IEooc_Methods4_Exercise 6: LCA with openLCA: Introduction and first steps

Goal: *Install and learn how to use the openLCA software for life cycle assessments using ecoinvent v3.2 and several impact assessment methods. Use of parameters, choice of electricity mix, sensitivity analysis, export of data, a small test case.*

Note: *For this exercise an ecoinvent licence for openLCA is needed. If no license is at hand the exercise can be modified, using the freely available life cycle databases on the openLCA Nexus.*

Step 1) Setting up openLCA

+ Download and install the openLCA software from http://www.openlca.org/download/

You find installation tutorials for Windows here: https://www.youtube.com/watch?v=QJ5m_G-45j8 and for MAC here: https://www.youtube.com/watch?v=_WiHpjlCXZY.

+ Download the required databases from the openLCA Nexus. Use only ecoinvent 3.2 to make sure you are all using the reference versions for this course to obtain comparable results.

+ ecoinvent_3_2_cutoff.zolca	ecoinvent 3.2 with cut-off model for use in openLCA
+ ecoinvent_3_2_lcia_methods.zolca	LCIA methods adapted to ecinv. 3.2 for use in openLCA

+ open the openLCA software, import the ecoinvent data and add the ecoinvent LCIA methods. Follow the description in this video: https://www.youtube.com/watch?v=FqVMbwhAEW4

The two steps shown in the video are:

+ import ecoinvent_3_2_cutoff.zolca by right-clicking the navigation tab and choosing 'import database'

+ add the ecoinvent LCIA methods to your version of the database by going via File → Import → Database import → From exported zolca file. NOT: right-clicking on the navigation tab again!

You are now ready to go!

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Step 2) Handling openLCA

In this second step you learn the basic steps of an LCA in openLCA. The instruction mainly follows the tutorial on Youtube https://www.youtube.com/watch?v=kEosW6PceVg with a few amendments.

2.1) It is a good idea to keep your self-defined products (flows) and processes, the so-called *foreground* separate from the ecoinvent *background* database. To do that, right-click on the ***Flows*** group and 'add a new child category' named '_MyFlows' or '_Foreground_Flows' or something like that. With the underscore in the beginning your group will show up first. The same for processes.

2.2) Within the new flow category, create a new flow 'TestBottle' (or something else) and specify it as a product with the reference unit 'number of items'. On the 'TestBottle' tab, click 'Create process' to create the corresponding unit process for the test bottle. In the dialogue box that opens, select the TestBottle as the reference product. The new unit process will appear somewhere in the process list. Move it to the _MyProcess (or so) group by drag and drop. **Or:** First create the process, and the reference flow with it.

2.3) In the input/output tab of the new process you can list the unit process inventory for that process. Enter a few input flows from the ecoinvent database (just make up some numbers), and add a few emissions as outputs. Right-click 'create new' to open the dialogue box where you can add those flows. You find emissions under 'elementary flows'. The result could look like this screenshot in Fig. E4.1.

