Swiss Centre
for Life Cycle
Inventories

Overview and methodology (draft)

Data quality guideline for the ecoinvent database version 3.0

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Acknowledgements v3

This data quality guideline builds upon the previous ecoinvent reports 1 and 2 (Frischknecht et al. 2007b, 2007c). A short history of the ecoinvent database is reported in Chapter 17.

Support for the continuous development of the ecoinvent database has been received from [sponsors and in-kind contributors to be acknowledged].

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Structure of this report

This report provides an introduction to the purpose of the ecoinvent database developed by the Swiss Centre for Life Cycle Inventories (Chapter 1), the applied LCA methodology (Chapter 2), and the general structure of the database (Chapter 3).

The main part of the report is the specific quality guidelines (chapters 4 to 11), established in order to ensure a coherent data acquisition and reporting across the various activity areas and data providers involved. This encompasses definitions of the different types of datasets, the level of detail required, how completeness is ensured, good practice for documentation, naming conventions, and rules for the reporting of uncertainty.

Chapters 12 and 13 describe the procedures for validation, review, and embedding new datasets into the database.

The calculation procedures for attributional and consequential models, and for arriving at the accumulated results for product systems, are described in Chapter 14.

Chapter 15 and 16 give advice to the database users and those who wish to contribute to the database.

Finally, Chapter 17 gives a short history of the database development.

[The sections in square brackets entitled "Changes relative to ecoinvent version 2" are not intended for the final version of this guideline, but serves as information during the development]

Table of Contents

1 Purpose of the ecoinvent database

The Swiss Centre for Life Cycle Inventories (the ecoinvent Centre) has the mission to promote the use and good practice of life cycle inventory analysis through supplying life cycle inventory (LCI) data to support assessment of the environmental and socio-economic impact of decisions.

The strategic objective is to provide the most relevant, reliable, transparent and accessible LCI data for users worldwide.

The ecoinvent database comprises LCI data covering all economic activities. Each activity dataset describes an activity at a unit process level. The complete list of all names of datasets, elementary exchanges, and of all regional codes is available at www.ecoinvent.org.

Consistent and coherent LCI datasets for different human activities make it easier to perform life cycle assessment (LCA) studies, and increase the credibility and acceptance of the LCA results. The assured quality of the life cycle data and the user-friendly access to the database are prerequisites to establish LCA as a reliable tool for environmental assessment that will support an Integrated Product Policy. Data quality is maintained by a rigorous validation and review system. The report at hand reports the data quality guidelines applied.

The ecoinvent LCI datasets are intended as background data for LCA studies where problem- and case-specific foreground data are supplied by the LCA practitioner. For comparative assessments, with the aim to identify environmentally preferable goods or services, the LCI and life cycle impact assessment (LCIA) results of ecoinvent datasets should not be used directly, without considering the relevance and completeness of the data for the specific assessment.

The ecoinvent datasets may also be useful as background datasets for studies in material flow accounting and general equilibrium modelling. The ecoinvent Centre is interested in a dialogue with such user groups, to improve the usability of the datasets in such contexts outside the narrower LCA field.

2 LCA methodology

2.1 LCI, LCIA and LCA

The ecoinvent database builds on the method of life cycle assessment (LCA) as standardised by International Organisation for Standardisation (International Organization for Standardization (ISO) 2006a; International Organization for Standardization (ISO) 2006b). LCA studies systematically and adequately address the environmental aspects of product systems, from raw material acquisition to final disposal (from "cradle to grave"). The method distinguishes four main steps, namely (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation (see Fig. 2.1).

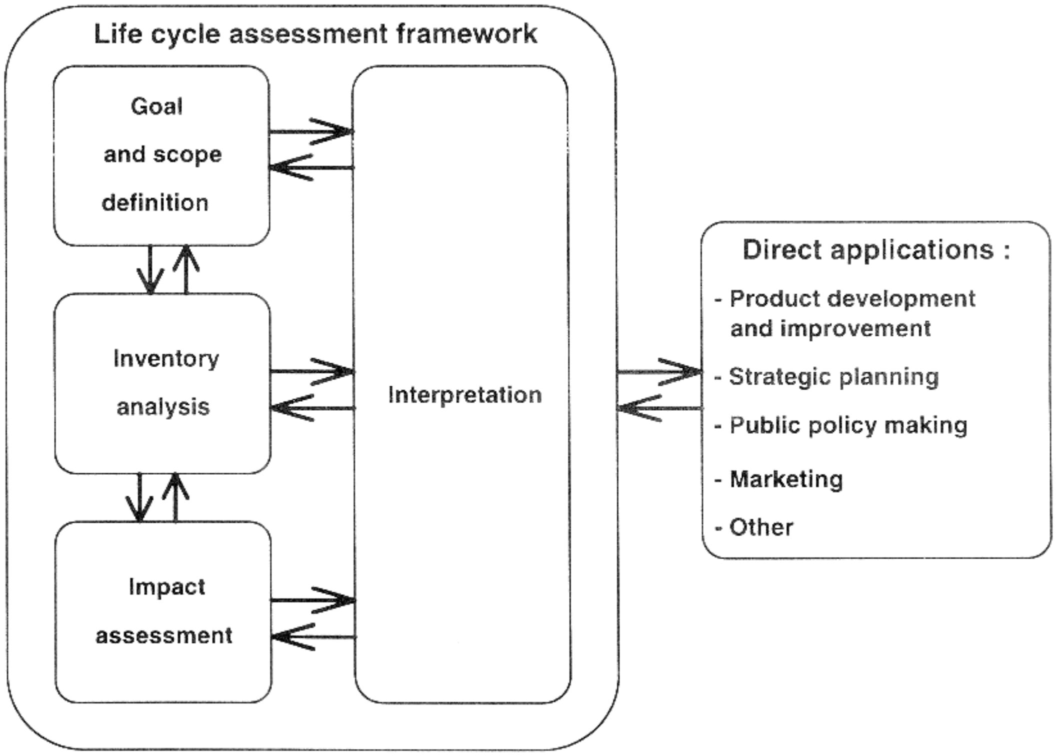

Fig. 2.1 Phases of an LCA (International Organization for Standardization (ISO) 2006a)

Focus of the ecoinvent database is on the compilation of the basic building blocks (LCI datasets), representing the individual unit processes of human activities and their exchanges with the environment, and the combination of these LCI datasets through the use of market models in life cycle inventory analysis (LCI), thus constructing life cycle inventories. Nevertheless, the ecoinvent database also contains data on impact assessment (LCIA) methods and results of applying these methods to the LCI data. However, the work on LCIA is limited to the implementation of already developed LCIA methods, such as the ecological scarcity or the Eco-indicator methods. No new ("ecoinvent") method has been developed (except for the cumulative energy demand, CED, for which no "official" or unified implementation exists). The implementation of the LCIA methods is done with the aim of giving guidance on how to combine ecoinvent LCI results with characterisation, damage or weighting factors of currently available LCIA methods.

2.2 Attributional and consequential modelling

For life cycle inventory analysis it is common to distinguish between consequential and attributional modelling (see Ekvall 1999; Frischknecht 1997; Guinée et al. 2001; Weidema 2003, Weidema & Ekvall 2009). The ecoinvent database with its modular structure supplying multi-product unit process raw data is suited to support both types of inventory modelling.

Consequential and attributional modelling is distinguished in two aspects:

- The linking of inputs to average or unconstrained suppliers, respectively, for attributional and consequential models.
- The procedures to arrive at single-product systems in situations of joint production of co-products, where attributional models partition (allocate) the co-producing system into two or more single-product systems, while consequential models eliminate the by-products by including the counterbalancing changes in supply and demand on the affected markets.

To allow calculation of both consequential and attributional model implementations of the ecoinvent database, the following data are required for each activity:

- Amounts for each co-product of the product properties that are applied for allocation (e.g. price, exergy, dry mass, carbon content).
- The distinction of reference products (determining products) from by-products, since the latter must be eliminated from consequential models.
- Market trends, since consequential models distinguish different suppliers to be affected on shrinking and growing markets.
- Technology level, since consequential models regard only activities with specific technology levels to be affected by changes in demand.

The specific way these data are included in the individual datasets is described in Chapters 4 to 6. More details on the construction of attributional and consequential implementations are provided in Chapter 14.

3 The basic structure of the ecoinvent database

The basic building blocks of the ecoinvent database are LCI datasets, representing the individual unit processes of human activities and their exchanges with the environment. For a more detailed description of the concept of datasets and exchanges, see Chapter 4.1. However, the ecoinvent database is not just a library of LCI datasets. The datasets are interlinked, so that all intermediate goods and service inputs to a unit process, be it the consumption of electricity, the demand for working materials, or the use of capital equipment, are linked to other unit processes that supply these intermediate goods and services. The accumulated LCI result for a dataset is calculated by following the supplies of intermediate inputs of each dataset and adding the environmental exchanges of these interlinked datasets. The calculation is done by matrix inversion, see Chapter 14.8 for details. This implies that any change in one unit process dataset will influence the accumulated LCI results of almost all other datasets.

In addition to the unit process LCI datasets, and the accumulated LCI results for these datasets, the ecoinvent database also contains data on impact assessment (LCIA) methods and results of applying these methods to the LCI data.

A large, network-based database and efficient calculation routines are required for handling, storage, calculation and presentation of data. These components are partly based on preceding work performed at ETH Zurich (Frischknecht & Kolm 1995).

The following text refers to Figure 3.1 and describes first the different sections of the database itself, and next the flow of a dataset through the editorial process.

The database consists of several separate sections. Besides the ones mentioned here, which concern only the datasets, there is also a section for administration of access rights etc. of data providers, reviewers and end users. Also not shown in the figure is the ‘service layer’ of the database, consisting of functionalities for import, export, validation etc. that are common for more than one of the satellite components. Many of the functionalities are in practice placed in this service component, and shared by the different user interfaces.

From the top down in the figure:

The first section contains incomplete datasets, which gives a data provider the option to use the validation functions of the database service layer during the editing and before the final upload to review.

The second section contains datasets currently under review, in their different stages of commenting and revision.

