product system , open the “ALU can” and in the “Model graph”, you can see the similar model to Figure 3.

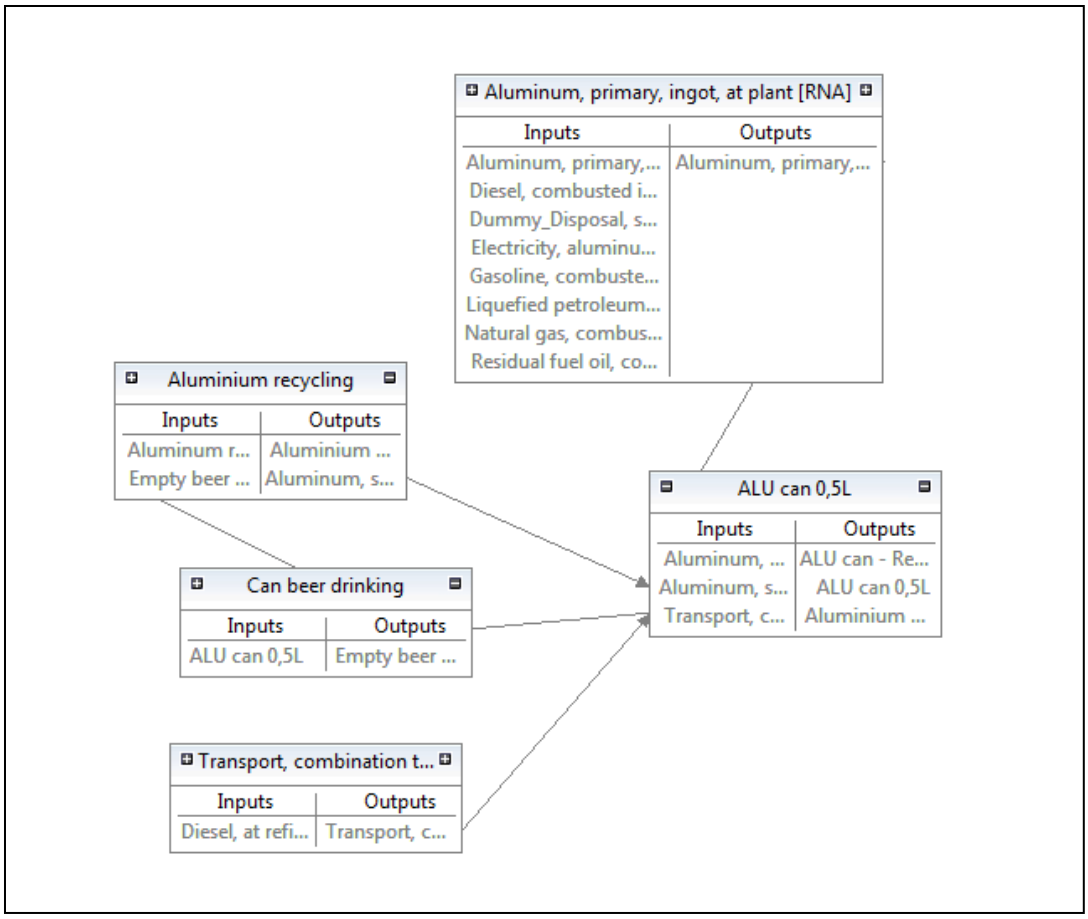


Figure 3, Product System "ALU can" model graph

- To assess the impact of this system:
  - Click on the " Calculate" button in the "General Information" in the "ALU can" product system,
  - select the LCIA-method 'IPCC 2007', you can choose "Quick result", or "Analysis" if you want to see Sankey diagram.
  - and click calculate.
  - Now, you can have a look at the full impact assessment data of this model.