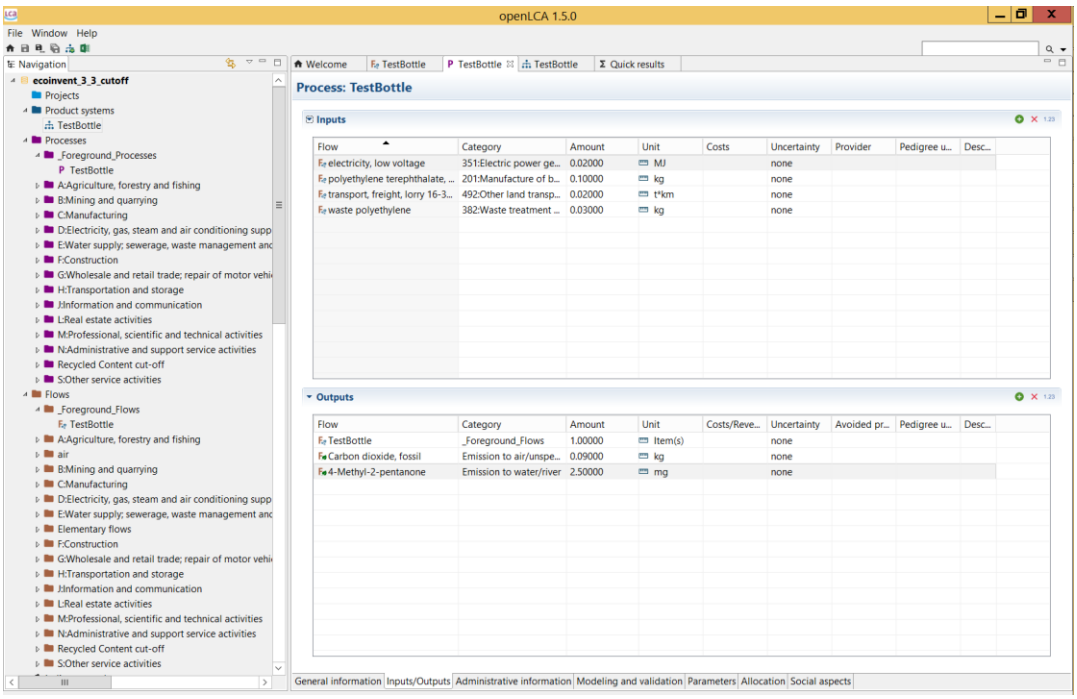

Figure E4.1: Snapshot for a sample foreground process inventory in LCA.

The video tutorial also shows how to parameterise your input data, for example, when the electricity demand depends on the mass of the plastic bottle.

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Note that we deal with two types of flows in openLCA (and LCA in general, Fig E4.2): Product flows (with the small blue circles as symbol) and elementary flows (emissions and resources, leaf as symbol). There is also a waste flow category in openLCA, but I don't know what it is good for, as waste is normally modelled as demand for waste treatment service, which is a product.

[*Update from June 8, 2020 on waste modelling*: Steve Allen, U Bath pointed out that "openLCA allows a modelling approach that they call 'material flow logic'. If modelling in that way, you need to use the waste flow categories. However, when using ecoinvent, we have to use what GreenDelta refer to as the 'opposite direction' approach, which is what I think you're referring to above.

The new pdf tutorial from GreenDelta has a section on waste modelling"]

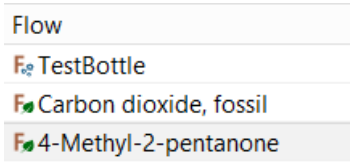

Figure E4.2: Snapshot for a sample foreground process inventory in LCA.

2.4) You can now create the product system by clicking 'create product system' on the 'General information' tab of the bottle process. You can browse the product system on the 'model graph' tab (if the graph gets messy, right click and on 'collapse all'. You can now also calculate the environmental impacts by clicking the 'calculation' button for the product system you created. Choose 'allocation method': 'none', 'CML 2001' as impact assessment method, and 'quick results'. You will get a large set of quantitative results, like the one shown below, plus an option to export results to Excel.