The third section contains the working version of the database, which contains all datasets that have currently passed the review and are therefore uploaded by the final editor for integration into the database, but which are not yet part of the current official version.

The fourth section only exists temporarily, when the database administrator initiates the preparation of a new release. At this point in time, a copy of the current working version becomes the pre-release candidate, which is closed for further entries. The result calculations are made on this version, and when this has been successfully completed, the pre-release candidate becomes the new ‘Current official version’, while the previous official version is retained together with all other older versions.

The current official version is the one accessed by the end-users and resellers through ecoQuery (the web-interface www.ecoinvent.org), while they – depending on user rights – also have access to the older versions.

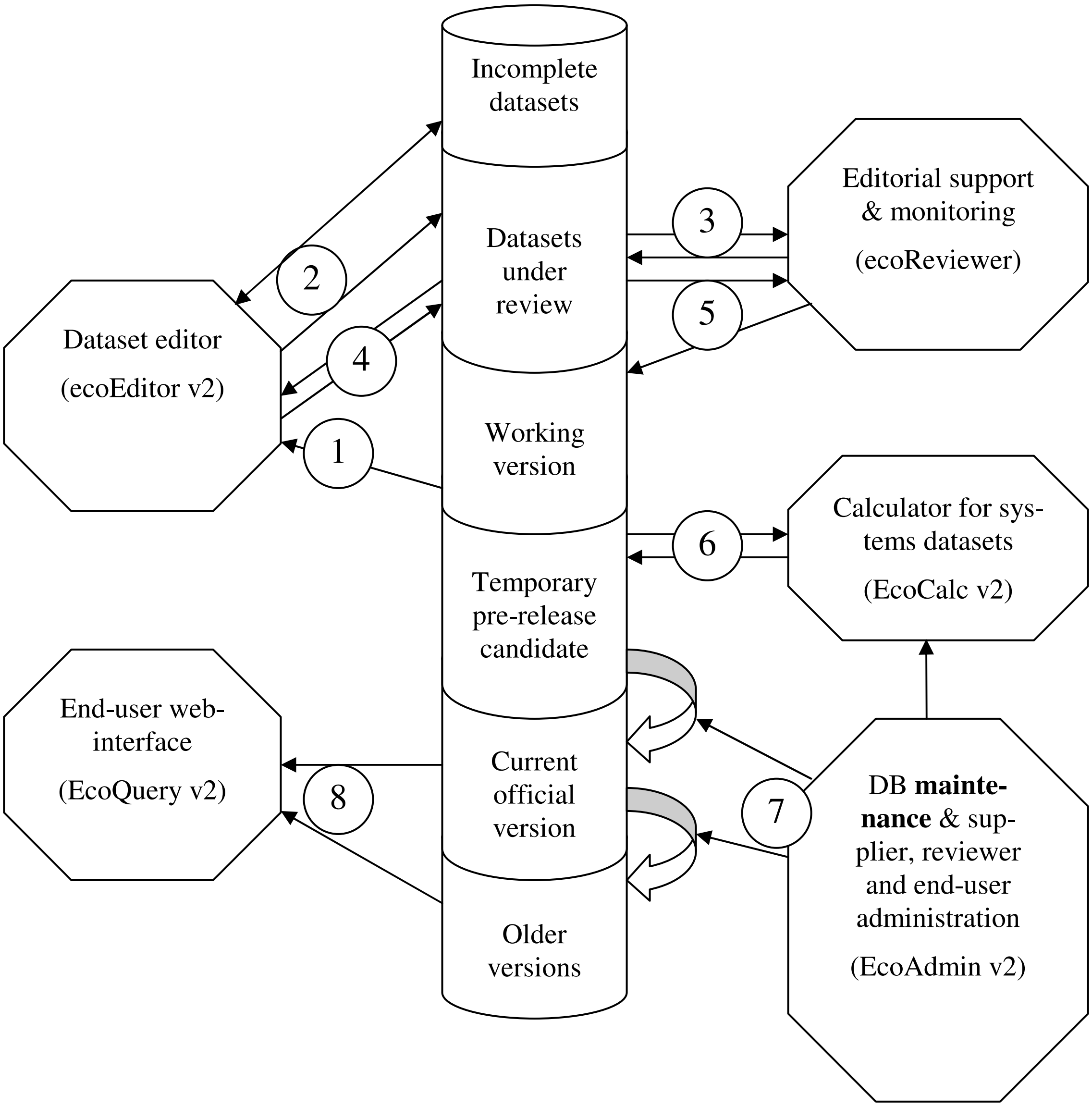

Fig. 3.1 The basic structure of ecoinvent database system

The flow of a dataset through the editorial process (numbers refer to Figure 3.1) is:

Creating a template for editing: Data providers use the ecoEditor v2 software to create new datasets in ecoSpold 2 data format and to edit existing datasets. This software is provided by the ecoinvent centre free of charge and includes some tools for a first automatic validation. The data provider may use the ecoEditor with a blank template, load a dataset from the working version of the database (1) or work from an imported, externally sourced XML-file in ecoSpold v1 or v2 format. The ecoSpold data exchange format has evolved from the international SPOLD data exchange format (Weidema 1999) and is available as Open Source.

Editing the data: The ecoEditor software includes validation routines to assist in identifying errors in the data before datasets are uploaded for review. Some of these validation routines require either on-line access to the central database or that the (incomplete) dataset is uploaded to the database via the website and stored as an incomplete dataset in the separate part of the database for this purpose (2).

Having finished the dataset and having applied the available pre-validation functions, the data provider uploads the dataset(s) to the 'Datasets under review' part of the database. During this upload, a final automatic validation is performed in interaction with the working version of the database.

Editorial process: The editors access the datasets for review through a special read-only-but-add-comments mode of ecoEditor v2. The procedural management of the review process (which persons, when) and the monitoring of this, as well as the reviewers interface to this (for personal status and status of datasets), is supported by a software called ecoReviewer (3)

During the review process, the dataset(s) may pass back and forth between data provider and reviewers several times (4), until all assigned reviewers have approved the dataset(s). Each dataset will pass at least 3 independent reviewers before upload to the database.

After the final approval: The main activity editor uploads the dataset to the working version of the database (5).

When the database administrator initiates the preparation of a new release, the database service layer (ecoCalc v2) performs the result calculations on the pre-release candidate (6).

The database administrator releases the new 'Current official version', while the previous official version is retained together with all other older versions (7).

The end-users and resellers access current and older versions through the ecoQuery v2 web-interface (8). Data can be viewed or downloaded, depending on users' rights.

4 Types of datasets

The term dataset can refer to activity datasets and impact assessment (LCIA) datasets. LCIA datasets are described in Chapter 4.13. All other sections of this Chapter deal exclusively with activity datasets.

4.1 Activity datasets, exchanges and meta-data

ecoSpold reference: type (field 110); inputGroup (fields 1500 and 1600); outputGroup (fields 1510 and 1610)

An ecoinvent activity dataset represents a unit process of a human activity and its exchanges with the environment and with other human activities. Several types of datasets are described in the following sub-chapters, but they all have in common that they have exchanges on the input side and on the output side, see Figure 4.1.

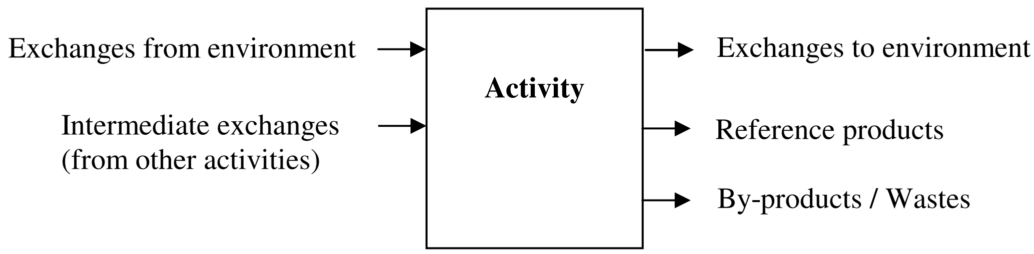

Figure 4.1. An activity dataset with its categories of exchanges

Exchanges from and to the environment, also called *elementary exchanges*[1], are placed on the input side and the output side respectively.

All other exchanges are intermediate exchanges, i.e. exchanges between activities. On the output side we distinguish between:

- Reference products
- By-products / Wastes

These distinctions are described in more detail in the following sub-chapters.

On the input side, the ecoSpold v2 format allows to differentiate intermediate exchanges into materials/fuels, electricity/heat and services, but this distinction is *not* actively used in the ecoinvent database. On the output side, the ecoSpold v2 format allows further to differentiate materials for treatment and stock additions. These distinctions are only used internally in the ecoinvent database when creating attributional and consequential datasets, see Chapter 4.14.

In addition to the exchanges, the dataset is described in terms of meta-data, i.e. data identifying the activity itself, in terms of its geographical, technological and temporal validity, the origin, representativeness and validation of the data, and administrative information. All relevant aspects of these meta-data are described in later Chapters of this report.

[1] Exchange with the natural, social or economic environment. Examples: Unprocessed inputs from nature, emissions to air, water and soil, physical impacts, working hours under specified conditions.

4.1.1 Exchanges from and to the environment

Exchanges *from* the environment are resources extracted and chemical reactants from the air (e.g. CO_2, O_2, N_2), water or soil that enter into a human activity or into biomass harvested in the wild. Also land transformation, land occupation, and working hours are recorded as exchanges from (services provided by) the natural, social or economic environment. Also inputs of primary production factors of the economy (labour costs, net taxes, net operation surplus, and rent, see Chapter 6.4) are recorded as exchanges *from* the environment although measured as the economic *expenditures* for these inputs.

Exchanges *to* the environment are emissions to the different environmental compartments (e.g., air, water).

To distinguish human activities from their environment, two principles are followed in combination:

1) "The natural background", i.e. to include everything that would not have occurred without the activity, and to exclude anything that would have occurred even without the activity.
2) "Human management", i.e. to include everything that takes place under human management and exclude anything that takes place after human management has terminated.

These principles, their limitations, and their practical implementation are further described in Annex A.

