MODELLING PRINCIPLES FOR THE COLLECTION OF CONSISTENT AND COMPREHENSIVE LCI DATA

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ABSTRACT

There are several European or international Life Cycle Inventory (LCI) databases available for Life Cycle Assessment (LCA) studies. For LCAs in New Zealand overseas data have to be used as no NZ data are available. This has led to criticism about whether the results are appropriate for New Zealand or not. There is only one way to respond to the critics: a NZ LCI database has to be developed. The first step is to define modelling principles for the collection of LCI data. This study gives an overview of the main modelling principles which are used in the ecoinvent LCI database and are planned to be used in the future Australian LCI database. The idea of this paper is to provide information for an early discussion on how New Zealand might potentially collect and present LCI data.

The Swiss LCI database *ecoinvent* has applied a consistent set of data collection principles. Ecoinvent is compatible with most common LCA Software tools (GaBi, SimaPro and others). It contains around 3500 datasets for unit processes which are fully consistent, transparent, harmonised and quality controlled for a large number of economic sectors: e.g. energy supply, building and construction, transportation, chemicals, etc.

The Australian LCI database (AUSLCI) initiative has currently published a draft version of their modelling principles. It will most probably adapt the data exchange format *EcoSpold* which is used for the U.S. LCI database as well for the ecoinvent database. EcoSpold enables extensive documentation, individual determination of allocation factors and, if required, confidential data management. The EcoSpold data format is open source (public licence) and independent of the database.

The development of a national LCI database for New Zealand should rely on the experiences made overseas. The presented modelling principles include a discussion on the geographical, temporal and technical scope, possible definitions of cut-off rules including problems of applying them, and whether to include capital goods or not, options for dealing with transportation distances, options on how waste treatment as a technical process could be included and how to include the overall impact of long-term emissions from landfills.

The conclusion is that New Zealand should start developing a national LCI database to counter complaints that it is not appropriate to use European/international datasets for an LCA in this country. It is recommended to stick to the planned Australian LCI database in order to be consistent and to minimise time and cost.

KEYWORDS

LCA, LCI, Database, EcoSpold

INTRODUCTION

All the LCA studies conducted in New Zealand include overseas LCI data as no comprehensive New Zealand LCI database is available. It is quite possible that direct input and output data for certain products (fibre cement cladding) or processes (wood drying) are based on national, local or even product-specific data but as soon as they are linked to the upstream products and processes generic LCI data from existing overseas databases are used. Most studies do not include a comprehensive analysis of the results following the upstream production chain back to the extraction of its raw materials (e.g. raw oil, limestone, etc.) to find out which of the products or processes have a significant impact on the result. This could be a product/process which relates to a different geographical region (e.g. Germany) and therefore not suitable for use in an LCA of a New Zealand product/process.
The only longer-term solution to this problem is to develop a New Zealand (or combined Australian/New Zealand) LCI database. To make it easier to perform life cycle assessment studies, and to increase the credibility and acceptance of the life cycle assessment results it is important to have consistent, coherent and transparent LCA datasets for basic processes. To assure quality of the life cycle inventory data it is a prerequisite to establish modelling principles. Besides aiding the collection of data they have to be presented in a form which enables fully transparent, and hence fully reviewable and verifiable data documentation. ISO 14048 (based on 14040) includes the data documentation format for LCI datasets for complete life cycle inventories, individual plants, and production lines, for example.
One of the widespread LCI data formats, EcoSpold, complies with ISO 14048. EcoSpold is used for the U.S. LCI database, and it is planned to use it for the future Australian database AUSLCI and the Swiss LCI database ecoinvent (www.ecoinvent.com). The technical specification, however, does not provide guidance on how to collect and prepare verifiable environmental information. An important part of this study is therefore to provide an overview of the EcoSpold Format in general and of the main modelling principles used in the ecoinvent database.
Another data format used in Europe is the ELCD (European Life Cycle Database) developed by the Joint Research Centre of the European Commission who decided for unknown reasons to use a different data format. Fortunately there is a format converter offered by Chalmers, a Swedish University.
This study gives an overview of the main modelling principles that are used in the current ecoinvent LCI database and are planned to be used in the future Australian LCI database. The idea is to provide a basis for a discussion on how data could be collected in New Zealand.