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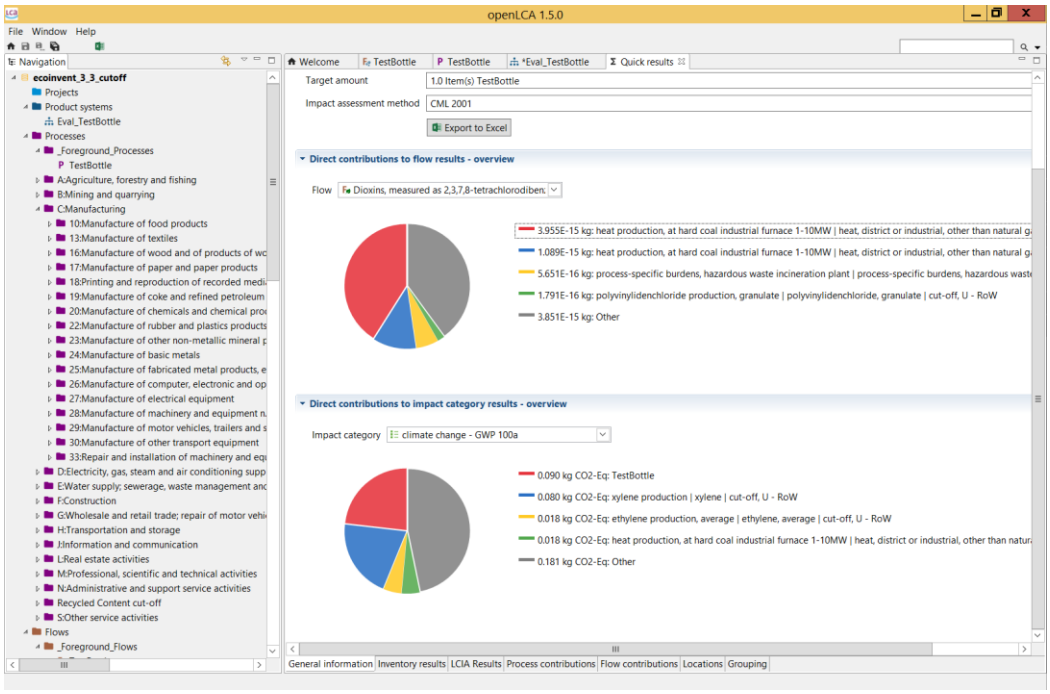

Figure E4.2: Snapshot for a sample impact assessment result in LCA.

The results provided by openLCA include:

+ Tab 'General information':

- 'Direct contribution to flow results': Top 5 processes in the supply chain of your reference flow that contribute to the selected elementary flow (emission).
- 'Direct contribution to impact category results – overview': Top five processes in the supply chain of your reference flow that contribute to the selected impact category.
-

+ Tab 'Inventory results':

- 'Inputs': All flows of natural resources entering your product system
- 'Outputs': All emission flows from your product system
- 'Total requirements': The total output of all industrial processes part of your product system

+ Tab 'LCIA results':

- 'LCIA results': List of all midpoint and endpoint indicators that are part of the selected LCIA method.

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+ Tab 'Process contributions':

- 'Direct contribution to flow results': Specify a cut-off (default is 2%) and get a sorted list of the processes that contribute to the selected elementary flow.
- 'Direct contribution to impact category results': Specify a cut-off (default is 2%) and get a sorted list of the processes that contribute to the selected impact category.

+ Tab 'Flow contributions':

- 'Flow contributions': Get a breakdown of which elementary flows contribute most to which impact category, with cut-off at 1% by default.

+ Tab 'Locations':

- 'Locations': Regional distribution of selected elementary flow. Rest of world RoW means in regions other than the already specified ones.

+ Tab 'Grouping':

- 'Grouping of results'. Define user-specific process groups (by clicking on the (+) symbol in the upper right corner) and show the breakdown of emissions and impact categories into the different groups.

Export to Excel: On the 'general information' tab you have the option to export results to Excel to visualise the results ore create Pivot tables. The exported Excel file contains the complete life cycle inventory and the final results of the impact assessment. For a more comprehensive export to Excel, choose 'Analysis' as calculation type, then export.

2.5) Combining different product systems into a project: You can create a project under 'project' in the tree on the left side of the openLCA window. In the project tab you can enter different product systems to compare, and you can modify the parameters within the product systems of you have defined any. When clicking the 'report' button, openLCA will calculate the LCA for all specified alternatives and show it to you on the 'report' tab. The report items can be specified on the 'report sections' tab as html tags, and the report can be exported by clicking the export icon in the upper left corner of the openLCA window.

Note: The openLCA calculations are very memory intensive. If you run out of memory ('calculation error' message), close other software, especially the web browser and MS office, and assign more memory to openLCA (via File→Preferences→Configuration).