4.1.2 Reference products

If the activity has only one product output, this is the reference product. The reference product is either a good or a service.

A co-producing activity normally has only *one* reference product, except if there are more co-products from the activity that have no alternative production routes. If more than one co-product from a joint production has no alternative production routes, all of these are reference products. The reference products are those co-products for which a change in demand will affect the production volume of the activity (also known as the *determining* products in consequential modelling, see Weidema & Ekvall 2009).

In most situations, by-products can easily be distinguished from reference products. Often by-products are close to waste and are therefore not even fully utilised, for example straw.

The distinction between reference products and by-products is necessary due to its relevance for identifying products that require additional treatments, e.g. for recycling, and in particular for consequential modelling, where the supply of by-products are counterbalanced to arrive at single-output activities.

Additional advice for data providers:
For treatment activities, see Chapter 4.8, the reference product is a negative physical flow of the material received for treatment. It is not necessary to specify the reference product as such, as long as the activity has an input which is a material for treatment, as defined in Chapter 4.8. This input to the treatment activity will then be interpreted by the database as the missing reference product.

Whether an output is a reference product or not can depend on local conditions and can change over time.

Examples of situations with more than one reference product, and additional advice for data providers are provided in Chapter 11.1.

[**Changes relative to ecoinvent version 2:** The distinction between reference products and by-products is new. All multi-product activities in version 2 have been reviewed and the reference products identified. This identification will be reviewed by the original dataset authors and/or the editors, before central implementation in the database. A number of treatment activities are missing their reference product. These need to be added, preferably by the original dataset author, who will be contacted by the ecoinvent management. A number of activities in version 2 have reference products that are not products or services, but refer to a fuel input, e.g. “diesel, burned in building machine”. Often these reference products are used by an activity producing heat. These activities, all with the term “burned in” in their name, shall have reference products of heat or work added, and be merged with any corresponding heat producing activity. These new reference products will be calculated from existing information in the database when available. The revised reference products will be reviewed by the original dataset authors and/or the editors, before central implementation in the database.]

4.1.3 By-products and wastes

The ecoinvent database does not discriminate between by-products and wastes and does *not* support any specific waste definition. Different database users may therefore apply their own waste definitions, if they wish to distinguish wastes from by-products.

Both wastes and by-products may be – or be transformed to be – valuable inputs to other product systems. Depending on their need for further treatment or transformation, they may be linked to different treatment activities, see Chapter 4.8.

It follows from the definition of reference products in Chapter 4.1.2, that by-products and wastes (any output that is neither a reference product nor an exchange to the environment) *must have* either an alternative production route or a treatment activity that transforms the by-product/waste either into a product with an alternative production route or into an exchange to the environment.

[**Changes relative to ecoinvent version 2:** In ecoinvent version 2, waste treatment is recorded as service inputs to the activities supplying the waste. All such waste treatment services have been reviewed and expressed as negative outputs of wastes. The name change will be reviewed by the original dataset authors and/or the editors, before central implementation in the database. For a number of products in version 2 that have now been identified as by-products (e.g. straw, sodium hydroxide), the activities that have the by-product as its reference product or as an input for treatment are missing. These activities need to be added; initially a default average dataset may be added as a placeholder.]

4.2 Global reference activity datasets and parent/child relationships between datasets

ecoSpold reference: parentActivityId (field 130)

[More advice on this issue, and a decision on the extent to which inheritance will be deployed in the ecoinvent database depends on experimentation yet to be performed.]

The geographical, temporal, and technological scope of the datasets is described in each individual dataset. Some datasets are extrapolated on the basis of data from another geography or year. Such extrapolations are described in the datasets, and will result in these datasets having a larger reported uncertainty.

To avoid artificial introduction of differences between datasets for the same technology, each technology is described in the form of a *reference activity dataset*, intended to be close to the global average, for a reference year and reference macro-economic scenario. Other datasets for the same technology, but for specific geographical locations and/or other time periods and/or other macro-economic scenario settings, can then described in child datasets, using the reference activity dataset as parent dataset. In this way, an improved description in the reference activity dataset will automatically be transferred to the specific datasets, while scenario, geographical, and temporal differences can be reported in these.

The ecoinvent data network does not require non-reference activity datasets to be described as child datasets, but data providers are encouraged to consider the advantages of supplying the data in this form.

More details on the implementation of parent/child dataset inheritance and the restrictions applied to this feature are provided in Annex B.

[**Changes relative to ecoinvent version 2**: The option to apply inheritance is new. For transforming activity datasets from version 2, reference activity datasets will be provided by automatic extrapolation from existing datasets. When several datasets exist for a given activity name, and it is unclear which of these are the most suitable basis for the reference activity dataset, the original author will be asked to identify this. Existing geographically differentiated datasets will not be changed to child datasets automatically. The decision to do so rests with the active dataset author. There is no requirement to use the inheritance option, but dataset authors are asked to consider revising the reference activity dataset to be more appropriate as a global reference, and to implement corresponding child datasets.]

4.2.1 Geographical localisation

ecoSpold reference: locationShortname (field 410); comment (field 420)

The geographical location of an activity can be:

- At one or more specific points, when the location of specific production facilities is known.
- Along one or more lines, e.g. for transport activities.
- Within one or more areas, as in farming, fishery and forestry, or when the location of the specific activity is unknown

Each geographical location (whether point-, line-, or area-based) is described by a short, unique name that links via a unique identifier to a more detailed description for each location, see Chapter 9.9. As part of the detailed description, the location is described in terms of geographical information system coordinates (longitude, latitude) in the Keyhole Markup Language (KML) used by e.g. Google Earth. This allows the database to identify which activities are located within a given area, and thus to link the activities to their geographically defined markets (see Chapter 4.4) and to flexibly provide geographically differentiated data for site-dependent impact assessment methods.

The geographical location indicated in this way is the location for which the dataset is intended to be valid. The data may be originally collected for a different geographical location, and inter- or extrapolated to the geography of validity. Such extrapolations are described in the dataset under “Extrapolations”.

To ensure completeness, the ecoinvent database contains a *global dataset* (a dataset with the geographical setting “Global”) for each of the included activities in a specific time period and macro-economic scenario. For the reference year and scenario (2005, Business-as-usual), this is the reference activity datasets. For other time periods and/or macro-economic scenarios, the global datasets may be constructed as child datasets of the corresponding reference dataset.

Geography child datasets may be constructed for any geographical location by entering a geographical location in a delta dataset referring to the corresponding reference dataset (using the “parentActivityId” field of the ecoSpold format). This implies that geography child datasets are only available for the reference year (2005) and the reference scenario (Business-as-Usual). Geographically specific datasets for other years and scenarios are constructed from the geographical child datasets as temporal and/or macro-economic scenario child datasets.

To avoid double-counting, overlapping geographical *areas* for datasets for the same activity is not allowed in the ecoinvent database, except that

- A global dataset is allowed to co-exist with datasets for smaller areas.
- Production and supply mixes (see Chapter 4.5) can be established for any area of interest, since these mixes are not used in further modelling.

All point and line locations belong to an area. This implies that a point location cannot be placed on the border of an area, a line location cannot be placed along (on top of) borders (but may cross borders, i.e. belong to more than one area), and a border cannot be placed exactly on top of a point or along a line location.

When a global dataset is the only dataset in the database for a given activity, time period, and macro-economic scenario, this global dataset is included like any other dataset in automatically calculated production, supply, or consumption mixes, attributional and consequential database implementations, and aggregated system datasets.

When both a global dataset and one or more non-global datasets are available for the same activity, time period, and macro-economic scenario:

- The global dataset is not included in any of the above mentioned calculations, but can serve as a parent dataset for other datasets.
- A dataset with the geographical location *Rest-Of-World* (ROW) can be calculated as the residual difference between the global dataset and the non-global datasets, when all datasets are scaled to the production volume of their reference product. In the ecoinvent database, this calculation is performed automatically.

Additional advice for data providers:
Since the ecoinvent database does not allow overlapping datasets, adding a dataset (whether point-, line-, or area-based), fully located within the geographical area of an existing dataset for the same activity, is effectively a disaggregation of the existing dataset, and requires that the existing dataset is modified to represent the residual of the original dataset, in terms of geography, production volume, and otherwise.

[**Changes relative to ecoinvent version 2:** The use of KML, and the options for automatic dataset handling that this provides, is new. All ecoinvent v2 geographies have been defined in KML in the new geographies master file. For version 2, geographical location was sometimes used as proxy for a specific technology. Such instances have been identified as far as possible and the original authors involved in suggesting or reviewing corrections, so that geographical location is no longer used as proxy for anything else.]

4.2.2 Time series

ecoSpold reference: startDate (field 600); endDate (field 610); isDataValidForEntirePeriod (field 620); Time period comment (field 630)

The time period for which an activity dataset is valid is described as an interval with a start date and an end date (e.g. 2005-01-01 and 2005-12-31). Datasets valid for whole years can be specified by the year(s) alone. Time periods of less than one year is currently not used in the ecoinvent database. Recurring time periods, such as peak seasons or peak hours, are distinguished by the product name.

The time period indicated in this way is the time period for which the dataset is intended to be valid. The data may be originally collected for a different time period, and inter- or extra-polated to the time period of validity. Such extrapolations are described in the dataset under “Extrapolations”.

When calculating production, supply, or consumption mixes, attributional and consequential database implementations, and aggregated system datasets, datasets from the same time period are linked. If a global dataset for an activity is missing for a specific time period, the activity datasets for the nearest preceding time period are applied, although not prior to the reference year (2005).

Temporal child datasets may be constructed for any time period and geographical location by entering a time period in a delta dataset and referring to the corresponding reference activity dataset or geography child dataset (using the “parentActivityId” field of the ecoSpold format). This implies that temporal child datasets are only available for the reference scenario (Business-as-Usual). Temporal specific datasets for other macro-economic scenarios are constructed from the temporal child datasets as macro-economic scenario child datasets. This allows the construction of time series of datasets for any activity, location and macro-economic scenario.

To avoid double-counting, overlapping time periods for datasets for the same activity and geographical location is not allowed.