ECOSPOLD LCI DATA DOCUMENTATION FORMAT

General

Parallel to the increased application of life cycle assessment in environmental policy and in industry, the demands for sufficient life cycle inventory data documentation are continuously increasing. The use of a standard data format facilitates the documentation of LCI data with information beyond bare input and output figures. Many leading LCA software tools are able to import EcoSpold datasets. That is why LCI data in EcoSpold format can be used independently of any particular LCA software tool (incl. ecoinvent database) and data exchange between LCA practitioners becomes more feasible. The EcoSpold software is open source software which means that the files are available to the general public with relaxed or non-existent intellectual property restrictions.
EcoSpold is a LCI data exchange format which is derived and simplified from an older version SPOLD 97/99 and has been adapted to the ISO 14048 data documentation format. Figure 1 gives an overview of the EcoSpold format in the ecoinvent database.

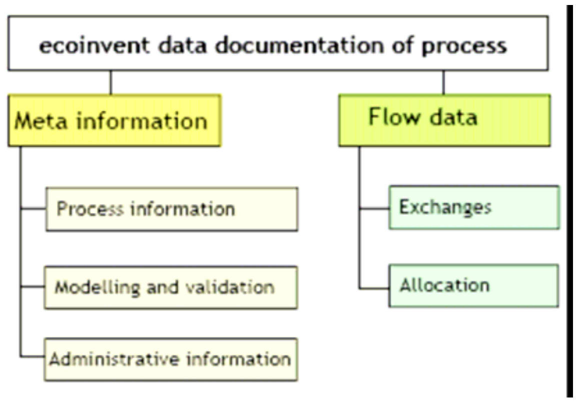

Fig. 1 General structure of the EcoSpold data format in the ecoinvent database

A process, its products and its life cycle inventory data are documented in the ecoinvent LCI database using the ecoinvent data format (EcoSpold) with the basic structure shown in Figure 2 (Frischknecht et al. 2004).

Meta information			
	Process		
		ReferenceFunction	defines the product or service output to which all emissions and re-quirements are referred
		TimePeriod	defines the temporal validity of the dataset
		Geography	defines the geographical validity of the dataset
		Technology	describes the technology(ies) of the process
		DataSetInformation	defines the kind of process or product system, and the version num-ber of the dataset
	Modelling and validation		
		Representativeness	defines the representativeness of the data used
		Sources	lists the literature and publications used
		Validations	lists the reviewers and their comments
	Administrative information		
		DataEntryBy	documents the person in charge of implementing the dataset in the database
		DataGenerator AndPublication	documents the originator and the published source of the dataset
		Persons	lists complete addresses of all persons mentioned in a dataset
Flow data			
		Exchanges	quantifies all flows from technical systems and nature to the process and from the process to nature and to other technical systems
		Allocations	describes allocation procedures and quantifies allocation factors, re-quired for multi-function processes

Fig. 2 Structure of the EcoSpold data format

The structure shown in Figure 1 and 2 demonstrates how extensive the documentation is. Besides documenting the studied process, it also includes all the direct input and output flows to the process from technical systems (e.g. cement as input for concrete) and from nature (e.g. limestone in nature), and from the process to nature (e.g. CO_2-emissions from cement production) and to other technical systems (e.g. waste disposal). Another important part concerns allocation decisions to be made for multi-function processes. ISO 14040 puts down three principles of allocation (see subchapter “Allocation and multi-output processes” later in this report).
The different elements in Figure 2 (e.g. technology) can be used for the description of unit processes (direct inputs and outputs), product systems (LCI results), elementary flows and impact assessment methods and results.