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Intermezzo: A few hints:

- Always use decimal point as decimal separator, not the comma: 3.14 or 10.123
- Use 'E' for the exponent ten: 1E-3, 1E5, etc. (means 0.001, 100000)
- openLCA features automatic unit conversion, units can be entered in any of the specified possible units for that aspect (mass, items, etc). Conversion to internal reference unit happens automatically
- A few abbreviations: RER means 'rest of Europe', GLO means 'global', UCTE and ENTSOE refer to European electricity grids.
- **Frequently save your results! openLCA does not have an undo-button!**
- openLCA issues few warnings only. If a 'calculation error' is issued, it often means that your memory if full. Restart openLCA in that case (save before your exit), and also close your web browser.

Step 3) Parameters in openLCA and sensitivity analysis

Instead of directly entering a numerical value into a process description, one can also enter pre-defined parameter. What are parameters good for?

- You can connect your original data to the values inserted in the process inventory by using parameters. For example: Gasoline requirement in MJ [entered as process input] = energy content of gasoline [parameter] * specific gasoline requirement [literature value]
- You can make sure that the same conversion factors are used all across your study. For example: By defining a parameter 'energy content of gasoline' and using it in all processes with gasoline input, you have one system wide reference value for the energy content. If you need to change it, you only have to do it once.
- Combining openLCA's parameter feature with the project option, you can run a sensitivity analysis by analysing the same product system with different parameter settings.
- You can specify the uncertainty of input values if you introduce parameters and use it in a subsequent uncertainty analysis, for example, a Monte-Carlo-Analysis.

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Parameters are defined on the 'parameter' tab of a process:

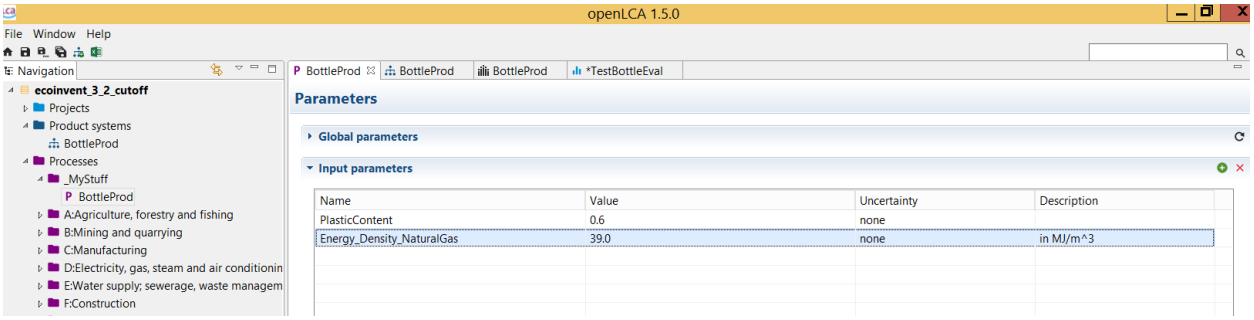

Figure E4.3: Parameter definition in openLCA.

Use the parameters by typing their name in the 'value' field. Toggle between parameter view and numerical view by clicking the button as indicated in Fig. E4.4.

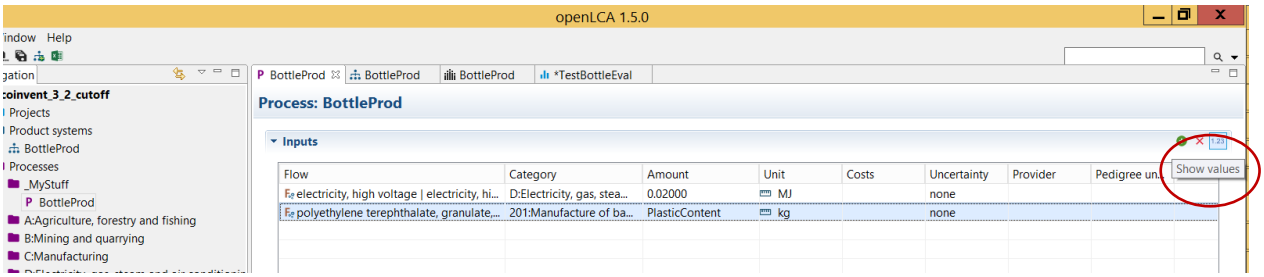

Figure E4.4: Parameter definition in openLCA.