[**Changes relative to ecoinvent version 2:** The option to have several temporal versions of the same dataset, and that separate linking is performed of datasets from the same time period, are new. Since the datasets of the database version 2 are linked, this implies an assumption that they are valid for the reference year of the database (2005) and that their temporal validity therefore can be automatically changed to include 2005 without any further ado. The original temporal setting is placed as text in the field "extrapolations" and the pedigree is automatically adjusted to reflect the correct additional uncertainty. Datasets for emerging technologies in the database version 2, with the suffix "future" in their name, include performance data which are currently not reached but are expected to be reached in a few years. The time period is therefore to be changed accordingly and the word "future" deleted from the name field. The changes for the emerging technology datasets should preferably be performed by the original dataset authors.]

4.2.3 Macro-economic scenarios

ecoSpold reference: Macro-economic scenario name (field 720); Macro-economic scenario comment (field 740)

A macro-economic scenario setting provides an option to have more than one dataset describing the same activity, for the same geographical location and time period. Macro-economic scenarios are only relevant for datasets for future years, since datasets for the current and historical years reflects the actual known situation.

The ecoinvent database currently operates with one default reference scenario only: "Business-as-Usual". The introduction of new macro-economic scenarios in the ecoinvent database is only done centrally after a decision by the ecoinvent Centre. More details on this can be found in Chapter 11.2.

[**Changes relative to ecoinvent version 2:** The option to add macro-economic scenarios is new.]

4.3 Market activities and transforming activities

ecoSpold reference: specialActivityType (field 115)

The ecoinvent database (and the ecoSpold 2 data format) distinguishes a number of special activity types, including market activities, production and supply mixes (see Chapter 4.5), import and export activities (see Chapter 11.5), and correction datasets (see Chapter 11.7).

All activities that are not of these special types are "ordinary" transforming activities. Transforming activities are human activities that *transform* inputs, so that the output of the activity is different from the inputs, e.g. a hard coal mine that transforms hard coal in ground to the marketable product hard coal. In contrast, market activities do not transform their inputs, but simply *transfer* the intermediate output from a transforming activity to the transforming activities that consume this intermediate output as an input, e.g. from hard coal at the supplier to hard coal at the consumer.

Transforming activities are here understood in the widest possible sense, including extraction, production, transport, consumption and waste treatment activities, i.e. any human activity where the intermediate output is different from the intermediate input. The concept "transforming activities" is introduced here simply to distinguish – in the further modelling and linking of activities; see Chapter 4.4 – these "ordinary" activities from the market activities, production and supply mixes, import and export activities, and correction datasets.

Market activities typically mix similar intermediate outputs from different transforming activities. Market activities therefore supply *consumption mixes* of the intermediate outputs. The term consumption mix is not part of the name of the output, but is a consequence of the activity being a market activity (as specified in the ecoSpold field 115 specialActivityType). However, in graphical presentations (see Figure 4.2) the term (consumption mix) in brackets may be added after the name of the output. When only one transforming activity is supplying a specific intermediate output to a market, the term consumption *mix* may seem a bit strange, but is nevertheless maintained for consistency reasons.

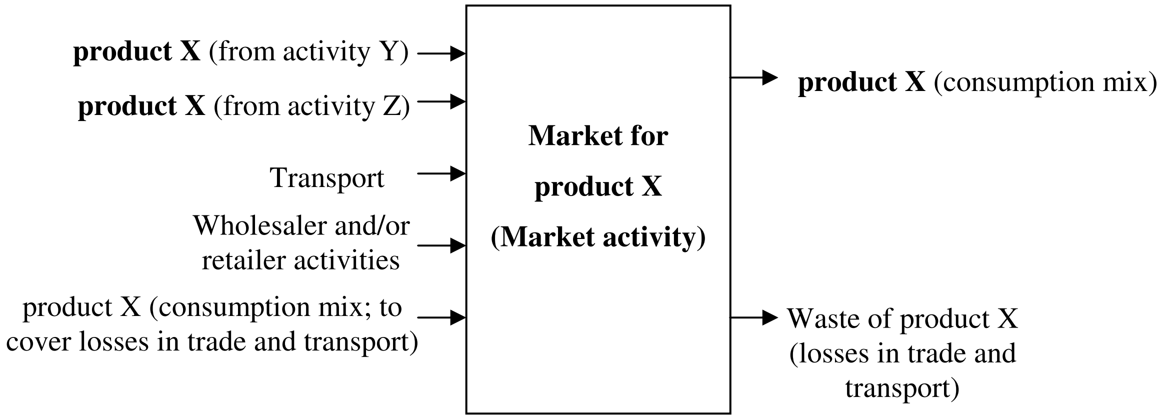

Figure 4.2. A market activity with its intermediate exchanges. Text in brackets are not part of the name of the exchange.

Market activities may be global or geographically delimited, as indicated by the ecoSpold field 410 locationShortname. As a default, markets are assumed to be global, since this is the most general situation, unless specific information is available to justify a geographical market boundary. The delimitation of markets, and their justification, is described in more detail in Chapter 4.4.

In its simplest form, a market dataset consists of a reference product, representing a consumption mix, and one or more inputs of the same product from the different transforming activities that are located within the geographical delimitation of the market. The ecoinvent database service layer automatically identifies these transforming activities based on the name of the reference product and the geographical location of the transforming activity, links the product inputs to the market from each transforming activity by adding the corresponding ActivityLinkId (ecoSpold field 1520), calculates the amount of input from each transforming activity in proportion to its available production volume, based on the entries in the ecoSpold field 1530 productionVolumeAmount of each transforming activity (see Chapter 5.4), and sums up these production volumes, which then becomes the production volume of the market activity.

In addition to providing consumption mixes of the intermediate outputs from different transforming activities, market activities play a role in adding average transport activities (Chapter 4.6), wholesaler and retailer activities (Chapter 4.7), and product losses in trade and transport. Product losses in trade and transport are added to the market activity datasets as waste outputs. To balance the waste output, an equivalent amount of product input is added. Since the loss is an average of the products traded, this compensating input is the consumption mix, i.e. the output of the market activity itself. Losses of specific input to the market are recorded in the specific supplying activity. The mentioned activities and losses also imply economic costs to the market activities and - together with product taxes and subsidies - these costs change the price of the products from basic prices to purchaser's prices (Chapter 5.6.5).

Market activities are placed in between any two transforming activities, unless a direct link is made between two specific transforming activities, thus avoiding the market (see Chapter 4.4). This implies that market activities may also be placed *within* an enterprise if the enterprise performs several separate, subsequent activities in the life cycle of a product. This depends entirely on the level of detail to which the transforming activities are represented (see also Chapter 5.1). In such cases, the markets should be understood as enterprise-internal markets, i.e. as supplying reference products between different parts or production lines of the same enterprise. This degree of sub-division in LCI data is only relevant if the product could alternatively be used outside the enterprise (or be supplied from outside the enterprise).

[**Changes relative to ecoinvent version 2:** A market dataset is now required for every reference product. When missing, a simple market dataset will be auto-generated by the database service layer, including default values for transport, trade margins, and product losses per product group. The editor for trade reviews existing market datasets for consistency.]

4.4 Linking transforming activities directly or via markets

ecoSpold reference: ActivityLinkId (field 1520); Geography comment (field 420) contains justifications for market boundaries.

4.4.1 Direct links between transforming activities

Goods and service inputs to a transforming activity are described in terms of the product name. Furthermore, a specific supplier of this product may be indicated (in the ecoSpold field 1520 ActivityLinkId), if the input is linked to this specific supplier. This may be the case if only one supplier exists, or if a specific group of enterprises are so closely linked in a supply chain that the production volumes of the specific suppliers can be shown to fluctuate with the demand of the specific customers. Examples of the latter situation are:

- When products do not store or transport easily, or have a low price compared to their weight, so that transport costs prohibit all other than the local producers. Examples are thermal heat, chlorine gas, and straw for heat and power production, where only the farmers closest to the power plant will supply the straw. Other examples of this can be found in the forestry sector and the building- and glass-industries. [more relevant examples from the current ecoinvent database?]
- When two or more companies are tied together by tradition, or when a supplier has developed its product to meet specific demands of the customer. An example is an aluminium industry that specifically co-locates with a specific electricity source.
- When the choice of supplier is not subject to normal market conditions. [relevant examples from the current ecoinvent database?]

The reason for linking directly to a specific supplying activity is provided in the comment field for the linked exchange.

When transforming activities are linked directly, thus avoiding the market activities, the activities and data that are normally included with the market activities, are instead added directly to the activity requiring the input. This includes transport activities, production losses, wholesaler and retailer activities, and product taxes and subsidies for the directly linked input.

[**Changes relative to ecoinvent version 2:** In version 2, all datasets were linked directly and no specific justification for this was required. The original dataset authors and/or editors will be asked to consider if there are any direct links that should be maintained for version 3 and if so, to provide the corresponding justification. The requirement for activities with more than one reference product to have direct links to the marginal consumption activities affected for each reference product is new.]

4.4.2 Linking via markets

As a default, when there is no information available to justify that the production volumes of a specific supplier (or group of suppliers) fluctuate with the demand of the specific customers, it is assumed that the input is provided by the local market. When no specific supplier is specified for the product input (in the ecoSpold field 1520 ActivityLinkId), the ecoinvent database automatically provides the specific link to the local market, i.e. the market that geographically covers the location of the activity that demands the input.

Markets are typically differentiated

- geographically,
- temporally, and
- in customer segments.

4.4.3 Geographical market segmentation

The geographical segmentation of markets may be determined by differences in:

- Natural geography (climate, landscape, transport distances etc.)
- Regulation or administration (regulation of competition and market transparency, legislative product requirements, product standards, taxes, subsidies)
- Consumer culture.

Geographical segments are identified and documented (in the ecoSpold field 420 Geography comment) by the lacking or constrained import of the product across the geographical boundary.

Three situations can be distinguished:

- No import, no export: The geographical segment is modelled by a single market activity for the geographical area.
- No import, but no restrictions on export: In addition to the market activity for the geographical area (X), the exports from this market to other markets are specified as separate transforming activities “product Y, import from market X” with the geographical specification of the receiving market and with direct links (specified in ecoSpold field 1520 ActivityLinkId) to the consumption mix of market X.
- Administratively constrained import: The contribution of import is modelled separately and added as an input to the market activity for the geographical area.