EcoSpold in ecoinvent

The data format was developed within the ecoinvent projects, and it became the most widespread, complete, working LCI data exchange format worldwide. All leading LCA software tools (SimaPro, GaBi, Team, Umberto, etc.) implemented the EcoSpold data format interface to enable easy importing and partly also editing and exporting of EcoSpold datasets. Beside the ecoinvent database, LCI data in the EcoSpold format are available from the US LCI database and will possibly be available from the future Australian database.

DATA COLLECTION BASED ON ISO 14044

Based on ISO 14040 and ISO 14044 the definition of the goal and scope of a study provides the initial plan for conducting the life cycle inventory phase of an LCA. The operational steps for executing the life cycle inventory analysis are outlined in Figure 3 (it should be noted that some iterative steps are not shown in that figure).

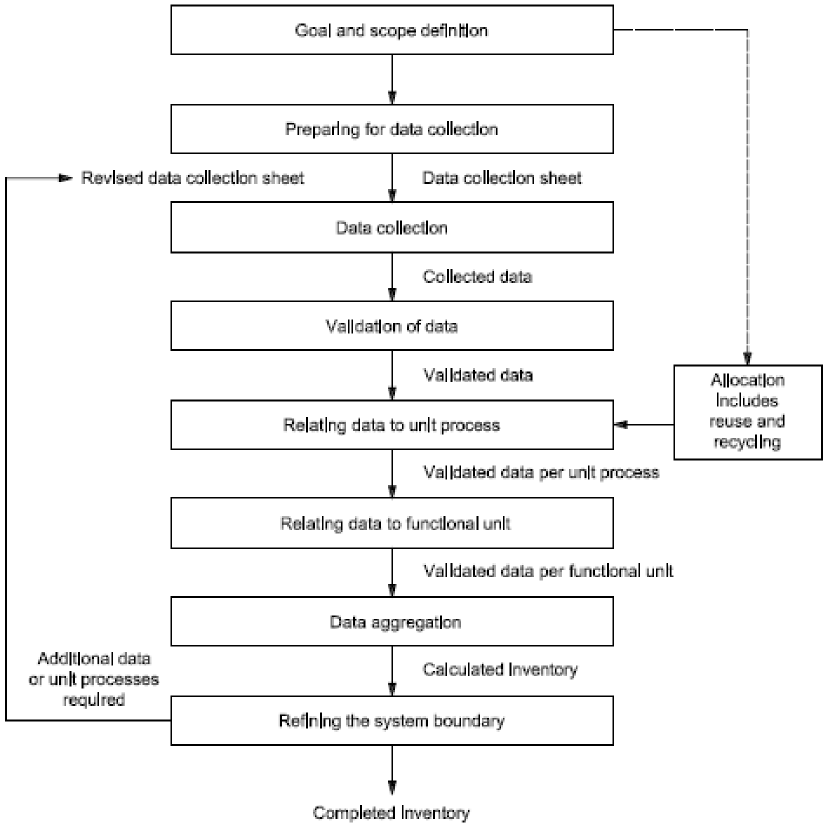

Fig. 3 Simplified procedures for inventory analysis (ISO 14044)

DATA COLLECTION AND MODELLING PRINCIPLES

Introduction

The numerous types of data that can be used for conducting an LCI include primary and secondary data. The primary data are those obtained from specific facilities (e.g. industry) and the secondary data are those included in the product system life-cycle inventory that have been obtained from published sources (e.g. published literature, other LCI studies, emissions permits, etc.) (ALCAS 2006). This study concentrates on the collection of primary data which are often supplied by companies. The selection of goods and services to be analysed has to rely mainly on the market and consumption situation; this can make collection quite difficult if the market includes several similar products made by different companies. The simplest situation for collecting and publishing average national LCI data is therefore when a product of a certain company has the main part of the market (e.g. glass wool insulation) within a geographical region (e.g. New Zealand). If such a market is shared by different producers, weighted average LCI datasets should be calculated. Accordingly the effort required is greater.

