ecoinvent

ecoinvent 3.10 implementation in openLCA

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1 What is new in ecoinvent 3.10?

The latest version 3.10 of the ecoinvent database includes major updates of the sectors Agriculture, Building and Construction, Chemicals, Electricity, Forestry and Wood, Fuels, Metals, Packaging, Pulp and Paper, and Waste and all details can be found at the ecoinvent website. In the following, some main differences and updates to the newest version 3.10 are given. This content is directly taken from the ecoinvent website or from the ecoinvent "Report of changes" and will be always marked in grey font for citation.
https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-v3-10/
https://ecoinvent.org/wp-content/uploads/2023/11/Change-Report-v3.10.pdf

1.1 Main updates of each sector

Petroleum and Natural Gas

Version 3.10 features an extensive full-scale update of petroleum and natural gas supply chains, incorporating the latest statistical data from 2021.

Other Fuels

Version 3.10 will introduce data modeling for the production of hard coal coke in China.

Chemicals

Unit process data for olefins and aromatics have replaced aggregated data. Additionally, new datasets modeling the production of hydrogen, methanol, chlorine, and cooling energy supply have been added.

Electricity

Market mixes have been updated with data from 2020, and for selected countries like China, India, and the United States, data from 2021 has been included. The residual mix markets for EU-28 and several other European countries have been refreshed based on 2022 data.

Waste

Version 3.10 contains fully disaggregated waste treatment chains, offering a more in-depth view of environmental impacts associated with waste treatment steps.

Agriculture

Datasets covering barley, oat, wheat, and rapeseed production in Australia, as well as data for potato, sweet corn, soybean, and maize production have been added for version 3.10. This includes detailed data modeling machinery and field operations in both countries.

Construction

Regionalized data for various construction materials, covering Tunisia, Ecuador, and Switzerland, have been introduced.

1.2 New and updated data

Agriculture:

ecoinvent is back with a fresh and promising update in version 3.10. The highlight of this update is the addition of comprehensive data on new crop production in two major countries for agricultural production – Australia and the United States. For Australia, data on crops like barley grain, maize grain, oat grain, and wheat grain are now available from new regions, ensuring a more accurate representation of their agricultural landscape. In the United States, the update brings data on maize grain, sweet corn, potato, soybean, and various field operations from new states, expanding the scope of information. Beyond that, average European data (RER) for Flax production and scutching are added. Version 3.10 introduces supplementing documentation for FLAG/non-FLAG emissions, providing additional support for the agricultural sector, empowering users to better understand and assess environmental impacts related to emissions based on SBTi's targets. Finally, version 3.10 takes a step further by enhancing the quality of data for some agricultural products, reviewing fertilizers' input data for lentil and pea production in Canada.

Building and construction:

The 3.10 update brings rich enhancements to the Building & Construction sector of the ecoinvent database, including a wealth of new data and several updates. We have added comprehensive information on clinker and various types of cement production for the Tunisia geographical scope, as well as their corresponding market activities. The Swiss market database has been updated, removing obsolete activities not compliant with the current production of building materials, and now shows updated figures for clinker and cement production (including Portland, CEM II/A, and CEM II/B) with their corresponding market activities. For the Ecuador region, we've introduced extensive datasets covering construction materials like adobe bricks, clay bricks, clinker, cement, concrete blocks, and clay roof tiles production, together with their corresponding market activities.

Chemicals:

The Chemicals sector is updated to improve the data representation for essential chemical precursors and their derivatives, such as short-chain alkenes (ethylene, propylene, butene, and butadiene), monocyclic aromatics (benzene, toluene, and xylenes [p-, o-, mixed]), ethylene oxide, and ethylene glycol. Industry data for European conditions was provided by Plastics Europe. Additional key updates comprise of technological and geographical coverage expansion for ethylene, propylene, hydrogen, and methanol. Specifically, ecoinvent v3.10 introduces data for China, United States, and Europe. Moreover, ecoinvent v3.10 introduces updated industry data covering the supply and demand of chlorine and sodium hydroxide, provided by Euro Chlor, diisocyanates (methylene diphenyl diisocyanate and toluene diisocyanate) and polyether polyols (short- and long-chain), provided by ISOPA. This version also introduces data for industrial cooling supply for process streams at temperatures well below ambient, i.e., –15, –25, –45, –55, –100, and –160°C. Finally, the Chemicals sector in ecoinvent v3.10 takes a step to a comprehensive content update. This content update focuses on nomenclature, documentation, technological relevance, inventory completeness, and harmonisation following the standard ecoinvent approach.

