New options for material flow accounting in the ecoinvent database

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Abstract

Embedding the ecoinvent process database into a hybrid (monetary and physical) supply-use framework, based on data on prices, material content and lifetime of products, the material inputs to the economy, as provided in resource statistics, can be traced through the economy until their eventual release as emissions. This additional feature will allow the ecoinvent database to be applied for material flow accounting at a very detailed level, both for geographical units and for product life cycles, thus allowing the detailed analysis of drivers of and policy responses to resource use. The data availability, validation options, and procedural aspects of data supply are discussed. The policy relevance of different modelling approaches is discussed, and it is shown how material and energy balances can also be maintained when analysing product systems with a global, consequential product and material flow accounting model.

Keywords: Supply-use, LCA, Data, Validation, Hybrid database.

1 The ecoinvent database

The ecoinvent Centre is the world's leading supplier of consistent and transparent Life Cycle Inventory (LCI) data, i.e. data on inputs and outputs from different human production and consumption activities. Created in 1997 and originally called the Swiss Centre for Life Cycle Inventories, the ecoinvent Centre is a joint initiative of institutes and departments of the Swiss Federal Institutes of Technology Zürich (ETH Zürich) and Lausanne (EPFL), of the Paul Scherrer Institute (PSI), of the Swiss Federal Laboratories for Materials Testing and Research (Empa), and of the Swiss Federal Research Station Agroscope Reckenholz-Tänikon (ART).

The ecoinvent Centre is the provider of the ecoinvent database, which in its current version 2.1 contains more than 4000 industrial LCI datasets. LCI data are used for Life Cycle Assessments (LCAs) for information and decision making related to Product Policy, Design for Environment (DfE), Environmental Management Systems (EMS) and Product Stewardship.

With its LCI datasets in the areas of agriculture, energy supply, transport, biofuels & biomaterials, bulk & speciality chemicals, construction materials, packaging materials, basic & precious metals, metals processing, ICT & electronics as well as waste treatment, the ecoinvent Centre offers one of the most comprehensive international LCI databases currently available. Its high-quality generic LCI datasets are based on industry data and have been compiled by internationally renowned research institutes and LCA consultants. The data are all available in the EcoSpold data format, and they are supplied with all major LCA and eco-design software tools.

1.1 New features for material flow accounting in ecoinvent version 3.0

Work is currently ongoing to prepare version 3 of the ecoinvent database for release in year 2011. Version 3 will have a number of new features that will facilitate its use in material flow accounting.

The calculation of mass balances for each activity will be facilitated by the new option to characterise each input and output flow in terms of its specific properties, including material content of specific elements or substances, and the new option to link specific inputs to specific outputs through the use of transfer coefficients. Also waste can now be described as a physical flow with specific material properties, so that a specific mass balance can be maintained throughout the waste treatment and/or recycling processes.

Version 3 of the ecoinvent database will also be prepared for integration with national supply-use data (monetary and physical input-output tables at the level of industries) by using the same statistical classification system (ISIC Rev. 4) and by adding information on price and production volume to all product outputs. This will mean that the high level of detail of the ecoinvent database can be combined with complete product balances and tracing of flows across the entire economy.

2 New features facilitating mass balances per process

2.1 Material properties per input and output flow

In the current version of the ecoinvent database, an input or output from an activity dataset can only be characterised in units of one specific property, typically mass or energy. However, in different contexts it can be different properties that are of interest. To make an energy balance, the energy content is relevant, dry mass and water content for mass balances, carbon content for carbon balances – maybe even different kinds of carbon according to origin (fossil, biogene, carbonate), not to mention the many specific heavy metals. Economists may want to make a monetary balance, requiring price to be a property of each input and output. And for material flow analysis, also the lifetime of a product may be a property of interest.

To accommodate all these different interests, the ecoinvent database version 3 will enable the recording of an unlimited number of properties for each flow.

2.2 Transfer coefficients linking specific inputs and outputs

Relating specific outputs to specific inputs through transfer coefficients (e.g. kg CO_2 output per litre diesel input, or litre juice output per kg fruit input) allows to establish mass balances per input or output, tracing specific elements and thereby discovering incorrect or missing information. Transfer coefficients can be compared across datasets as part of data validation or extrapolation.

While maintaining the option to enter output values as absolute numbers, version 3 of the ecoinvent database will allow also express outputs as calculated results using transfer coefficients.

2.3 Physical characterisation of wastes and stocks

To make mass, energy, material or monetary balances of an activity, both wastes and additions to stock need to be characterised by these properties, in the same way as all other inputs and outputs.

Seen from the waste generating activity, the treatment of waste is a service input, while the wastes are physical outputs. To avoid describing the waste treatment service in isolation from the physical waste, we can use the simple balancing rule, that a positive input is identical to a negative output. From the perspective of the waste generating activity, waste treatment can therefore be expressed as a negative service output, with a positive mass (or alternatively as a positive service input with a negative mass).

2.4 Data availability, validation options and procedural aspects of data supply

Saying that the ecoinvent database version 3 will enable the recording of transfer coefficients and an unlimited number of properties for each flow is of course not the same as saying that the database will contain information on all these coefficients and properties for each single flow. This will require a data collection effort over many years to come. In the first instance, we will focus on dry mass, water content, carbon content and price to be available for all flows, so that simple monetary, mass and carbon balances can be made. Already this will be a major improvement.

When many different balances can be made at the same time, this increases the options for cross-validation of data.

The data for the ecoinvent database are supplied by many different experts from each their field of expertise. Review and validation are performed by domain experts. Special cross-cutting editors for the entire database have the task to ensure consistency in the way data sources are used, flow properties are entered, and balances performed.