The three situations are described in more detail in Chapter 11.5, where the linking of geographical markets is discussed.

[**Changes relative to ecoinvent version 2:** Non-global market activities (consumption mixes) now requires justification. The original authors and/or editors of such datasets will be asked to provide this justification or alternatively to recommend deletion of the dataset.]

4.4.4 Temporal market segmentation

Temporal segmentation of markets is common for service products (e.g. peak hours and night hours in electricity consumption, rush hours in traffic and telecommunication, seasons in the tourist industry). For physical goods, markets are generally only segmented temporally when adequate supply or storage capacity is missing, either due to the nature of the product (e.g. food products), or due to immature or unstable markets, as can been found for treatment of some recycled materials.

Although the ecoSpold format allows time periods to be specified at a higher resolution than years, the format does not have any way to specify recurring time periods such as peak hours that occur at the same time every day. Temporal markets are therefore specified as part of the product name, e.g. “electricity, peak” and “electricity, non-peak” as opposed to an average “electricity”. Currently, the ecoinvent database does not include temporal market segments, but does not restrict data providers from contributing such data when available.

The temporal segmentation should be distinguished from the fact that markets generally develop in time, e.g. governed by developments in fashion and technology, and that both geographical and temporal segmentation and customer segmentation therefore may change over time. In general, there is a tendency for markets to become more transparent and geographically homogenous with time, but at the same time more segmented with regard to customer requirements and thus product differentiation.

4.4.5 Customer segmentation

Customer segmentation within each geographical market is defined in terms of clearly distinct function-based requirements, i.e. based on the needs fulfilled by the products rather than based on the physical products themselves. This can be expressed in terms of the *obligatory product properties*, i.e. properties that the product *must have* in order to be at all considered as a relevant alternative. Very similar products may serve different needs and hence serve different markets. And very different products may serve the same need, thus being in competition on the same market.

As for temporal markets, customer segments are expressed in the name of the product, so that each customer segment has its own product. The name includes as far as possible all relevant aspects of the obligatory product properties. Product properties may be related to:

- Functionality, related to the main function of the product
- Technical quality, such as stability, durability, ease of maintenance
- Additional services rendered during use and disposal
- Aesthetics, such as appearance and design
- Image (of the product or the producer)
- Costs related to purchase, use and disposal
- Specific environmental properties

Functionality, aesthetics, and image characterise the primary services provided to the user. Technical quality and additional services ensure the primary services during the expected duration of these. Of the above-mentioned properties, price is the only one that can be put into well-defined terms. Technical quality and functionality can be described a little less well defined, but still quantitatively. Other properties, such as aesthetics and image, cannot be measured directly, but can only be described qualitatively. Some of these properties can seem very irrational, since they are not present in the product, but in the buyer’s perception of it. These properties can be greatly influenced by commercial activities of the supplier. Differences in customer requirements may be based on differences in the purchase situation, the use situation, customer scale, age, sex, education, status, “culture”, attitudes etc.

To have a practical relevance, market segments must be of a size that can provide adequate revenue to support a separate product line, and *clearly distinct with a minimum of overlap*, so that all products targeted for a segment are considered substitutable by the customers of this segment, while there should be low probability that a product targeted for another segment would be substitutable, implying that product substitution from segment to segment can be neglected.

As a default, if no information is available to justify a market boundary, it is assumed that no market boundary exists, since this is the most general situation.

4.4.6 Market niches

Market segments may be further sub-divided into market niches. A *market niche* is a sub-category of a market segment, where a part of the customers consider only niche products substitutable, although the majority of the customers allow substitution between products from the niche and other products in the segment. Thus, the difference between a segment and a niche is that between segments substitution is negligible, while a large part of the customers in a segment will allow substitution between niche products. Niche products are aimed at a smaller group of consumers within a segment, for whom specific product properties are obligatory, while the same properties in the broader market segment are only *positioning product properties*, i.e. properties that are considered *nice to have* by the customer and which may therefore position the product more favourably with the customer, relative to other products with the same obligatory properties.

When market niches exist, the niche product has its own, separate name, indicating the additional obligatory product properties of the niche, e.g. "vegetable oil, sunflower" to separate this market niche from the general "vegetable oil". As only some of the niche product is consumed by niche consumers, the remaining amount is channelled into the general market segment through separate relabelling "niche product to generic market" transforming activities, e.g. "sunflower oil to generic vegetable oil market", which have as its input the niche products and as output the products of the general market segment. Besides the change in name of the product, the "niche product to generic market" activities will also include a change in the price of the products, see Chapter 5.6.5. If the properties of the niche product affect downstream use or disposal activities differently from the other products in the general market segment, these downstream differences must be added separately to the niche production, as described in Chapter 11.7.

4.5 Production and supply mixes

ecoSpold reference: specialActivityType (field 115)

The database distinguishes between production, supply and consumption mixes.

A production mix represents the production-volume-weighted average of the suppliers of a specific product within a specific geographical area. A supply mix is a production mix with the addition of the import of the specified product to the specified geographical area. A consumption mix is the output of a market activity, as described in the previous section. Consumption mixes represent production-volume-weighted averages of the suppliers to a specific market. Market boundaries may or may not be congruent with the geographical areas for which production and supply mixes are provided.

Production mixes are automatically generated by the ecoinvent database service layer in the same way as consumption mixes (as described in Chapter 4.3): The database automatically identifies the relevant transforming activities based on the product name and the geographical location of the transforming activity, links the product inputs of the production mix to each transforming activity by adding the corresponding ActivityLinkId (ecoSpold field 1520), calculating the amount of input from each transforming activity in proportion to its production volume, as indicated in the ecoSpold field 1530 productionVolumeAmount of each transforming activity, and sums up the production volumes, which then becomes the production volume of the production mix.

A supply mix is automatically generated by the ecoinvent database service layer by adding the import (see Chapter 11.5) for the geographical area as an input to the corresponding production mix.

Production and supply mixes are not systematically provided for all products and all geographical areas. For compatibility with the ecoinvent database version 2, production and supply mixes are provided in most situations where these were supplied in the ecoinvent database version 2. Production mixes may be provided in specific cases for comparisons, or to represent the export from a geographical area, but are not used in the further modelling of LCI results, except when required to reduce the matrix size before calculation of accumulated systems results, see Chapter 14.8.

[**Changes relative to ecoinvent version 2:** Datasets in version 3 are linked exclusively via well-defined and justified direct links or via market datasets providing consumption mixes. Since production and supply mixes can be generated for any geographical area, irrespective of the market boundaries, they are no longer applied in the further modelling.]

4.6 Transport

Freight transport occurs for most physical flows between activities in a product system. They are added to the market activity datasets based as far as possible on data for the real market situation. For intermediate inputs that are not provided via markets, i.e. where a using activity is directly linked to a supplying activity or for situations where the actual transport is different from the market average, the difference in transport is added directly to the receiving activity. Additional transport between markets (international transport) is added to the import datasets (see Chapter 11.5) for the geographical area of each market.

The total amount of freight services provided by the road, rail, ship and air transport industries are divided over the transported products based on the average transport distance and the modal distribution from transport statistics, and the wet weight or volume of each specific product. Transports are assumed to be weight-limited when the packed product has a density above 250 kg/m^3 and volume-limited when the density is below 250 kg/m^3.

The transport datasets have names beginning with "transport, …". The freight transport products furthermore have a tag "Goods transport" and describe the transport services in metric ton-kilometres with average load factors including the average share of empty return trips.

[**Changes relative to ecoinvent version 2:** In line with the requirement in the reports for ecoinvent v2, where the assessment of transport distances were based mainly on assumptions, further research is now undertaken by the ecoinvent Centre to provide data on transport services per product type (modal metric ton*km/kg product), based on transport statistics. These datasets include the vehicle and supporting infrastructure, whether paid by the transport service or by indirect subsidy, in parallel to the current inclusion of road infrastructure. These new data on transport services per product type will be used to establish algorithms for database-generated inputs to the market datasets, to replace the current transport inputs to transforming activity datasets.]

4.7 Trade margins and product taxes/subsidies

The wholesale and retail industries perform trade activities, which involve e.g. re-packaging, advertising, use of office machinery, warehousing, retail stores, with their use of electricity, heating and cooling. Also, some of the transports of goods cannot be specified on products and are indirectly included via the purchase of freight services by the wholesale and retail industries. Like other service industries, trade involves relatively large wage expenditures.

Altogether these activities result in a price difference also known as the trade margin, which together with the transport costs makes up the difference between the producer's prices and the purchaser's prices reported in the market activity datasets.

If product taxes less subsidies are subtracted from the producer's prices, we arrive at the basic price reported in the transforming activity datasets. We thus have:

basic prices + product taxes - product subsidies + trade margins + transport costs = purchaser's prices

The trade margins are, in parallel to the transport services, added as service inputs from the wholesale and retail industries to the market datasets. Product taxes less subsidies are added as primary inputs (monetary elementary exchanges, see Chapters **Fehler! Verweisquelle konnte nicht gefunden werden.** and 6.4) to the market activity datasets.

[**Changes relative to ecoinvent version 2:** Wholesale and retail activities were largely missing in version 2. Further research is now undertaken by the ecoinvent Centre to provide data on wholesale and retail services, as well as product taxes and subsidies, per product type, based on national statistics. These new data on trade margins and product taxes and subsidies per product type will be used to establish algorithms for database-generated inputs to the market datasets.]

4.8 Treatment activities

A treatment activity is a transforming activity with a reference product with a *negative sign*, which effectively means that the activity is supplying the service of treating or disposing of the reference product.

Most treatment activities are waste treatment activities, including recycling activities. However, some by-products that are normally not regarded as wastes may also need treatment before they can enter into a market where they can compete with or substitute reference products from other activities. Such by-products and wastes are called *materials for treatment* to distinguish them from those by-products that can immediately – without further treatment – substitute a reference product as an input to an activity. Note that it is not the economic value that determines whether a material is a material for treatment, but exclusively its need for treatment.