Electricity:

ecoinvent v3.10 updates the electricity market mixes to reflect the situation in 2020. In the specific cases of Brasil, China, USA, Canada, and Switzerland the electricity mixes are updated to reflect the situation in 2021. India was updated to represent the fiscal year of April 2019/March 2020. All specific cases are based national while the remaining countries are based on global statistics. Besides additional minor corrections, harmonization efforts were performed in order to update documentation and meta information of electricity markets, transformation and import datasets. ecoinvent v3.10 further introduces datasets on the production of a small-scale wind power plant.

Forestry and wood:

The Forestry & Wood sector has been enhanced with the addition of three new datasets related to bamboo forestry, bamboo pole production, and flattened bamboo production in Ecuador. The data was provided by Empa (Swiss Federal Laboratories for Materials Science and Technology).

Fuels:

The new version significantly expands the geographical coverage of the Oil and Gas sector. There are oil and gas production datasets from 41 different geographies, compared to the previous 27 in v3.10. This update increases the coverage to more than 96% of the global production of crude petroleum oil and more than 98% of natural gas output. By incorporating data from countries such as Australia, Oman, and Turkmenistan, which are key contributors to natural gas supply especially in Asian economies, we have greatly improved the representation of the sector. The new release reflects the supply situation in 2021 (previously 2019).

Metals:

This update expands the data coverage of the Metals sector with new and updated data. Specifically, ecoinvent v3.10 introduces data on thermal spraying (Atmospheric Plasma Spray (APS), High Velocity OxyFuel (HVOF), and Cold Spray (CS)). Prices of rare earth oxides are also updated.

Pulp and paper:

The Pulp and Paper sector has been updated with three new datasets related to beverage carton production. Additionally, the corrugated board production datasets in the European region have been updated in accordance with the latest study conducted by the European Federation of Corrugated Board Manufacturers (FEFCO) and Cepi ContainerBoard (CCB).

Waste:

In version 3.10, the waste sector continues to evolve by carrying on with the second phase of the sector overhaul. The updates focus on disaggregating more than 450 solid waste treatment datasets. The users are now able to see the entire supply chain of treatment activities broken down into separate datasets. All the by-products are transparently reported, emissions are properly allocated in the respective activities generating them, and local waste transport distances are added. Moreover, the geographical coverage of the sector is enhanced by adding solid waste treatment datasets in other countries.

1.3 Database-wide changes

Renamed activities:

Some activities were renamed for version 3.10. Most of the activity name changes aim at better defining the scope of the activity.

Renamed exchanges:

Some intermediate exchanges were renamed for more precision, correction of mistakes, or alignment with elementary exchanges names.

Updated exchanges data:

Some of the data for elementary exchanges and intermediate exchanges was updated. This concerns CAS number, formulas, and comments. CAS numbers and formulas were added where missing and removed for exchanges referring to a group of substances with different possible formulas. Formulas for isotopes now include the mass number (number of nucleons), for example, “234U” for “Uranium-234”. Furthermore, elemental contents of exchanges with a formula were updated based on these formulas to ensure completeness and consistent calculation of elemental contents. “Manganese-55” is a stable isotope and hence the name for emissions to water was changed to “Manganese” and the unit from kBq to kg. The exchange is not used in the database.

Deleted and replaced elementary exchanges:

Several elementary exchanges (EEs) were deleted as they either should not be used. EEs for extraction of mineral resources from ground (or in a few cases water) included the ore composition in older versions (for example, “Silver, Ag 1.5E-4%, Au 6.8E-4%, in ore”), but the flow refers to silver. Hence, the flow given in the example should only be “Silver” (and the ore is modelled as the single elements plus gangue according to the given composition). All EEs named the old way were deleted from the master data (and can be replaced by those having only the element as name if still existing in data projects). They had already been replaced in the datasets for version 3.6 and have therefore not been in use since that version. Emissions to the sub-compartment “lower stratosphere + upper troposphere”, which is the flight altitude compartment, are meant for emissions from air transport. However, several EEs, which do not belong to an aircraft emission profile were available. These were deleted. Furthermore, EEs in datasets using wrongly this sub-compartment were replaced with the EEs with the “unspecified” sub-compartment.

Changes in geographies:

The source GIS data was updated to Natural Earth version 5.1.1, and the way we construct regions was changed to a union of all the provinces within a country. This change was necessary because there were sometimes small differences between the Natural Earth country and province border definitions.