3.5 Important explanations on flow management

A product system must be considered within its boundaries. Inside these, any process and connection can exist. The only interactions with the environment are the elementary flows and the functional unit (also called here the reference exchange). In the aluminum can model, they reuse the aluminum material from the recycled can, therefore there is an internal loop in this system. This product flow leaves the system and all calculations (leading to the life cycle inventory) are based on this flow. This means, it cannot be at the same time linked to other processes and/or used in internal loops. This would lead to false results. The trick is thus to have one flow as reference (here: 'ALU can - Reference flow'), and one used for internal

connections (here: 'ALU can 0.5L'). **Moreover, both flows must be allocated with the same factor (here: 0.5 and 0.5).**

Aluminum waste flow here is not considered in this multi-output process, so it is not necessary to set allocation factors for it.

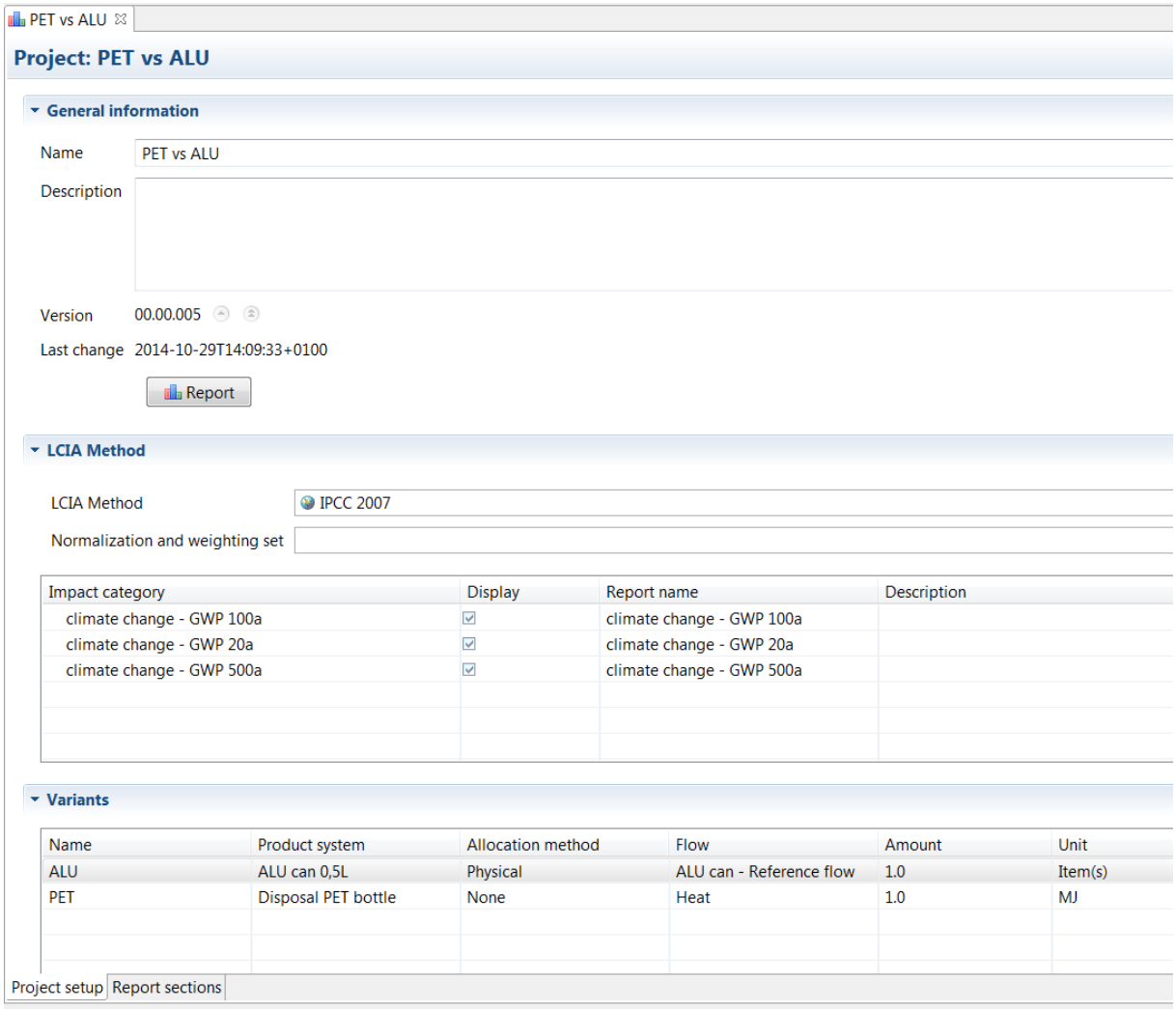
- Go to the process "ALU can 0.5L", and find the "Allocation" tab, set the "Physical factors" as below
    - ALU can – reference flow : 0.5
    - ALU can 500ml : 0.5