Definition of unit process raw data

ISO 14040 describes a unit process as the "smallest portion of a product system for which data are collected when performing a life-cycle assessment". This would include all direct input and all direct output products and processes (elementary flows). Input products/processes can be resources from nature (e.g. limestone), processed materials from technosphere (e.g. quicklime), (semi-finished) products (e.g. plastic foil), capital goods (e.g. machine, building), processes (packing) and energy (e.g. heat from gas). Output products/processes can be emissions to water/soil/air (e.g. CO_2 to air, heat), waste (e.g. plastic foil to landfill) and products (e.g. brick).

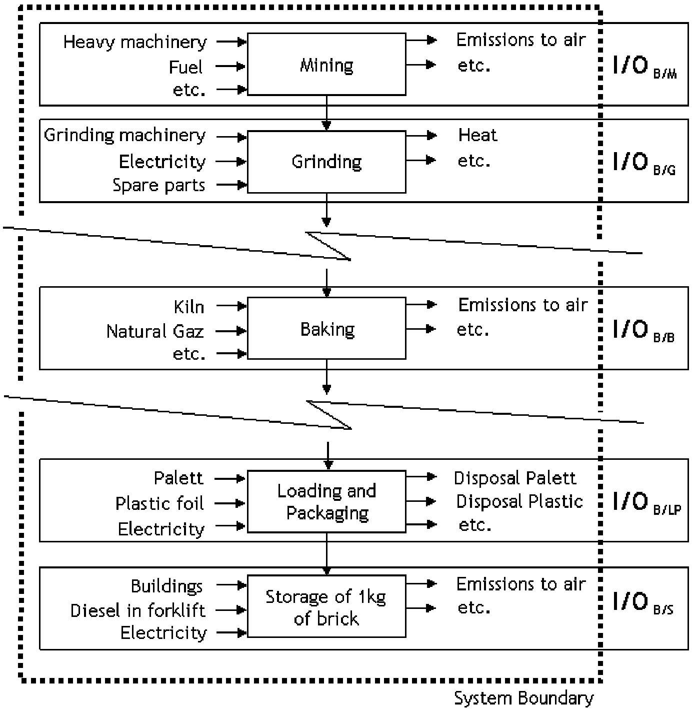

Fig. 4 Example of a unit process

The example of brick in Figure 4 shows possible elementary flows separated into the different production steps. I/O $_{B/B}$ stands for **I**nput/**O**utput of the **B**acking process within **B**rick production. As far as possible, the collected data on a unit process level should be aggregated neither vertically (summarizing different life cycle steps, e.g. mining and grinding) nor horizontally (using aggregated Input or Output data). Exceptions are possible if only cumulative datasets are available (e.g. chemicals in the ecoinvent database).

Geographical scope

This is important for the collection of New Zealand LCI data as the market is strongly infiltrated by overseas products. In the ecoinvent database (Frischknecht et al. 2004) goods and services are described at the level of economic regions within which such a distinction in meaningful. For cement, for instance, a national distinction is useful and meaningful because cement is hardly traded across national borders and trade movements are rather easy to identify. For globally traded products such as steel, a distinction at the level of continental economies (New Zealand, Australia, Asia, Northern

America) is sufficient because these commodities can hardly be traced back on a national or regional level.

ALCAS (2006) states in the discussion draft on Guidelines for Data Development for an Australian LCI Database for non-domestic products that they "should be modelled as Australian production with adjustment for fuel mixes for the dominant country(ies) of origin and the relevant transport impacts of importing unless there are LCI data from the data of origin which is consistent with the scope of this LCI." This Guideline aims to offer LCI data specific to Australia whereas the ecoinvent LCI database tries to represent the reality, although assumptions are essential for information which is not available.