1.4 Impact assessment methods

The main task in implementing impact assessment methods is mapping the ecoinvent elementary exchanges list to method elementary exchanges lists. This includes assumptions concerning many aspects, for example, flow names and compartment/sub-compartment mapping choices. These assumptions are documented in the LCIA implementation report (Sonderegger & Stoikou, 2023). The result of the implementation is available in a series of spreadsheets, showing the explicit mapping between the nomenclature of the database and each LCIA method. This section discusses some changes made to these implementation files and – to start with – added and deleted methods.

New and deleted methods

The following methods were introduced with v3.10:

- EN15804 EPD PCR extension for GWP
  (introduced as impact category in EF v3.X EN15804 methods, see section 2.3.2)
- IMPACT World+ v2.0.1, footprint version
- Inventory results and indicators
- USEtox v2.13

The addition of methods allowed to delete some old methods. These are the following:

- EDIP 2003
- IMPACT 2002+ (Endpoint)
- IMPACT 2002+ (Midpoint)
- selected LCI results
- selected LCI results, additional
- USEtox

“IMPACT World+ v2.0.1, footprint version” and “USEtox v2.13” replace “IMPACT 2002+” and “USEtox”, respectively. “Inventory results and indicators” builds on selected LCI methods and integrates some of the waste indicators used in “EDIP 2003”.

2 Unique properties of the ecoinvent database

Several aspects are worth being noted about the ecoinvent database. Most of them have also been provided with previous versions of the database. These include:

- Three different "system models" exist that reflect different allocation and substitution rules, and different rules for modelling end-of-life and recycling.

- Every process dataset is available as a unit process and as a system process in each of the three system models (with very few exceptions).

- Separate documentations are available for each data set, and the link to this information can be found in openLCA inside the process data set descriptions.
  Process → General Information → Description → first sentence contains the ecoQuery link

- Correspondence files are provided by ecoinvent with changes from the previous version to the current version of ecoinvent databases:
  https://ecoinvent.org/wp-content/uploads/2023/11/Correspondance-File-v3.9.1-v.3.10.xlsx

- Costs and revenues (prices) provided by ecoinvent are included in the databases, with the exception of waste flows and products from recycling.

For more information about the content and methodology of the ecoinvent 3.10 database:
https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-v3-10/

You will also find the report of changes between ecoinvent 3.9.1 and 3.10 there:
https://ecoinvent.org/wp-content/uploads/2023/11/Change-Report-v3.10.pdf

3 Get ecoinvent 3.10 for openLCA from Nexus

ecoinvent 3.10 is available for download for openLCA exclusively on https://nexus.openlca.org. Please note that versions of ecoinvent 3.10 obtained elsewhere will not be compatible with openLCA. The ecoinvent licence purchased via nexus.openLCA.org is downward compatible. In addition, users with an ecoinvent 3.10 license will also receive access to older versions of ecoinvent. All the different data packs can be used as independent databases in openLCA. However, special attention should be paid to integrating older versions of ecoinvent databases with the ecoinvent version 3.10 database.

The life cycle impact assessment (LCIA) methods that are implemented by ecoinvent are already integrated in each database and they are available in a method package via openLCA Nexus, too. With this package it is possible to reproduce the LCIA results provided by the ecoinvent Association. However, the use of the latest version of the openLCA LCIA methods package is also possible and recommended by GreenDelta. The current version at the release is the openLCA LCIA methods package version 2.3.2 which is compatible to ecoinvent v3.9.1 and a new openLCA LCIA methods package version will follows very soon to be compatible to ecoinvent v3.10.

4 Implementation of ecoinvent 3.10 in openLCA

All ecoinvent 3.10 databases with the system models Cutoff, APOS and Consequential are implemented for openLCA 2 (the latest version at the release date is openLCA 2.0.4). Like in previous ecoinvent 3 versions, data packs are generated by the ecoinvent centre from the undefined ecoinvent database. All these data packs are provided as unit- and fully aggregated system processes. More information on the system models can be found on the ecoinvent website, and here is a short description which is cited from there:

Allocation cut-off by classification (Cutoff):

The system model "Allocation, cut-off by classification", or the cut-off system model, is based on the recycled content, or cut-off, approach. In this system model, wastes are the producer's responsibility ("polluter pays"), and there is an incentivisation to use recyclable products, that are available burden free (cut-off).[1]

Allocation at the Point of Substitution (APOS):

The system model "Allocation at the point of substitution" is also known as the APOS system model. It follows an attributional approach in which the responsibility over wastes (burdens) are shared between producers and sub-sequent users benefiting of the treatment processes by using valuable products generated in these.