Any transforming activity can be(come) a treatment activity, if one of its inputs is a material for treatment, but in general, treatment activities are activities dedicated to treatment, i.e. having treatment as their original main purpose.

Additional advice for data providers:
If no dedicated treatment activity exists in the database for a newly added material for treatment, this must be added before upload of the activity supplying the material for treatment, or alternatively, at least one of the activities that currently use the material must be identified as a treatment activity for this material, implying that the original reference product of this activity is changed to be a by-product.

[examples from the database?]

Treatment activities are modelled like any other technical service activities. Material characteristics like elemental composition, heating value, combustibility, and degradation rates, are used to calculate material-specific outputs and expenditures of treatment activities. The treatment activities are modelled so that each activity has one and only one material for treatment as input. The treatment technologies are as far as possible modelled with variables (see Chapter 5.7), so that e.g. the average values for DeNOx-equipment in municipal waste incineration plants can be changed by the user according to the extent of installation of this equipment in a particular situation. [additional description of how to use the variables in a waste treatment dataset to be added based on experience from experimentation of the new implementation]

Treatment services (the reference product outputs with negative signs) are inputs to treatment markets, i.e. the market activities that in turn provide the treatment services to the activities that provide the materials for treatment, see Chapter 4.9.

Treatment activities may be modelled according to the physical reality, with the material for treatment as an input, and without specified reference product. The database will then identify the material for treatment as the missing reference product.

Similarly, in principle, it does not matter whether a waste supplying activity records its waste as a physical output or as a negative physical input from a waste treatment service. In both situations, the database will calculate the waste as a negative input and as a result the appropriate amount of waste treatment service is supplied to the waste supplying activity. A positive output is the same as a negative input, so the mass balance for the waste supplying activity is maintained.

[**Changes relative to ecoinvent version 2:** The distinction between materials for treatment and other by-products is new. The definition of treatment activities is new. In some disposal datasets from version 2 (the 'disposal, building,...' modules, and wastewater which is transported in sewers), transports are included in the disposal datasets. As for other transforming activity datasets, this has to be deleted and included instead in the corresponding market activities.]

4.9 Treatment markets

Treatment markets are a specific kind of market activities (see Chapter 4.3), which operate on negative reference products, i.e. on the services of treating or disposing of the reference product. The reference products of the treatment activities and of the treatment markets are the materials for treatment arising as waste or by-product outputs of other activities, identifiable as wastes or by-products that cannot immediately – without further treatment – substitute a reference product as an input to an activity.

The treatment markets distribute the materials for treatment over the available treatment activities and speciality productions, in the same way as a normal market activity distributes the demand over different suppliers in proportion to their production volume. Treatment markets therefore supply *treatment mixes* for specific materials for treatment. The term treatment mix is not part of the name of the output, but is a consequence of the activity being a market activity (as specified in the ecoSpold field 115 specialActivityType) with a *negative* reference product. In graphical presentations, the term (treatment mix) in brackets may be added after the name of the output.

As for normal market activities, the ecoinvent database automatically identifies the treatment activities and speciality productions that contribute to a specific treatment market, based on the name of the reference product (the material for treatment) and the geographical location of the activities, links the negative inputs to the treatment market from each treatment/speciality production activity by adding the corresponding ActivityLinkId (ecoSpold field 1520), calculates the amount of input from each treatment activity or speciality production in proportion to the available production (treatment) volumes (based on the data in the ecoSpold field 1530 productionVolumeAmount; see Chapter 5.4) of each of these negative outputs of material for treatment, and sums up these production volumes, which then becomes the production volume of the treatment market. Note that the production (treatment) volumes of the treatment markets do not necessarily match the generated amounts of material for treatment, unless also accounting for the material arising from decommissioning of stocks, see Chapter 11.10.1.

As for normal market activities, treatment markets add average transport activities (incl. collection of the material for treatment) and any activities related to the trade of the material for treatment.

Treatment markets reflect as far as possible the specific local situation of the treatment of specific materials for treatment. If information about the treatment of specific materials is not available, generic treatment activities are applied, based on waste treatment statistics and similar generic data sources.

4.10 Recycling

All possible situations of recycling, including energy recovery, are exhaustively covered by the description of treatment activities in Chapter 4.8:

Recycling activities, i.e. treatment activities that directly or indirectly supply outputs of by-products that can substitute a reference product as an input to an activity, are modelled exactly in the same way as treatment activities that do not provide such by-products.

In the same way, materials for recycling, i.e. materials for treatment that enable the treatment activities to generate by-product outputs that can substitute a reference product as an input to an activity, are treated in exactly the same way as other materials for treatment, as described in Chapter 4.8.

[**Changes relative to ecoinvent version 2:** The ecoinvent database no longer operates with cut-offs. Thus, all outputs of wastes and by-products, for recycling or not, are treated in the same way and are linked to the relevant market activities. Because cut-offs were applied for version 2, some transforming datasets may be missing adequate outputs of minor by-products. These should be added, preferably by the original dataset authors, together with their necessary treatment activities.]

4.11 Infrastructure / Capital goods

Infrastructure (also known as capital goods or investments) are products with a lifetime exceeding one year, not intended for consumption. Consumption here implies either final use by the receiving activity or incorporation in its products. The lifetime is the period between the time of production and the time of initiating waste treatment of the product.

The activity datasets for infrastructure production (*infrastructure datasets*) normally include the maintenance of the infrastructure during its lifetime, its land occupation and transformation, and its decommissioning and waste treatment. Since the mass of the infrastructure products thus leaves the infrastructure dataset as wastes, the reference products of these datasets do not have any mass, but must be regarded as services providing production capacity. Therefore the reference product of the infrastructure production activities have the property “capacity” or “lifetime_capacity”, and the wastes of the infrastructure have the property “lifetime” exceeding one year (see also Chapter 4.21.1 on how by-products and wastes with a lifetime exceeding 1 year are identified as additions to stock).

As far as possible, infrastructure is provided in terms of lifetime capacity at full utilisation. For example:

- The activity “lignite power plant construction, 500 MW” has the reference product “lignite power plant” expressed by the infrastructure lifetime (34 year or 300’000 hour) with the property “capacity” of 500MW (or 139kWh/s), of which an activity “electricity production, lignite” with the reference product 1 kWh electricity and a capacity utilisation of 0.68 will require 1kWh/(0.68*139kWh/s) = 0.01058 s (or 2.94E-6 hour). Alternatively, the infrastructure product can be expressed in the dimensionless “1 unit” with the property “lifetime_capacity” 1.5E11 kWh (corresponding to 300’000 hour * 500MW). The electricity production activity will require 1kWh/(0.68 * lifetime_capacity) = 9.8E-12 unit of this input to produce 1 kWh electricity.
- The activity “oil mill construction, 68.5 metric ton oil/day” has the reference product “oil mill” expressed by the infrastructure lifetime (50 year or 1.58E9 s) with the property “capacity” of 0.79kg/s (or 68.5 metric ton/day), of which an oil mill activity with the reference product 1 kg oil and a capacity utilisation of 0.9 will require 1kg/(0.9*0.79kg/s) = 1.406 s (or 4.46E-8 year). Alternatively, the infrastructure product can be expressed in the dimensionless “1 unit” with the property “lifetime_capacity” 1.25E9 kg (corresponding to 50 year * 68.5 metric ton/day). The oil mill activity will require 1kg/(0.9 * lifetime_capacity) = 8.89E-10 unit of this input to produce 1 kg oil.
- The activity “milking parlour construction, 4 milking units” has the reference product “milking parlour” expressed by the infrastructure lifetime 55’000 hours of milking with the property “capacity” of 335 litre/hour, of which a milking activity with the reference product 1 litre and a capacity utilisation of 0.4 will require 1 litre/(0.4*335 litre/hour) = 0.0075 hour of milking parlour. Alternatively, the infrastructure product can be expressed in the dimensionless “1 unit” with the property “lifetime_capacity” 1.84E7 litre (corresponding to 55000 hours * 335 litre/hour). The milking activity will require 1 litre/(0.4 * lifetime_capacity) = 1.36 E-7 unit of this input to provide milking service for 1 litre milk.

In the above examples, lifetime is expressed in time units. In some cases, it may be relevant to express the lifetime in other terms, as in the following example, where the lifetime of a vehicle is expressed in kilometres:

- The activity "lorry production, 16 metric ton" has the reference product "lorry, 16 metric ton" expressed by the infrastructure lifetime (540'000 km) with the property "capacity" of 9200 kg payload (16 metric ton minus 6800 kg net weight), of which a transport activity with the reference product 1 metric ton*km and a capacity utilisation of 0.1065 will require 1 metric ton*km/(0.1065*9200 kg) = 1.0206 km. Alternatively, the infrastructure product can be expressed in the dimensionless "1 unit" with the property "lifetime_capacity" 4.97E6 metric ton*km (corresponding to 540'000 km * 9200 kg). The transport activity will require 1 metric ton*km/(0.1065 * lifetime_capacity) = 1.89E-6 unit of this input to produce 1 metric ton*km.

Additional advice for data providers:
For new datasets, it is recommended to express the infrastructure products by the infrastructure lifetime at full capacity and provide the production capacity as a property, typically per time unit.

[In line with the requirement in the reports for ecoinvent v2, where the assessment of infrastructures and capital equipments were based on very rough estimations, further research is now undertaken by the ecoinvent Centre to provide data on infrastructure per product group, based on investment statistics.]

[**Changes relative to ecoinvent version 2:** The definition and description of infrastructure is now more precise. Infrastructure activities are now identified by the property "capacity" or "lifetime_capacity". The recommendation to present the assumptions on lifetime, production capacity, and capacity utilisation more explicitly in the datasets, makes it easier to review these assumptions for consistency and to adjust them when better data are available.]

4.12 Operation, use situations and household activities

Activity datasets with the term "operation" as part of their name signifies activities that use specific infrastructures, e.g. "mine operation" as opposed to "mine construction". Operation datasets therefore always have inputs of infrastructure. Thus, "operation" is used as a synonym for "use". The term is used both for industrial activities and household activities.