Temporal scope

As production processes and therefore the elementary flows can change very fast depending on the product/process, it is important to target a certain year of validity. The choice of one single year increases the transparency and facilitates future updates. It is obvious that the electricity mixes especially can change pretty quickly when, for example, a new giant wind farm is connected to the grid. If data for the targeted year are not available, the published data then must be declared. This is a requested part of the Meta information in the EcoSpold format. The ecoinvent database has defined the year 2000 as the reference year.

Emissions in the ecoinvent LCI database are included without temporal boundaries. This means that emissions produced in the past (e.g. construction of infrastructure), the present (e.g. heating) and the future (e.g. disposal options) are all included in the inventory analysis.

Technical scope

As already stated above, the production processes can change very fast but they can also vary considerably within a certain product (e.g. brick). Therefore the technology represented in the dataset should be clearly defined. The processes included in the ecoinvent LCI database (Frischknecht et al. 2004) usually represent the average technology in operation in the year 2000. In a few cases the average of technologies offered on the market today, the best available technology or even near-future best available technology is modelled additionally.

Cut-off rules

According to ISO 14044, the criteria used to decide which inputs are to be studied include a) mass, b) energy, and c) environmental relevance. For the development of the ecoinvent LCI datasets no quantitative cut-off rule is prescribed. Environmental knowledge of the experts involved in compiling the LCI data is used to judge whether or not to include the production of a certain input or the release of a certain pollutant (Frischknecht et al. 2004). In contrast the "Guidelines for Data Development for an Australian LCI database" (ALCAS 2006) prescribe that "mass or energy flows of less than 1% may be excluded but total exclusions should not represent more than 5%. Items with a significant environmental impact in any indicator, such as highly toxic inputs, should be included regardless of mass or energy flows. Small flows should also be included when data is available." For example, the use of less than 1% by weight of a wood-treating chemical (heavy-metal based) can have a significant impact on air/water/soil. To decide whether an item has a significant environmental impact a lot of expert knowledge is needed. This shows how difficult it is to apply the rules.

Capital goods

Althaus et al. 2005 in "Manufacturing and Disposal of Building Materials and Inventorying Infrastructure in ecoinvent" questions why capital goods should be included, starting with different definitions of capital goods. In lexicons and dictionaries the definition ranges from "the foundation or underlying framework of basic services, facilities and institutions upon which the growth and development of an area, community or a system depend" to "the basic facilities, equipment, and installations needed to provide the utility products and services crucial for the growth and functioning

of an economy, community or organization" (explicitly including "the safety and control engineering systems (not only hardware devices, but including operational procedures, organization and management) needed to make the system function according to its functional specifications"). It is questionable debate whether, for example, an extruder to manufacture plastic tubes would be considered infrastructure according to these definitions. The electricity network on the other hand clearly would be. Depending on the definition, the environmental impacts of some processes are caused exclusively by the infrastructure involved. Examples are hydro, wind and solar power. For material production, on the other hand, infrastructure usually is responsible for almost none to about 10% of the environmental impact. Thus, the consistency of all data in a generic database in every possible context depends on infrastructure being included in the inventories.
For these reasons, the ecoinvent team decided to include infrastructure. To ensure it is inventoried in ecoinvent as consistently as possible, the administrators produced a common set of rules:

- Technical production facilities such as factories, machines, roads, cars, electricity transmission networks, etc. are regarded as infrastructure.
- Natural means of production such as mineral extraction sites, forests or agricultural land are not considered infrastructure.