The APOS system model was previously called "allocation, ecoinvent default". The name was changed with the release of ecoinvent version 3.2.[2]

Substitution, consequential, long-term (Consequential):

The system model "Substitution, consequential, long-term" is also known as the consequential system model. This model uses different basic assumptions to assess the consequences of a change in an existing system. It applies substitution to credit processes with the avoided burdens from supply chains that are replaced by the by-products generated within them.[3]

[1] https://ecoinvent.org/the-ecoinvent-database/system-models/ - !/allocation-cut-off

[2] https://ecoinvent.org/the-ecoinvent-database/system-models/ - !/allocation

[3] https://ecoinvent.org/the-ecoinvent-database/system-models/ - !/substitution

4.1 Improvements in the openLCA implementation

Compared to previous version, several improvements are done in the openLCA implementation of ecoinvent 3.10:

- All ecoinvent impact methods include now a short documentation and the links to sources that are provided by ecoinvent.
- All processes include now sector tags, for example “Sector: Chemicals”, to enable easy sector and grouping analysis of the results.
- All impact contributions from each sector tag inside the “Tags” results add up to the total impacts.
- All exchanges include now prices to enable consistent calculations of supply chain costs and revenues from existing ecoinvent price data.
- All exchange prices are either directly from ecoinvent data sets (only provided for the quantitative reference and recyclables) or from calculations of the default provider prices times the exchange amounts.
- All validation checks pass the tests.
- All exchanges inside processes include now the location from the default provider (to faster see and catch provider from different locations than the process).
- All ecoinvent elementary flows that are used inside the ecoinvent impact methods or inside the ecoinvent processes are included in the databases (also if they are not used inside processes, but only used in the methods).
- All locations are now sorted into folders.
- All geometries of the locations are now updated to the Natural Earth Data version 5.1.1 provided by ecoinvent.
- All locations now include the description of overlapping regions/countries.
- All recycled content cut-off processes (empty cut-off processes) and recycled content cut-off flows (cut-off recyclables) are sorted into one folder.
- All product flows include now descriptions in case the data is available from ecoinvent.
- All flows include the CAS numbers, formula, synonyms in case the data that is available from ecoinvent.
- All openLCA currencies are updated to average exchange rates between 2019 and 2023 (past 5 years).
- All versions and change dates are set to zero inside database elements to easily track user changes from the initial release version.

- Only flow properties and unit groups that are used inside the database are included in the databases for having a clean overview. But more flow properties and unit groups can be imported any time from other databases or existing project.
- Some flow properties and unit groups are renamed (no change of the UUID) to harmonise the naming.
- The flow property and unit group for the standard volume “Sm3” is changed to the general volume “m3”.
- Different process UUIDs are used for the system process databases to permit combinations with the same unit process databases if needed.
- Normalisation and weighting factors are added to the “EF v3.1” ecoinvent implementation method.
- Uncertainty values for exchanges with Gaussian distributions (only ca. 0.3% of all exchanges in the databases) are removed due to inconsistencies that are found between the mean and sigma values.
- Some elementary flow UUIDs are changed, as it is also done in previous database versions, to map the openLCA UUIDs and to prepare all databases for compatibility to the upcoming openLCA methods package releases (the next version will be the openLCA methods package 2.4.0 and it will be compatible).

4.2 Modifications for elementary flow compartments

The compartments and subcompartments of the elementary flows inside the original ecoinvent database and inside openLCA follow slightly different structures. Hence, aiming to achieve a better organisation of the database when it is used together with openLCA impact methods or databases from Nexus, the categories (folders) of the openLCA elementary flows are adapted to the openLCA reference system. This means that the names of the folders (compartments and subcompartments) of the ecoinvent elementary flows were modified according to Table 1. The same structure is applied for the flows inside the ecoinvent LCIA methods package and the openLCA LCIA methods package.