3 Preparing for integration with national supply-use data.

National supply-use data in physical units allows performing mass balances across the entire economy, due to the complete coverage of all human activities. However, supply-use data are aggregated to a level that makes it difficult to obtain meaningful results for specific products. Combining the detail of the ecoinvent LCI database with the completeness of national supply-use data holds the promise to obtain the advantages of both: Completeness *and* detail. In addition to the balances per industry and per activity, adding data for imports and exports allows to make mass balances for geographical units. The simple rule that what is produced must also be used, allows product balances to be established across the economy, completing the data gaps in the bottom-up LCI data.

3.1 Embedding bottom-up activity data in a supply-use framework

Embedding bottom-up activity data in a national supply-use framework is theoretically straightforward. The data fit into the same basic format (activities with inputs and outputs) and their origin is also the same (industry data) although their subsequent treatment has made them look quite disparate. The nationally aggregated supply-use data may be seen as default datasets for an industry, which are then broken down by the aid of the bottom-up data, either completely or resulting in a *residual* default dataset (for that part of the industry for which bottom-up data were not available).

In practice, the embedding may involve a substantial amount of work to align the two data sources. It requires that the data sources are (re-)classified in the same classification system, and that prices and production volumes are available for each of the bottom-up datasets, in order to scale them up to the national level and subtract them from the industry level data, thereby creating the completing residual datasets.

Furthermore, the scaled up product data must be balanced across the economy, and the residuals redistributed to the detailed activity datasets. With an appropriate software algorithm, this part of the embedding can be done automatically.

While monetary supply-use data are available for most countries, their physical equivalents are not produced on a regular basis but have to be calculated from resource and production statistics, import and export data, and price information for products. The need to maintain a balance across the economy as well as for each individual activity provides rich options for validation, thus reducing the overall uncertainty of the exercise.

The ecoinvent Centre plans to provide a guideline for formatting monetary and physical supply-use tables so that they become applicable for integration with bottom-up LCI data.

4 Using process data for policy analysis

The detailed material flow accounting that will be possible with the ecoinvent database version 3 can be used to analyse the drivers of and policy responses to resource use, answering questions such as:

- How are resource extracting activities affected by changes in final demands for products or changes in production and consumption technologies, including recycling activities?
- How will specific policy responses, such as different kinds of support for recycling activities, affect the resource use and what side-effects will this have on other activities and what will be the overall biophysical, social and economic impacts?

4.1 Modelling material flows for policy analysis

Since policy analysis is concerned with “what if” questions, i.e. consequences of changes, the most appropriate modelling approach is what has become known in LCA terminology as “consequential” modelling, i.e. the analysis of how the system and its individual activities change as a result of a specific decision.

Consequential modelling requires knowledge about market boundaries, since a decision affects specific markets, and within each market specific activities are affected while others may not be affected due to constraints in their ability to change in response to changes in demand. To allow consequential modelling, the ecoinvent database version 3 will provide specific market datasets for every modelled product. For some products, like aluminium, there is only one global market, while other products, like building products, have specific local markets, delimited by physical or administrative barriers.

4.2 Policy relevance of mass balances for geographical units

Mass balances for specific activities and geographical units are the core statistical basis for any material accounting model. A material balance for an administrative area may obviously also be of policy interest, e.g. to design and monitor the use of taxation or quota instruments, if there is a policy goal to reduce specific flows within the area.

However, if the administrative area is not isolated, i.e. if imports and exports occur, the effects outside the administrative area will not be covered by a material balance for the area alone. For such situations, and where the global consequences of a decision are of policy concern, the appropriate model to use is a global, consequential product and material flow accounting model. Such a model builds on the statistical data for specific activities and geographical units, but links these activities and geographical units according to how changes in one unit affects the other units.

4.3 Maintaining mass balances in a product system

Mass, energy and monetary balances can also be maintained in a material flow accounting model for a product system in which the individual activities needed to produce the product are linked. However, this requires that the individual activity datasets are maintained intact, and not allocated.

Allocation (partitioning) of inputs and outputs of an activity over the product outputs from the activity implies an artificial sub-division of the activity according to a specified allocation key. Most often, the applied allocation key is the revenue obtained from the products, but also the use of mass or energy content is quite common in LCA practice, although allocation is generally dissuaded by both the ISO 14044 LCA standard and by economic modellers (Almon 2008, Konijn 1994).

After allocation, the resulting artificial sub-activities have only one product output, which is the purpose of the allocation, and all the other inputs and outputs are included in the allocated sub-activities in proportion to the specified allocation key. If the allocation key is mass, the mass balance remains intact for the sub-activities, but energy and elementary balances (e.g. the carbon balance) are skewed; with economic allocation none of the physical balances remain intact in the sub-activities except if by chance there is a physical parameter that follows the revenue from the products.

Avoiding allocation by the use of system expansion, as required (or recommended, depending on stringency in interpretation) in the ISO 14044, has the advantage that all balances remain intact in the expanded systems, i.e. both mass balance, energy balance, monetary balances, and balances for each element remains intact. The reason for this is that in the system expansion procedure, where the alternative production route for the by-product is subtracted from the system producing the by-product, all the affected unit activity datasets are scaled up or down, but there is no artificial partitioning, and since the resulting system is a simple sum of the affected activity datasets, each of which maintain their balances intact, all physical and monetary balances will also be intact in the resulting system.

By supporting consequential modeling, version 3 of the ecoinvent database will therefore be able to support complete physical balancing of the included product systems.

References

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