In any case, when a process has a multiple outputs, allocation factors must be set up so it knows how to deal with the calculation. Otherwise, openLCA will compute the model with wrong settings.

3.6 Compare results

To compare the results of the two product systems, PET bottle and ALU can, you need to create a new Project in openLCA:

- Right click on **Projects** and create a new child category called 'Case study – beer bottle'. Right click on it to create a new project:
    - Name: Beer bottle: PET vs. ALU
- select the "IPCC 2007" as LCIA method, and choose all the impact category to display.
- Add the 2 product systems "PET bottle" and "ALU can" into the "Variants", Change the name according to the product system, and choose the "Allocation method " of the "ALU can" as Physical.
- **Save it first** and click the "Report" button.



Tip 4:

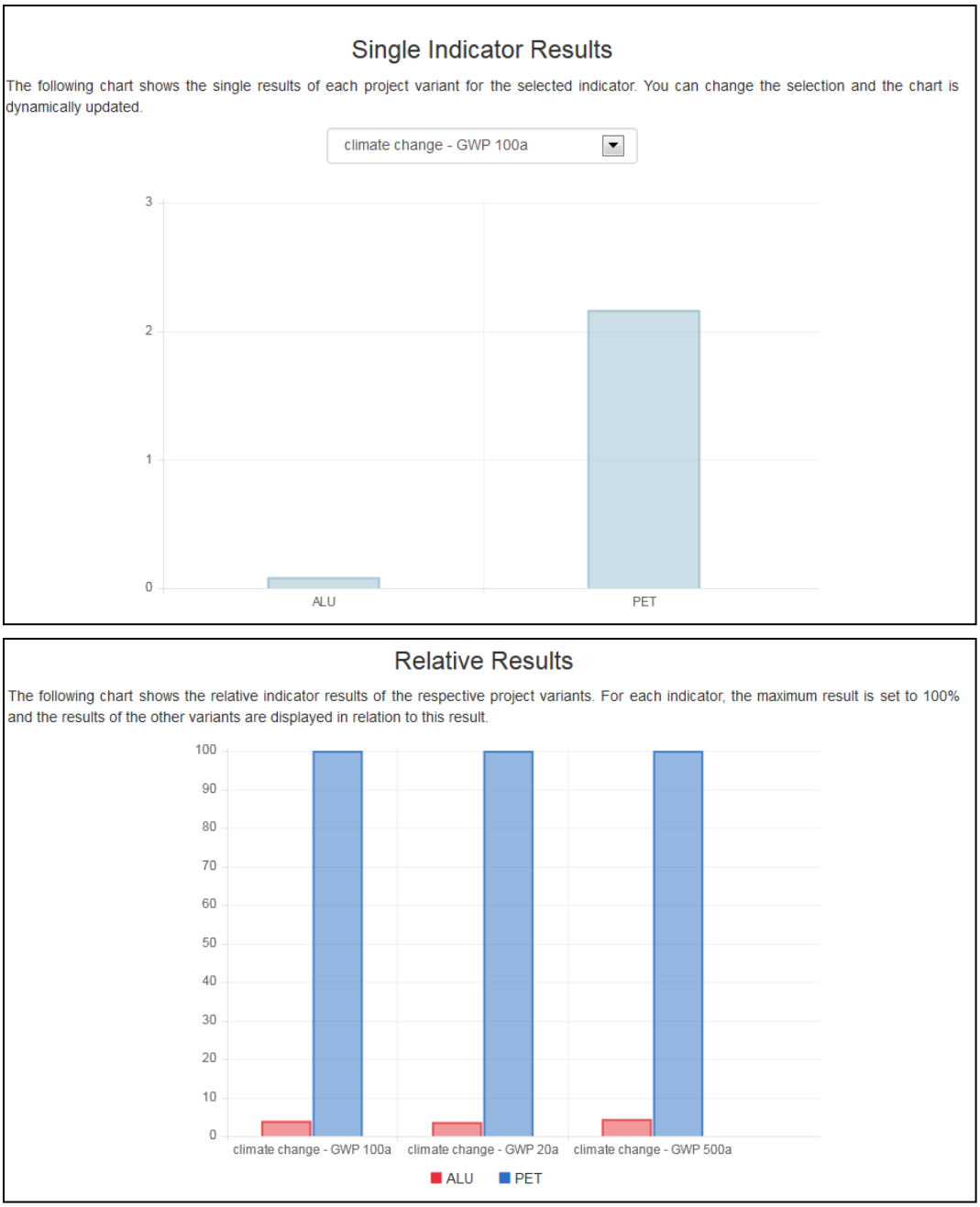
Always save first, before producing a new report or a new product system.