Table 1: Overview of ecoinvent 3.10 and openLCA folder structure for elementary flows

ecoinvent 3.10 Compartment	**openLCA Compartment**	**ecoinvent 3.10 Subcompartment**	**openLCA Subcompartment**
air	Emission to air	urban air close to ground	high population density
air	Emission to air	non-urban air or from high stacks	low population density
air	Emission to air	low population density, long-term	low population density, long-term
air	Emission to air	lower stratosphere + upper troposphere	lower stratosphere + upper troposphere
air	Emission to air	unspecified	unspecified
soil	Emission to soil	agricultural	agricultural
soil	Emission to soil	forestry	forestry
soil	Emission to soil	industrial	industrial
soil	Emission to soil	unspecified	unspecified
water	Emission to water	ground-	ground water
water	Emission to water	ground-, long-term	ground water, long-term
water	Emission to water	ocean	ocean
water	Emission to water	surface water	surface water
water	Emission to water	unspecified	unspecified
natural resource	Resource	biotic	biotic
natural resource	Resource	fossil well	fossil well
natural resource	Resource	in air	in air
natural resource	Resource	in ground	in ground
natural resource	Resource	in water	in water
natural resource	Resource	land	land
inventory indicator	Inventory indicator	waste	waste

4.3 Locations and geographies

The list of the locations was updated and the shapes (polygons) of the locations are included, using the geographies file from ecoinvent. The codes (short names) of the locations were replaced by their extended, full names to allow an easier visibility and comprehension for the user and all locations are sorted into folders (Figure 1).

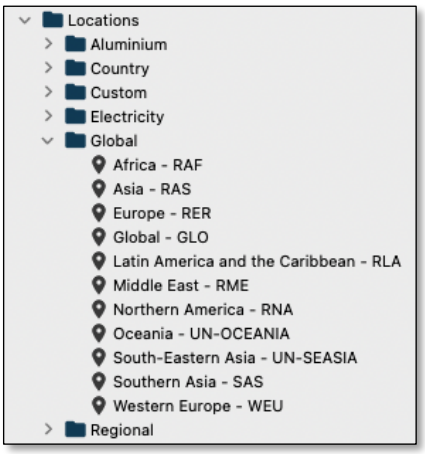

Figure 1: Locations (Geographies) in openLCA

4.4 Addition and extension of price data

The price information for all the quantitative reference products and for all recyclables are provided by ecoinvent. In the new ecoinvent v3.10 database the price information was also extended to all other exchanges where a provider exists and where the provider has a price. That means, that all product exchanges have a price value which was simply added by taking the cost of the reference product in the default provider and multiplying it by the amount of the exchange that will get the new price information.

As in previous versions of ecoinvent, the prices of the reference products are provided by ecoinvent only per product, and they do not differ across different process for the same product and they also do not differ across different countries. This implies that the prices are the same for unit and system processes, and thus, for system processes, they do not reflect life cycle costs but “merely” prices.

openLCA includes an advanced Life Cycle Costing feature, which, in addition to the price data of products included in ecoinvent 3.10, allows you to calculate the net added value and the life cycle costs of ecoinvent product systems. For further details on how to perform such calculations, please check the manual "Life Cycle Costing in openLCA" available on the openLCA website.

4.5 Regionalised calculations

Besides the data packs provided by ecoinvent, GreenDelta also prepared a regionalised version of the database (only for the unit process database). In the non-regionalised versions of ecoinvent, elementary flows in the inventory of a process are generic and not assigned to a specific location (Figure 2). In the regionalised versions of ecoinvent, some elementary flows in the inventory of a process are region-specific as indicated by codes for the names of countries, dependent territories, and particular areas of geographical interest. Region-specific elementary flows allow usage of region-specific characterisation/impact factors in Life Cycle Impact Assessment methods (e.g. “Ammonia / Emission to air / low population density” in Figure 3).

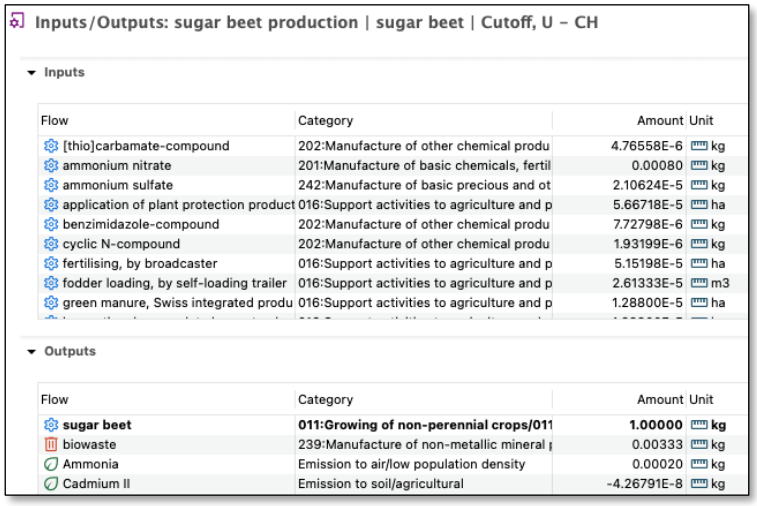

Figure 2: ecoinvent process “sugar beet production | sugar beet | Cutoff, U – CH” unregionalised