The second rule is still problematic in a system of life cycle unit processes because it depends on the point of view whether a dataset is to be considered as "production facility" or as product. Drilling of a well for exploration and production of oil, on the one hand, is a process with a drill as infrastructure. On the other hand, the well itself is the infrastructure for the extraction of oil. In such cases the final intention of an ecoinvent dataset is used. In this example, the drilling of the well is regarded as infrastructure because it is intended to be used only in this context and not for an analysis of the process of drilling.
After the release of the latest version of the ecoinvent LCI database (v.1.3) the impact of capital goods on the overall results in different dataset categories was analysed (Frischknecht et al. 2007) and the recommendation was that "the capital goods must be included in the assessment of climate change impacts of non-fossil electricity, agricultural products and processes, transport services and waste management services. They must be included in any sector regarding the assessment of toxic effects. Energy analyses (quantifying the non-renewable cumulative energy demand) of agricultural products and processes, of wooden products and of transport services should include capital goods as well." This indicates that, in assessment of mineral building materials, capital goods do not necessarily have to be included.
The datasets in the ecoinvent LCI database have separate inputs and outputs for the production means (machinery, etc.) and the capital goods. This allows them to be excluded easily if used with datasets that do not have capital goods included.
The discussion paper on possible guidelines for an LCI database in Australia (ALCAS 2006) states that estimates of infrastructure are to be included in the system; however, administrative overheads are not.

Transport

The ecoinvent LCI database offers generic transport datasets for air, rail, road and water transportation. In order to facilitate easy application, the reference unit for all data is a 1-tonne kilometre with average load factors. If no detailed real market information is available, standard distances are applied on the ecoinvent LCIs. For most materials 100 km by road (lorry) plus 200 to 600 km by rail are assumed (Frischknecht et al. 2004). They can easily be changed by copying the dataset and creating a new one with a specific transport distance.
For the Australian LCI database (ALCAS 2006) it is planned to make a standard unit available for average transport modules. These should then be used by all other inventories unless the transport is a significant input and likely to be different from the average mix. To this author that approach might lead to difficulties because it assumes a lot of knowledge on the part of the data collector. Whether an Input is significant or not can only be proved after having it included and after calculating an LCA.

Waste treatment

Waste treatment is part of the technical system (based on Frischknecht et al. 2004) and is therefore modelled like all other technical processes in the ecoinvent LCI database which means that it is part of the technical systems. The processes deliver the service of waste treatment. If information on the treatment of specific waste is not available, generic treatment processes are applied according to the list in Figure 5.

Material	Standard disposal route
plastics	waste incineration
wood and particle board cardboard and paper	waste incineration
concrete and other mineral building materials (incl. gypsum)	datasets 'disposal, building, ..., to final disposal', include the dismantling/ demolition of the building, waste goes to inert material landfill, without recycling or sorting
glass	inert material landfill
oils	hazardous waste incineration
metals, if separable	recycling
coating on metals	recycling, disposal of the coating considered in the recycling process

Fig. 5 Material-specific waste treatment processes missing particular information used in the modelling principles of the ecoinvent LCI database

A study on waste treatment and assessment of long-term emissions (Doka & Hischier 2005) states that "the landfills prove to be generally relevant disposal processes, as also incineration and wastewater treatment processes produce landfilled wastes. Heavy metals tend to concentrate in landfills and are washed out to a varying degree over time. Long-term emissions usually represent an important burden from landfills. Comparisons between burdens from production of materials and the burdens from their disposal show that disposal has certain relevance."

The variety of disposal options in New Zealand is very small as all the waste goes to land fill. For each of the datasets a default disposal dataset would be very useful. Experience has shown that one has to be very careful that the disposal process uses the same material characteristics (water content in wood) as the original product in the database although some examples have shown that the characteristics of certain materials will change over the life span (e.g. wood often dries out). The only way to deal with this is to make transparent all the assumptions essential for the disposal dataset.