Different products may be distinguished for the same use situation and modelled as separate transforming activities. For example, the operation of desktop computers is modelled by separate activity datasets for the use situations "active mode", "standby/sleep mode" and "off mode" for different types of computers. The average use mix of these products may then be represented by a market activity (consumption mix) for the generic computer in each use situation, e.g. "operation, computer, desktop, active mode". These average use situations may be further combined in transforming activities for e.g. "operation, computer, desktop, office use", which has a different combination of the use situations than "operation, computer, desktop, home use".

In order not to introduce artificial differences between similar use situations, the ecoinvent database generally classifies household activities together with the similar activities in industries, i.e. using the ISIC rev. 4 classification of activities. For example, home gardening of potatoes is classified under "Growing of vegetables and melons, roots and tubers" (ISIC class 1.13), although in national statistics, this class will only contain market-oriented activities.

When a distinction is required between the way the same product is used in large industries and in small businesses and households, this is done by naming the activity "industrial …", "home and small business …" or "private …", and if needed by introducing similar distinctions in the product of the activity. Furthermore, the tag (see Chapter 9.8) "household activity" is added when it is necessary to distinguish household activities from commercial activities.

[**Changes relative to ecoinvent version 2:** In version 2, the modelling of datasets with the term "operation" as part of their names is sometimes in accordance with the above described, sometimes not. The following groups of datasets need to be changed, preferably by the current dataset authors, to ensure consistency with the above description: Metal working, forestry, transport, road, rail and port operation and maintenance. The modelling of electronic equipment in the current database is not exactly equal to what is described above with computers as an example. This should be modified by the current dataset author.]

4.13 Impact assessment data

4.13.1 Impact assessment datasets

[to be revised depending on format definition, currently under elaboration]

Impact assessment datasets are available for various impact assessment methods, and their constituent impact categories.

An impact assessment *method* dataset contains a grouping of impact categories, and documentation for this grouping.

An impact *category* dataset contains impact pathway characterisation and/or weighting factors that describes the relative contribution to an impact category from one or more environmental exchanges or intermediate impact assessment results.

[more text describing the additional fields of the LCIA format]

[**Changes relative to ecoinvent version 2:** The separate datasets for impact assessment methods and categories allows a more flexible combination and sharing of impact categories across methods.]

4.13.2 Impact assessment results

When the impact assessment data are combined with the amounts of exchanges from a specific activity or accumulated system dataset (see Chapter 4.15), the result is a list of impacts for that activity or product system.

Impact assessment results can be viewed for any activity or accumulated system dataset for which environmental exchanges are available, including the allocated activity datasets of attributional market models.

[**Changes relative to ecoinvent version 2:** In version 2, impact assessment results were available for accumulated system dataset only.]

4.14 Attributional and consequential datasets

ecoSpold reference: marketModelName (field 3005); OutputGroup (field 1510)

In the preceding sub-Chapters (4.1 - 4.12), the activity datasets have mainly been described as stand-alone datasets, each representing a specific human activity as it can be observed “in real life”. No specific model has been described to explain how these stand-alone datasets can be combined into contiguous, isolated product systems (life cycles). Since practically all human activities influence and link to each other, isolated product systems do not exist “in real life”. They are artificial thought constructs that isolate some human activities from the rest, and define these as a product system, related to one specific product.

It is the purpose of *market models* to provide rules for linking the activity datasets into contiguous product systems, each one isolated from all other product systems.

In the stand-alone description of an activity, which can be validated against its real life counterpart, the market model (ecoSpold field 3005 marketModelName) is *undefined*. These activity datasets will typically have more than one product output and cannot be immediately linked except if all intermediate inputs are already specified with a supplying activity (ecoSpold field 1520 ActivityLinkId). When the activity is to be linked into a product system, a choice of a market model therefore has to be made, which provides the information on how to generate single-product datasets from multi-product datasets and which supplying activities to link to each specific intermediate input.

Two classes of market models can be distinguished: attributional and consequential. Within each of these two classes, several instances can be defined. The ecoinvent database supports currently only one consequential market model:

- *Consequential, small-scale, long-term decisions*

and four attributional market models:

- *Attributional, average current suppliers, true value allocation, with corrections for carbon*
- *Attributional, average current suppliers, revenue allocation*
- *Attributional, average current suppliers, dry mass allocation*
- *Attributional, average current suppliers, carbon allocation*

These market models, and the rationales behind them, are explained in more detail in Chapter 14. For each market model, a set of linking and/or allocation rules is applied, described in Chapter 14, that allows the database service layer to add the missing direct links to each input of each activity, and to generate single-product datasets from multi-product datasets.

Additional advice for data providers:
The resulting database-generated dataset implementations, each with the name of their market model in the field marketModelName, are *not* intended for further editing by the data provider. If, upon inspection of a database-generated market model dataset, an error or unintended link or allocation is discovered, the corresponding correction must be made in the underlying dataset with market model *undefined*.

4.15 Accumulated system datasets

ecoSpold reference: type (field 110)

An accumulated system dataset shows the aggregated environmental exchanges and impacts of the product system related to one specific product from one specific activity. This implies that accumulated datasets are calculated for each product output of each activity dataset in the database (for consequential market models only for reference products). The calculation of accumulated system datasets is performed by the database service layer according to the algorithm described in Chapter 14.8.

The product systems include all upstream activity datasets, as linked by the intermediate exchanges, and therefore do not themselves have any intermediate exchanges, only environmental exchanges and accumulated impact assessment results.

5 Level of detail

5.1 Unit process data level

As far as possible, the database contains data on a unit process level that are neither vertically nor horizontally aggregated (aggregating two or several subsequent activities in a supply chain, and aggregating two or several different activities delivering the same intermediate outputs, respectively).

[The APME plastics and basic chemicals data, where only cumulative LCI results data were available in ecoinvent v2, will be replaced by unit process data.]

In general, inputs and outputs of several distinct unit processes are aggregated only if *a)* individual data are not available, or *b)* individual data are confidential.

However, we seek to avoid the separate reporting of unit processes when this does not add any useful information in an LCA context. This is the case when one unit processes always supplies all of its products directly to another specific unit process at the same location, so that the product of the first unit process never appears as a marketable product, and cannot be supplied by an external supplier. In such cases, the use of parameterisation is preferred to further subdivision of unit processes, see Chapter 5.7.

The necessary degree of detail in unit process descriptions as well as in naming of products depends on whether markets are identified for the different reference products. The lowest level of market segmentation is the market niche (see Chapter 4.4.6) and the obligatory product properties in this niche defines how detailed the reference product needs to be described to distinguish it from other products in other niches or market segments. For example, the product name "argon, crude, liquid" includes the necessary specification to distinguish it from the purified “argon, liquid", while the term “liquid” is only relevant if argon is also marketed in other forms. If products on the same market differ in terms of non-obligatory properties, these differences are not reported in the name, but may be reported as product properties (see Chapter 5.5). Obviously, the necessary level of unit process description follows from this, since it is the unit processes that provide the reference products and each unit process typically only provides one reference product.

When data for different exchanges are representing incongruent system boundaries, e.g. when VOC emissions are measured for unit process A separately and for unit processes B+C together, while energy use is measured for unit process A+B together and for unit process C separately, a separate description for each unit process can only be obtained by partitioning the data, separating from the original measurements that part of the energy and emissions that belong to unit process B. In this situation, the uncertainty in the partitioning must be held up against the need for separate data for each unit process, as opposed to provide only one dataset for A+B+C together (Weidema et al. 2003).

It should be noted that when individual data for an activity are available at different levels of detail (e.g. data on energy use may be available at production line detail, VOC emissions only available at plant level, while other emissions are only available at industry level), reporting at the highest level of detail (i.e. production line detail) implies an assumption that the data with a low degree of detail (data at industry level) are representative for the more specific situation, i.e. that the population is homogeneous. However, given the available data, this assumption appears to provide the best possible estimate.

[**Changes relative to ecoinvent version 2:** The desired level of detail is now described more precisely, seeking to avoid unnecessary sub-division of activities]

5.2 Confidential datasets

ecoSpold reference: accessRestrictedTo (field 3550); companyCode (field 3562)

An activity dataset that includes confidential information may be kept inaccessible as a unit process dataset while still being included in calculations of accumulated systems datasets. This is achieved by setting the ecoSpold field accessRestrictedTo to an option different from the default "public" or "ecoinvent". Access may be further protected by passwords and encryption, but these forms of protection are not part of the ecoSpold format as such.

Confidential datasets are subject to the same data quality guidelines as any other ecoinvent dataset, but the review procedure will be performed under the direct management of the ecoinvent database administrator that signs and/or manages the necessary confidentiality agreements, also in case of re-delegation of the review to independent reviewers.

This option is applicable to branded datasets, see Chapter 11.3, if an individual enterprise wishes to present its activity not as a unit process, but as an accumulated dataset only. When at least three independent data providers have provided confidential datasets for the same type of product, the ecoinvent Centre may include the supplied data in an averaged dataset for the generic product.

5.3 Sub-dividing activities with combined production

Multi-product activities are ubiquitous in LCA product systems. The ecoinvent database accommodates unallocated multi-product activity datasets as well as their derived single-product datasets.

A distinction is made between combined and joint production. In *combined production* the output volumes of the (combined) co-products can be independently varied, while in *joint production* the relative output volume of the (joint) co-products is fixed. For joint production, the single-product datasets are automatically calculated by the database service layer according to the procedures described in Chapter 14.4.

In many production activities where one raw material is used to produce several outputs, the production parameters can be adjusted to give different relative yields of the co-products, but only within certain limits. For example, in oil refining, the output of bitumen (asphalt) varies between 7% and 79% depending on the origin of the raw oil. Thus, for each individual raw oil type, the output of bitumen is not variable, but for refineries as a whole, bitumen can be regarded as a variable output as long as the demand as a whole does not fall below 7% of the demand for the remaining refinery products. In general, the ecoinvent database does not support modelling of large changes (see Chapter 14.6.2), and the datasets therefore reflect only operation within the current limits.