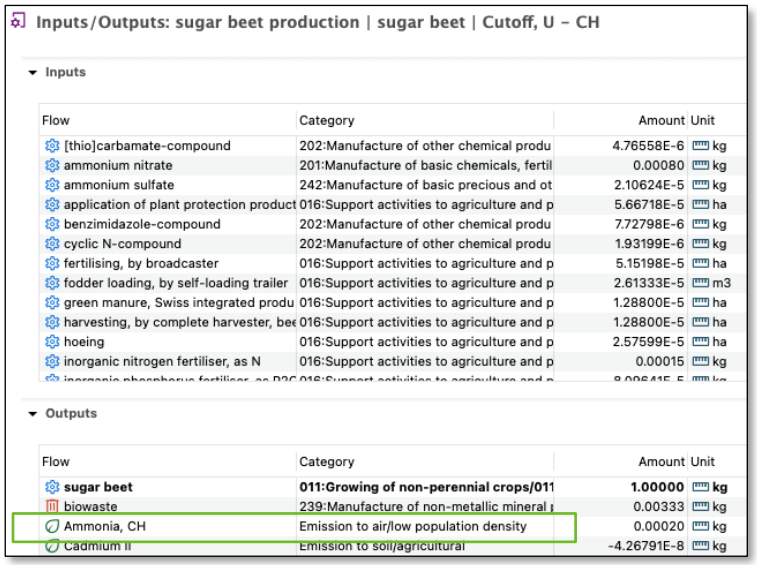

Figure 3: ecoinvent process “sugar beet production | sugar beet | Cutoff, U – CH” regionalised

4.6 Quality assurance and compatibility

ecoinvent 3.10 for openLCA has been thoroughly tested and found to be 100% compatible without any constraints. The inventory and impact assessment results calculated for product systems using unit process datasets from the ecoinvent-implemented methods in openLCA were compared to the LCI (inventory) and LCIA (impacts) results published by the ecoinvent Association. The results obtained in openLCA match the results from the ecoinvent Association. In Figure 5 an exemplary overview is given for more than 13000 processes that are calculated with in the "ecoinvent 3.10 Cutoff Unit-Process" database in openLCA using the EF v3.1 impact method (ecoinvent 3.10 LCIA Methods). The calculated values in openLCA are given as a relative difference to the ecoQuery results from the ecoinvent Association and the difference is in the range of only 0.00000001 (1E-8) and the differences only have a maximum of about 0.001, which is equal to 0.1 %.