Allocation and multi-output processes

Processes that result in several products are called multi-output process. Figure 6 shows an example:

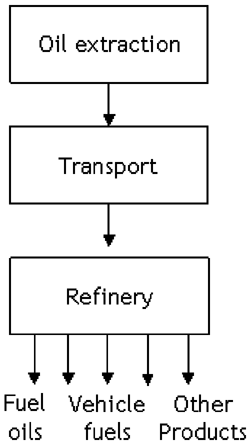

Fig. 6 Example of multi-output (refinery) taken from Baumann & Tillmann 2004

Allocation is defined in ISO 14040 as "Partitioning the input or output flows of a unit process to the product system under study". A possible allocation problem would be when waste incineration has two functions: it does away with the waste and at the same time it delivers heat for a district heating system. The problem of how to allocate the emissions from incineration can be solved by partitioning them between the two functions, waste treatment and heat production. An important aspect which is not dealt with in this study is choice of a suitable allocation method (economics, weight, volume, etc.) (Baumann & Tillmann 2004).
A short version of the ISO allocation procedure (ISO 14044) states:

1. Whenever possible allocation should be avoided by
   a. Increased level of detail of the model
   b. System expansion.
2. Where allocation cannot be avoided the environmental loads should be partitioned between the system's different functions. Partititioning should reflect the underlying physical relationship. The resulting allocation will not necessarily be in proportion to any simple measurement such as the mass or molar flow of co-products.
3. Where physical relationships alone cannot be established or used, allocation may be based on the **other relationship** between products, such as economic value of products.

In the ecoinvent LCI database (Frischknecht et al. 2004) "multi-output unit processes are entered into the database before allocation. Additionally, the allocation factor applied is defined at the multi-output process level. The database creates single output processes with the help of multi-output process data and their allocation factors. Allocation factors are separately attributed to each individual input and output has been applied. System expansion is avoided wherever possible. In most cases, allocation according to "other relationship" (see short version of ISO allocation procedure above) is used. Where possible, processes have been split up in order to avoid allocation. For oil refineries, for instance, allocation factors have been determined on the basis of detailed mass and energy flows of the individual sub-processes such as atmospheric distillation, etc."
The discussion draft paper on guidelines for data development for an Australian LCI database (ALCAS 2006) has adopted the same approach proposing that "all multi-output processes shall be documented in an unallocated from, with allocation factors for individual product streams specified". It also proposes that "allocation should be based on physical causation or economic value and may be undertaken at a flow by flow level rather than only at a process level. No system boundary extension will be used but information and model structure should be provided to allow for uses to undertake such allocation."

It seems that the two LCI databases are very much in agreement on this point.

There are some more modelling principles which need clarification before collecting data:

1. **Land-use**: Is included in the ecoinvent LCI database and it is planned to include it in the future Australian LCI database
2. **Uncertainty consideration**: Is included in the ecoinvent LCI database but no information has been found for the future Australian database
3. **Recycling**: In the ecoinvent LCI database the cut-off approach has been applied, whereas the future Australian database plans separate open and closed loop recycling. Open loop will be based on the recovery rates for the material in Australia, and closed loop will use the cut-off approach which means that recycled materials will enter the system burden-free (only collection and recovery will be included)

CONCLUSION

A lot of people in New Zealand and Australia complain that it is not appropriate to use European data for an LCA. Most LCA studies in these countries mix local data (on the unit process level) with European data (for the upstream and downstream processes) due to lack of a consistent database. These critics must be taken seriously and, as noticed in Australia, a consistent LCI database is needed. This paper shows the most important issues when collecting LCI data. It discusses the main modelling principles on the basis of the ecoinvent LCI database and compares them with the draft guidelines for development of a future Australian LCI database.

Unfortunately it seems that the Australian database does not use exactly the same modelling principles as the ecoinvent database. The main reason is because the Australians are trying to compile information that will best serve the end user(s) of the LCI data.

Before collecting data in different data formats and with different modelling principles it is therefore important that New Zealand starts a serious discussion on an appropriate future strategy.

Defining modelling principles for the collection of consistent and comprehensive LCI data is a long and therefore cost intensive process. This is mainly because it has to be well-founded and well-accepted by a wide range of stakeholders. To avoid this huge effort and to save time it should be considered to follow the Australian example and to represent New Zealand’s interests within that database.

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