Parts of the report should be like this:

LCIA Results

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

LCIA category	ALU	PET	Unit
climate change - GWP 100a	8.59700e-2	2.16651e+0	kg CO2-Eq
climate change - GWP 20a	8.06481e-2	2.20637e+0	kg CO2-Eq
climate change - GWP 500a	9.56253e-2	2.14972e+0	kg CO2-Eq



In three categories, the PET bottle has higher impacts, try other LCIA methods to see if this is the case with other impact assessment categories.

4 Analysis of the models

4.1 Sankey diagram

A Sankey diagram can help to find the source of an impact. Regarding the previous comparison, it is interesting to analyse the PET model to find out why the impacts are so high.

- Go to the Product System “Disposal PET Bottle”, and calculate again, but choose the “Calculation Type” “Analysis”.
- Find the “Sankey diagram” tab. It shows that the high impact ‘climate change-GWP 20a’ comes mostly from the ‘Crude oil, in refinery’. (Figure 4,)
- To create the same diagram with a different impact category, click on the title on the upper left-hand side of the diagram or right click anywhere on the diagram and select "set Sankey diagram options". You can then select the flow or impact category as well as the cut off level.

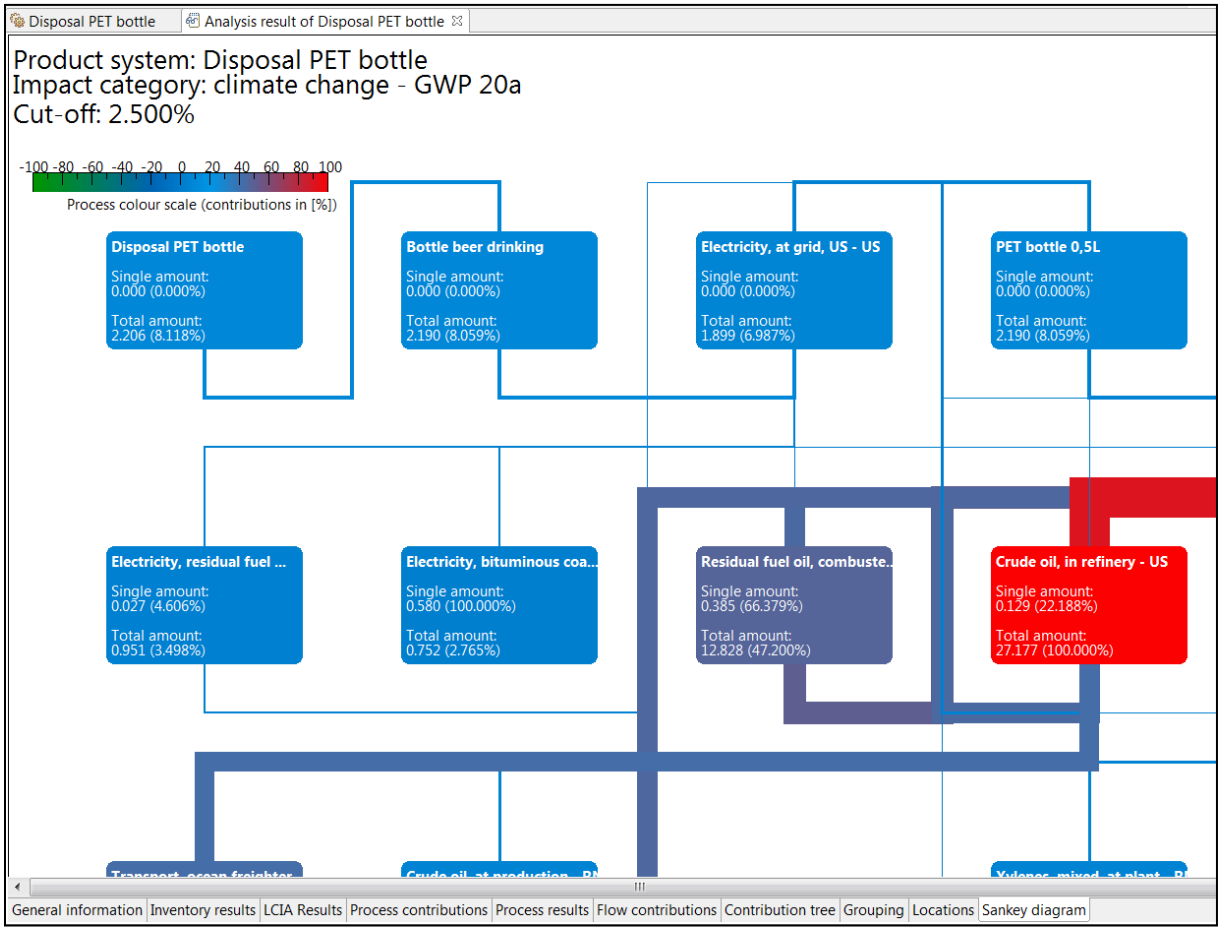


Figure 4, Sankey Diagram of “PET bottle” analysis

4.2 Recycling scenarios

Creating different scenarios is a helpful way to analyse the influence of parameters and their impact on the final result. In our study, we can point out two hot spots:

- Part of aluminum needed for a can that comes from recycled aluminum (Parameter: recycledalu in the ‘ALU can 0.5L’ process)