To make parameters available for sensitivity and Monte-Carlo Analysis, you need to import them on the 'parameter' tab of the product system.

If you then import the same product system several times to a project (Fig. E4.4), you will see different choice options for the parameters in the system. Change those parameters to conduct a **sensitivity analysis.**

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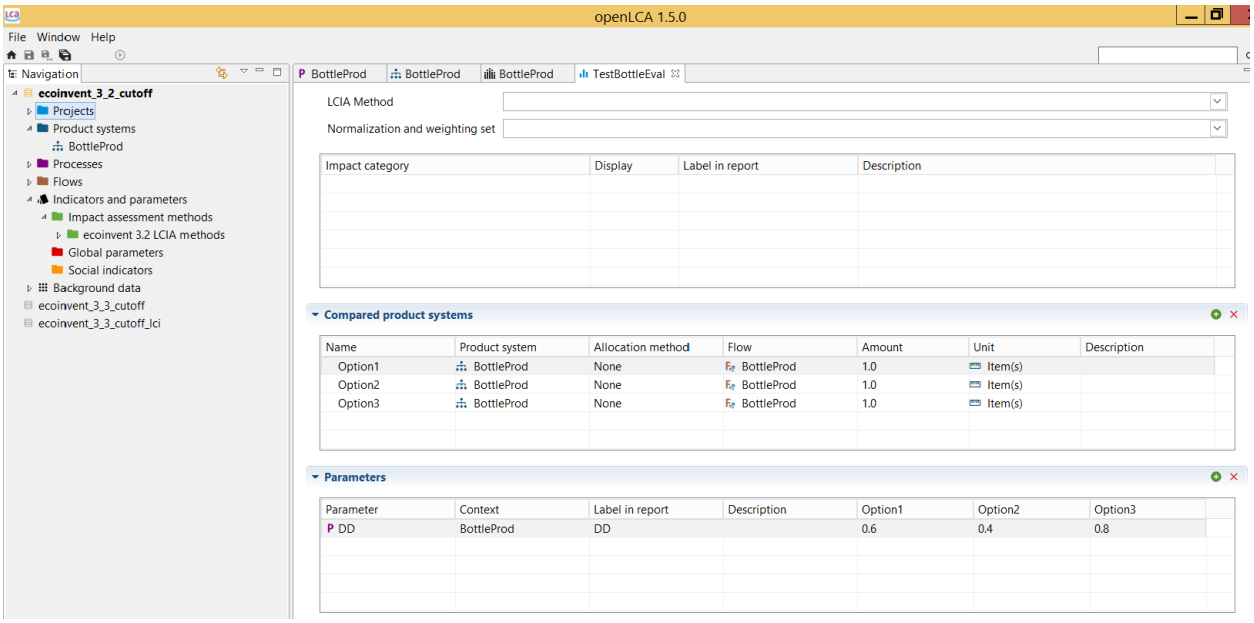

Figure E4.4: Snapshot for a sample impact assessment result in LCA.

The different steps of parameter handling are explained also here:

https://www.youtube.com/watch?v=yu6IGozXm-E

Step 4) Choosing an electricity mix

In ecoinvent different voltage levels, regional electricity mixes, and production technologies are distinguished (Fig. E4.5).