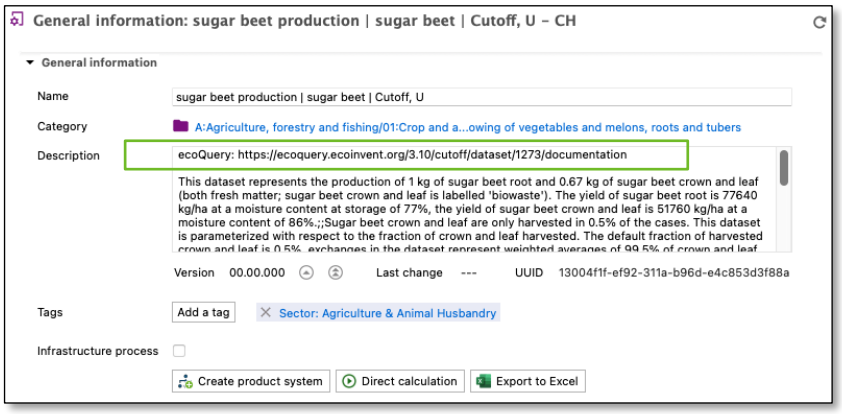

Figure 4: Link to ecoQuery inside the process datasets

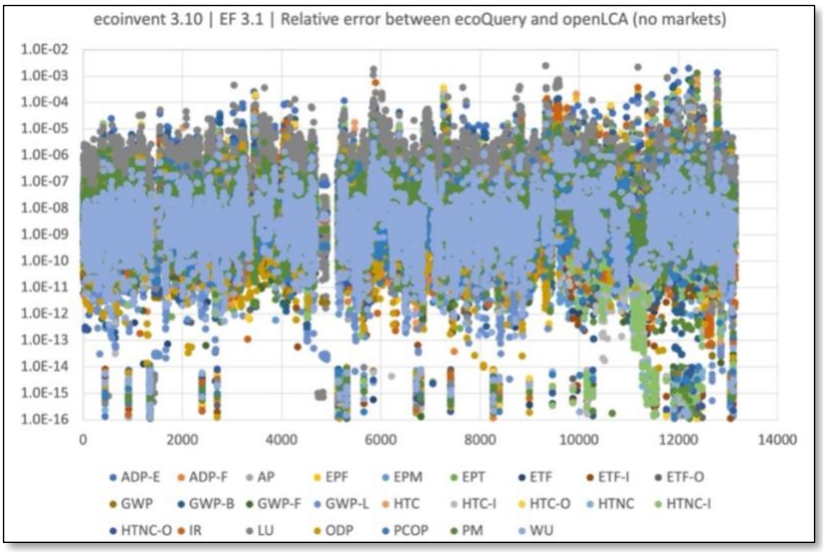

Figure 5: Comparison of openLCA calculations with ecoQuery results for more than 13000 processes

4.7 Memory requirements

With an increased ecoinvent database size, the product systems in openLCA typically have about 16000 processes and about 180000 connections within unit processes. These values can be seen when enabling the "Statistics" sheet for product systems (Figure 6). When working with ecoinvent 3.10 in openLCA, it is recommended to increase the maximum memory usage of openLCA. This enables smoother and faster calculation of product systems.

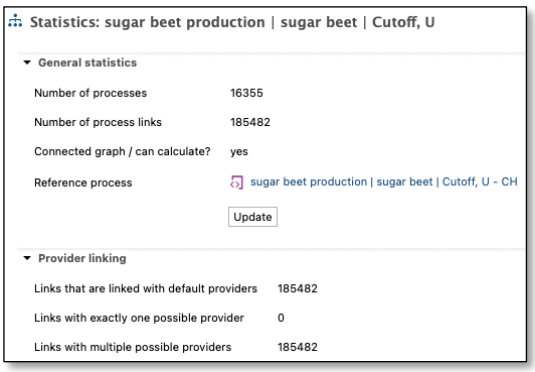

Figure 6: Statistics for the product system created for sugar beet production

openLCA can handle these systems efficiently, which results in short calculation times and memory requirements. However, to calculate a full model, at least 4 to 6 GB of RAM should be available, but it depends on the operating system. By using the “Lazy/On-demand” calculation, already 3 GB of RAM could be sufficient for ecoinvent 3.10, but as mentioned before this also depends on the operating system. When using the new feature for regionalised calculations in openLCA 2, at least 10 to 12 GB of RAM are recommended. The maximum memory usage of openLCA can be increased in the following settings window inside the software:

File → Settings → Configuration → Maximum memory usage in MB

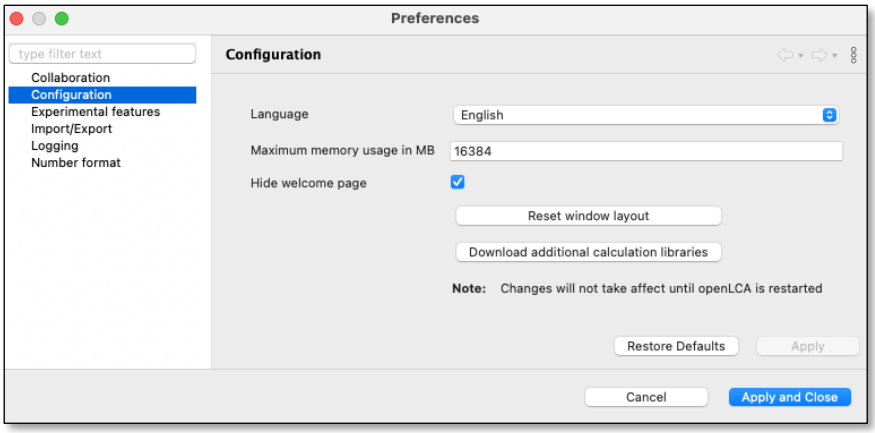

Figure 7: Allocating more memory resources (RAM) to openLCA

This value should not exceed ca. 80% of the installed RAM of the computer. If it is not possible to allocate more memory (RAM), openLCA allows to specify a “cut-off” value when creating the product system, which reduces the number of processes and the number of connections that are calculated. In this section, the wording “cut-off” should not be mixed with the ecoinvent system model “Cutoff”.