- Recycling rate of an aluminum can (Parameter: alurecyrate in the ‘Aluminum recycling’ process)

These two processes have been built with the two mentioned parameters inside. You can find them under "Processes" in the "Case study - beer bottle" folder. Try to imagine what these parameters are useful for.

Parameters set at the process level can be overwritten at the Product System and Project levels. Without changing any data in processes, they simply overwrite process’ parameters and allow for new values for calculations.

Now we want to compare different recycling rates for aluminum.

Table 2: Scenario names and Parameter values for the project 'Recycling options for an aluminum can"

		Variant 1	Variant 2	Variant 3	Variant 4
	Parameter	**Basic**	**Plus**	**Can 95%**	**ALU 60%**
Recycling rate of aluminum	recycledalu	0.5	0.6	0.5	0.6
Recycling rate of cans	alurecyrate	0.9	0.95	0.95	0.9

- First, create a new project ‘Recycling options for an aluminum can’
- In the Project, choose the LCIA Method “IPCC 2007” and select all of the impact categories you would like to display.
- In the “Variants” section add the product system “ALU can 0.5L” four times by clicking on the green "+" button and selecting the product system. Change the name of each scenario according to Table 2, and select the allocation “Physical” for each.
- Then, add the Parameters “recycledalu” and “alurecyrate” into the project, and change the values according to Table 2. Your project settings should look as shown in Figure 5.
- Save the project, then click the “Report” button. Some parts of the analysis report will look as shown in Figure 6.