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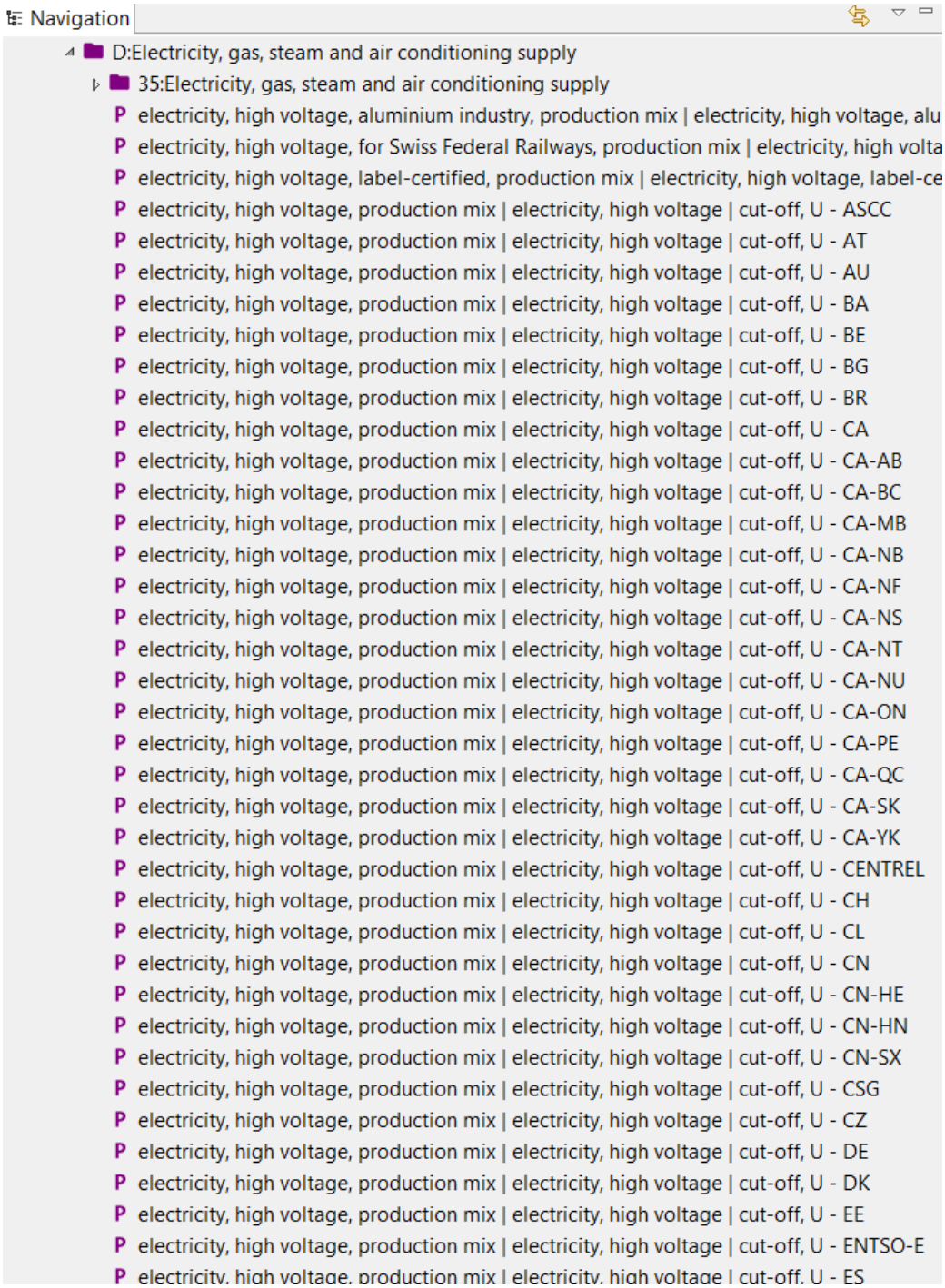

Figure E4.5: Snapshot for a sample impact assessment result in LCA.