For reduced memory usage, cut-off means in this case that process links with very small contributions (the threshold is selected by the user) are cut from the calculations (not considered). For small cut-offs the impact on the result will be not significant. This user option is shown in Figure 8 and the impact can be controlled by checking and comparing the system process result. This feature is more important in input/output databases with very high memory demands, and in ecoinvent 3.10 usually no cut-off is necessary due to the low amount of memory (RAM) needed by the newest version of openLCA 2.

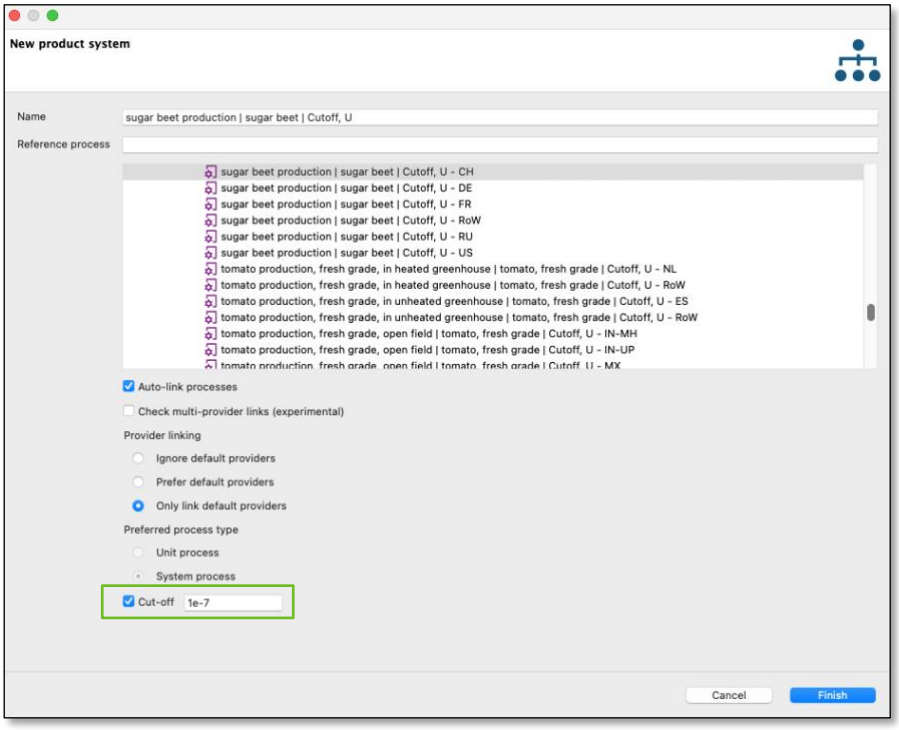

Figure 8: Setting a cut-off value while creating a product system

5 Migrating to ecoinvent 3.10

It is possible to import product systems from a previous version of ecoinvent (for example database version 3.9.1) into the newest version of ecoinvent 3.10. In cases, were the UUID of a process was changed from one version to another, the providers have to be manually re-selected. But this has to be done only for the linking of providers inside the own foreground model and not for the ecoinvent linking. Please note that migration will only be possible for ecoinvent databases having the same system model (consequential, cut-off, apos) and selection of unit processes (UPR) or system processes (LCI). openLCA 2 should be used.

Before migrating data from a previous version of ecoinvent into ecoinvent 3.10, perform a compatibility check and create a backup of your databases to ensure that the original data is retrievable.

A guideline on how to export data and import it again into the new ecoinvent version can be found on Nexus in the Documents sections: https://nexus.openlca.org/database/ecoinvent

6 Support

GreenDelta GmbH, developer of openLCA, offers prioritised and professional support for the users of openLCA via the GreenDelta helpdesk:
https://openlca.org/helpdesk
https://nexus.openlca.org/services

Public (user to user) support for openLCA is available via:
https://ask.openlca.org

In case you have questions, which are not addressed in this report or you have comments about the ecoinvent 3.10 database implementation in openLCA, please contact us or write us a mail.