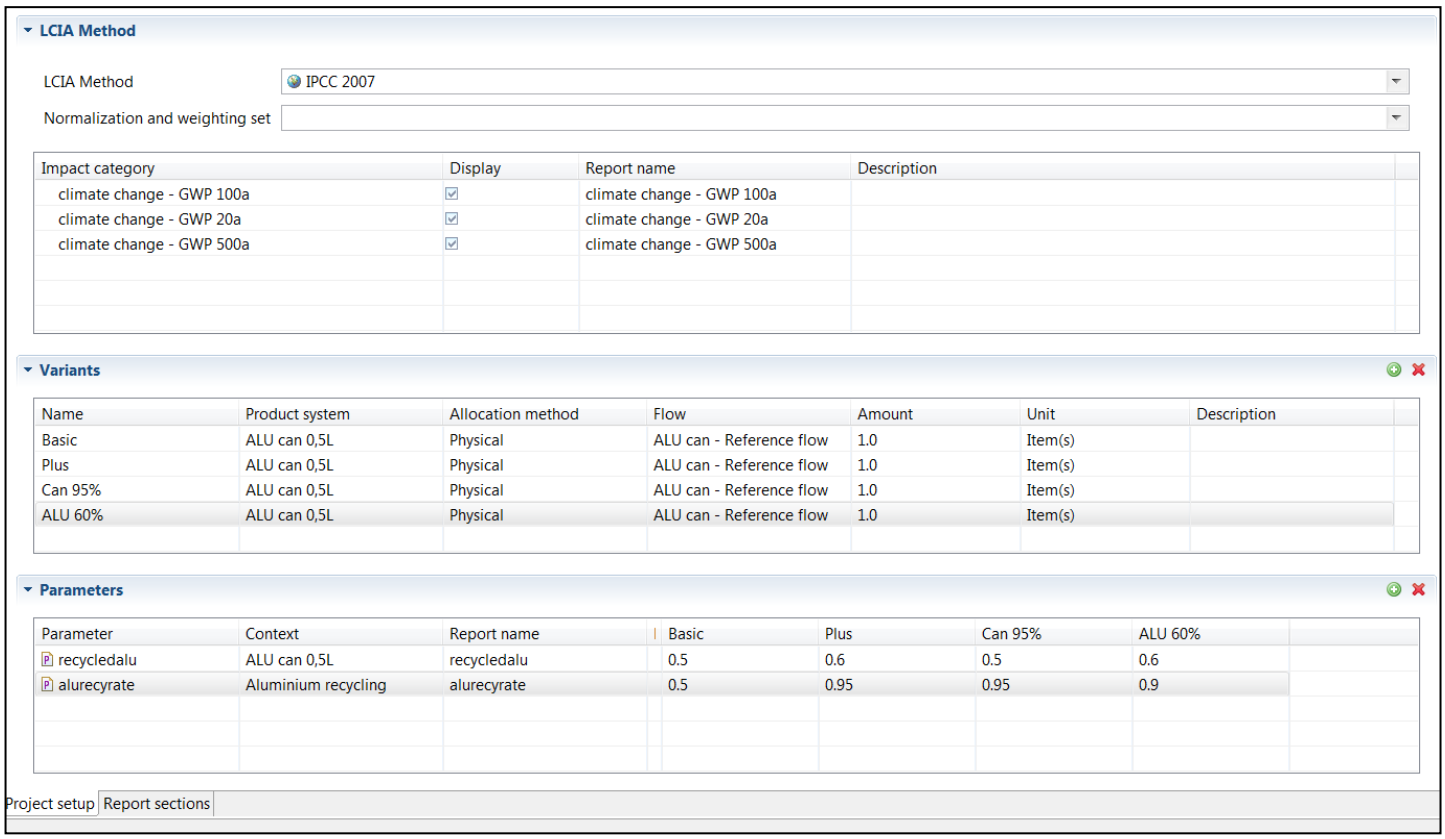


Figure 5: Project settings as described in Section 4.2.