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Which of the many processes to use? Answer:

- If you know that 'your industry' buys very large quantities of electricity directly from specific suppliers, use the specific technology/region combination or production mix or a desired region and use 'electricity, high voltage …' as input product. You may want to model transport losses and emissions in addition.
- If you know that 'your industry' buys very large quantities of electricity from 'the grid' in a specific region, select the 'market for electricity, high voltage' in a specific region as an input process, and 'electricity, high voltage …' and input product.
- For 'small' processes that get their electricity from the local grid, use the 'market for electricity, low voltage' in a specific region as an input process, and 'electricity, low voltage …' and input product.
- For 'small' processes that purchase a specially labelled electricity from the local grid ('Ökostrom', 'green electricity' or also coal or nuclear), link your process to the original suppliers of that electricity and model the transmission losses and infrastructure requirements in addition.

Step 5) export of data

You should save your foreground data by exporting them periodically. To do so, go to File → Export, and then choose one of the export file formats. We recommend openLCA's own format for a comprehensive export of process descriptions and flows (including parameters), a more widely useful format would be ecospold (the ecoinvent format) for process inventories. You will be asked to select the objects that you want to export (Fig. E4.6). Note that the export of product systems and projects will lead to an export of the entire database (several 100 MB file size), uff. Better only export the process and flow data, as the link between your foreground and the background will be kept (each background dataset has UUIDs to identify reference products and flows, and those are the same for each version of ecoinvent no matter where it is used). Cool, isn't it?

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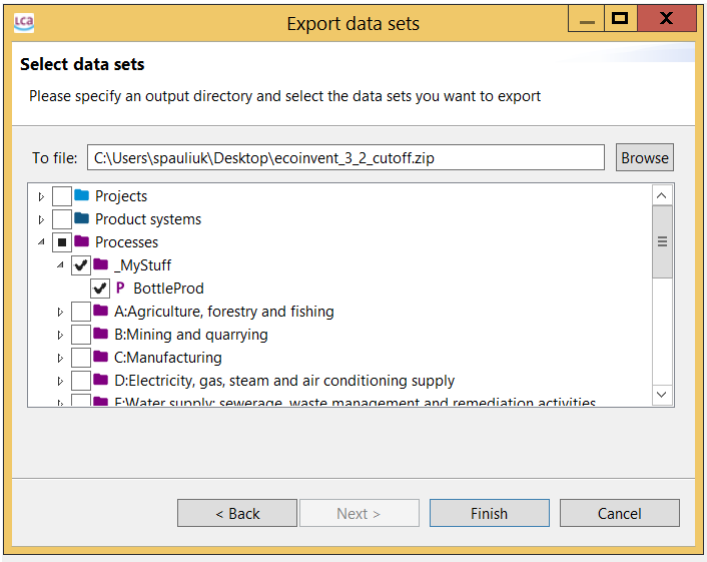

Figure E4.6: Select data objects for export in openLCA.

Step 6) A small test case

Table E4.1 shows the material and energy purchased by the entire university in 2013. Make a quick LCA check of the carbon footprint per student or employee on the most relevant purchases! Check different electricity mixes as well.

Table E4.1: Inventory of the University of Freiburg.

Energy and material inventory of the University of Freiburg		
	Units	**2013**
Associated people		
University incl. medical faculty	FTE	5,804
Students	Number	24,721
Electricity consumption	kWh/a	48,598,599
Heating and cooling		
Steam	kWh/a	70,287,962
Natural gas	kWh/a	3,129,962
Heating oil	kWh/a	2,041,420
Wood pellets	kWh/a	302,500
Water consumption		
Drinking water	m^3/a	151,723

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Well water	m³/a	177,910
Paper consumption		
New paper	t/a	27.75
Recycled paper	t/a	89.61
Waste		
Paper waste	t/a	297
Waste for composting	t/a	64
Waste for incineration	t/a	146
Radioactive waste	t/a	1
MSW (municipal solid waste)	t/a	421
Hazardous waste	t/a	91
Source: Inventory of the University of Freiburg, 'Stabsstelle Umweltschutz', Dr. Jürgen Steck		

More tutorials for openLCA:

https://www.youtube.com/channel/UCGiahq1YZWK4pRXDVXuIi6w

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