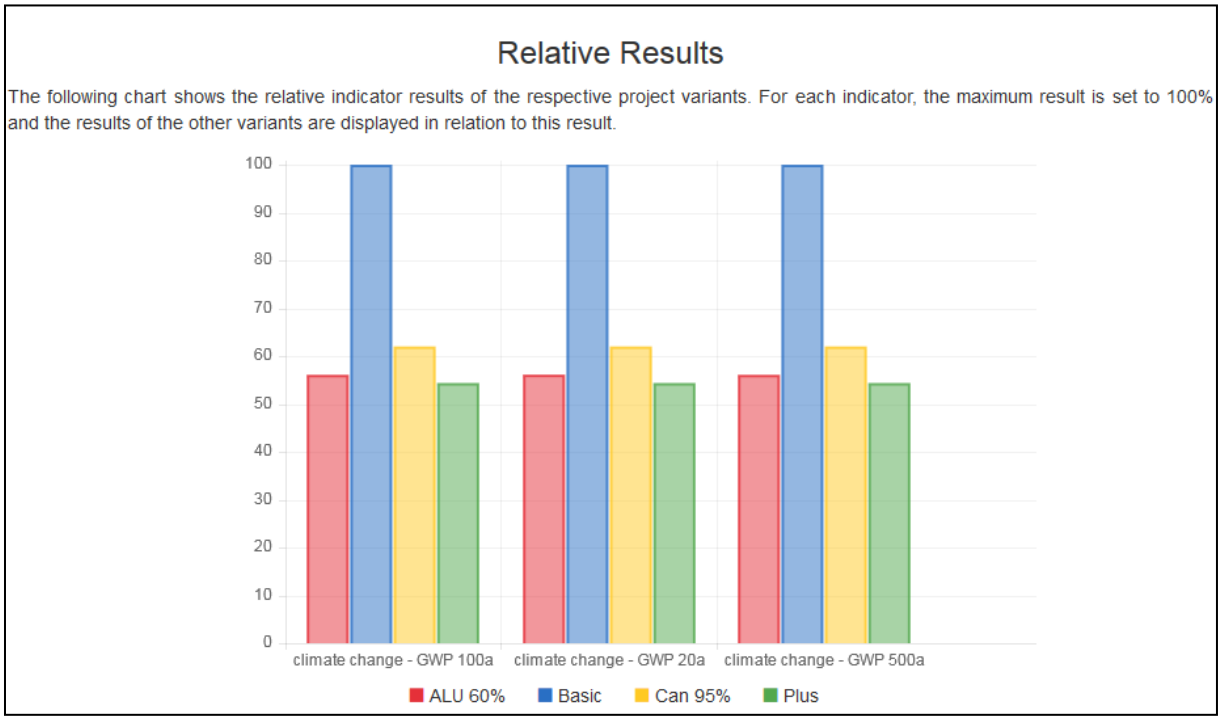


Figure 5: Portion of results from project as described in Section 4.2

The chart allows us to make a few conclusions:

- Increasing the recycling efficiency from 90% to 95% improves the impact in each category slightly.
- Changing the recycled part of aluminum from 50% to 60% has a greater positive effect.
- What other conclusions would you make from this analysis?

5 Conclusions

This case study has is for educational purposes only. Thus, results should not be considered as part of a complete life cycle assessment.

Nevertheless, it gives a bit of insight on how to model and compare different product designs. This case study shows also how recycling scenarios can be modeled and used to find the recycling way with the least environmental impacts. Especially in case of allocation, multi-output processes, waste management and closed loops, there are few model rules which are needed to be considered.

6 References

To improve this case study and go further into details, you can have a look at the following websites and documents:

- Life Cycle Assessment of aluminium products: http://www.alueurope.eu/sustainability/life-cycle-assessment/
- "LCA and recycling policy - a case study in plastic": http://www.lcacenter.org/LCA9/presentations/208.pdf
- "Aluminum Association challenges PETRA's LCA study": http://www.life-cycle.org/?p=805
- “Life Cycle Impact Assessment of Aluminum Beverage Cans- Final Report. May, 2010” ;Aluminum Association,Inc. http://www.aluminum.org/sites/default/files/FINAL_CAN_LCA_REPORT.pdf
- "Life Cycle Inventory of 100% postconsumer HDPE and PET recycled resin from postconsumer containers and packaging": http://www.napcor.com/pdf/FinalReport_LCI_Postconsumer_PETandHDPE.pdf