Some activities may appear as allowing individual variation in output, but when subjected to a closer analysis it is only possible to keep the output of the other co-products constant by adjusting sub-processes not involved in the original production. Thus, what appears at the superficial level to be a case of individually variable co-products may in fact be a joint production requiring use of the procedures described in Chapter 14.4. For example, if an oil refinery is regarded as a black box, the outputs of different fuels, olefins and other refinery fractions may be individually varied, so that practically any desired relation between the outputs can be obtained. The only fixed fractions are refinery gas and bitumen. However, when having access to data for the individual processes within the refinery, it becomes clear that this flexibility in outputs is achieved by allowing simultaneous changes in a large number of individual processes and alternative production routes, for which the choice depends on the price relations, constraints on raw material availability, and the demand for the different co-products.

When the output volumes can be independently varied, all exchanges can be related to the combined co-products by a mathematical relation (see Chapter 5.7). For example, factors for sub-dividing oil refineries have been determined on the basis of detailed mass and energy flows of the individual sub-processes, such as atmospheric distillation, etc. The co-products can often be expressed in terms of the physical parameter which is the limiting parameter for the co-producing activity, e.g. weight or volume in different situations of combined transport.

When all exchanges of an activity dataset are related by mathematical relations to two or more of the intermediate outputs, the mathematical relations are then used to sub-divide the multi-product activity (manually or by the database service layer, see Chapter 14.1, linking rule no. 4) into an equivalent number of separate datasets, each with one of these intermediate outputs as its reference product. The other exchanges of the sub-divided datasets are determined by the mathematical relations provided in the original dataset, so that each sub-divided dataset describe only the part of the multi-product activity that changes with a change in output of that specific co-product. Thus, the modelling of combined production involves only the internal working of the multi-product activity and is modelled in the same way for both attributional and consequential market models.

Datasets with combined co-products may be sub-divided manually by the data provider, in which case the original multi-product dataset is not available in the ecoinvent database. If the dataset is supplied as a multi-output dataset (recommended) with all other exchanges expressed as mathematical functions of the amount of the combined products, the multi-product dataset will be available as such. The sub-division is then performed by the database service layer, and the sub-divided datasets are only available in the database-generated attributional and consequential implementations (see Chapter 14). When the subdivision is performed by the database service layer, the subdivided datasets have the same activity ID as the original dataset, which implies that the product name is required to distinguish the datasets from each other.

[Note that this feature of the database service layer may not be implemented in the first beta version, so that manual disaggregation may initially still be required]

[examples from the current database]

[**Changes relative to ecoinvent version 2:** In version 2, some datasets with combined production were not sub-divided, but allocated. The following multi-product activities are covering combined production and must be expressed with mathematical relations and sub-divided: ethanolamine production, gravel and sand quarry operation, petroleum refinery operation, hydroformylation of butane and propylene, benzene chlorination, sheep production, helium extraction. This should preferably be done by the original dataset author and/or editor.]

5.4 Production volumes

ecoSpold reference: productionVolumeAmount (field 1530); productionVolumeComment (field 1535)

All transforming datasets are provided with data on the production volume of the production facility, or from statistical sources on supply when the dataset represents several facilities. When statistical sources on supply are not available, the production volumes may be indirectly estimated from the demand.

[Examples]

Data is always *annual* production volumes relating to the time period and geographical area of the dataset and the unit of the product. This implies that

- When calculating total production volumes, e.g. for market datasets, the data can be utilised unmodified even when the time period of the dataset is different from a full year.
- When more than one activity produces the same product within the same market area, the production volume of each activity reflects that activity alone, i.e. the production volumes are additive.

Production volumes of market datasets are automatically calculated by the database service layer and are available in the attributional dataset implementations. If provided in the datasets with market model *undefined*, production volumes for market activities are provided only as text in the comment field.

Production volumes of treatment activities include treatment of wastes from previous years and will therefore not (necessarily) equal the total amount of waste generated in the time period of the treatment datasets. In parallel, production volumes of average operation/use datasets reflect the use of the current "fleet" of equipment, which may not be identical to the equipment currently produced. For an LCI of a specific type of equipment, the corresponding specific operation/use dataset should therefore be applied.

[**Changes relative to ecoinvent version 2:** Production volume data are now systematically provided for all intermediate outputs.]

5.5 Technology level of activities

ecoSpold reference: technologyLevel (field 500)

The technology level of each transforming activity is classified in one of these five classes:

"New" for a technology assumed to be on some aspects technically superior to modern technology, but not yet the most commonly installed when investment is based on purely economic considerations.

"Modern" for a technology currently installed, when investment is based on purely economic considerations (most competitive technology).

"Current" for a technology in between modern and old.

"Old" for a technology that is currently taken out of use, when decommissioning is based on purely economic considerations (least competitive technology).

"Outdated" for a technology no longer in use.

Market activities do not have a technology level.

It should be noted that the terms used do not necessarily reflect the *age* of the technologies. A modern technology can be a century old, if it is still the most competitive technology, and an old technology can be relatively young, if it is one that has quickly become superseded by other more competitive ones.

The technology level is relative to the year for which the data are valid, as given under temporal validity; see Chapter 4.2.2. In a time series, the same technology can move between different technology levels over time. For forecasted datasets, the technology level can also depend on the macro-economic scenario. The same technology can also be given different technology levels in different geographical locations, even in the same year.

The technology level is of particular importance in consequential market models, where the setting of the technology level determines whether an activity is included as an unconstrained supplier to the markets, depending on the specific rules for the particular consequential market model (see Chapter 14.5). For example, in the market model "Consequential, small-scale, long-term decisions", an activity is identified as unconstrained if its technology level is "Modern" for increasing, stable, or slowly decreasing market volumes of its reference product, while the activity is identified as unconstrained if its technology level is "Old" for rapidly decreasing market volumes. The other technology levels may come into play if the database does not contain any datasets with the required technologies.

The distinction between technology levels is based on an economic rationale since capacity adjustments typically are decided on the basis of long-term competitiveness as determined by the expected production costs per unit over long-term. With respect to geographical location, it is assumed that competitiveness is determined by the cost structure of the most important production factor (labour costs for labour intensive products, else energy and raw material costs). When comparing labour costs, local differences in productivity and labour skills are taken into account. If producers are distinguished by their cost structure and location, the most competitive supplier for a specific localised demand can be assessed by adding the specific transport costs.

[**Changes relative to ecoinvent version 2:** The classification according to technology level is new. By default all datasets in the ecoinvent version 2 are set to “current”, which implies that a change to other technology levels must be done manually by the dataset authors. A list of situations where a change should be considered will be supplied to the current dataset authors and/or editors.]

5.6 Properties of exchanges

ecoSpold reference: property (field 1400); complex type TProperty; TProperty definingValue (field 2312)

5.6.1 Mass and elemental composition

All exchanges are provided with data on wet mass, dry mass, and water mass, given per unit of the exchange, and water and carbon content per dry mass, the latter subdivided in fossil carbon and biogenic carbon. The content of other elements may be provided in addition. If the product output is specified in terms of elemental composition, these elements are also specified in the inputs that provide these elements.

For substances other than water, dry mass is *not* the same as ash content, but is calculated as the wet mass minus the water mass, and thus includes chemically bound H and O. Inputs or outputs of water may therefore, somewhat counter-intuitively, have a dry mass, when the water is incorporated into or released from chemical reactions involving chemically bound H and O.

Elemental composition is always given per dry mass. This implies that if the elemental composition is required per amount of an exchange, e.g. for use as an allocation property, the elemental composition shall be multiplied by the dry mass, before multiplying with the amount of the exchange.

[**Changes relative to ecoinvent version 2:** Wet mass, dry mass, water mass, and water and carbon content (the latter divided in fossil and biogenic) to be provided when missing, and reviewed by the original dataset authors.

5.6.2 Fossil and biogenic carbon

A distinction is made between fossil and biogenic sources of CO_2, CO and CH_4. The sources of fossil carbon are fossil fuels and calcium carbonate.

The resource consumption of “Carbon dioxide, in air” is calculated from the carbon in harvested plants and wild animals and increases in carbon stored in soils and plants. The latter is recorded as an output of "Carbon dioxide, to soil or biomass stocks". Carbon in harvested plants and wild animals is the only source of biogenic carbon.

Reductions in the carbon stored in soils and the release of carbon from the burning of biomass residues in connection to land transformation, e.g. the clear-cutting of primary forests, are recorded in the elementary exchange (resource) "Carbon, organic, in soil or biomass stocks". All of this input is included in the corresponding emission “Carbon dioxide, from soil and biomass stocks” and therefore does not contribute to any biogene or fossil content of any intermediate exchanges.

The properties carbon_content_biogenic and carbon_content_fossil are used by the database service layer to calculate the properties carbon_content and carbon_allocation for use in the carbon allocated implementation of the ecoinvent database, see Chapter 14.7.3.

[**Changes relative to ecoinvent version 2:** The exchanges "Carbon, organic, in soil or biomass stocks" and “Carbon dioxide, from soil and biomass stocks” replaces the exchanges "Carbon, in organic matter, in soil" and "Carbon dioxide, land transformation" used in version 2. All datasets with these exchanges need to be revisited to ensure that carbon balances are correct.]

5.6.3 Energy content

ecoSpold reference: energyValues (field 180)

Energy content is not a required property of exchanges in the ecoinvent database.

If reported, the property “energy content” is accounted for in gross heating value (gross calorific value, higher heating value, upper heating value) in energy units per unit of the exchange.

Heat and electricity are measured directly in energy units.

Due to the significant energy losses or costs in transporting steam or hot air, the necessary heat is always produced in close geographical proximity to the activity requiring heating or cooling energy, often in an in-house boiler or purchased from a local heat producer. Thus, for site specific datasets, the fuel type, boiler efficiency and operational emissions will typically be known and can be modelled specifically.

For the more generic datasets in ecoinvent, covering several, possibly unspecified, locations, typically only the amount of heat or the amount of fuel required will be available, sometimes with a specification on fuel type. For these situations, the generic boiler datasets delivering useful heat at average efficiencies are used.

The gross calorific value is the amount of heat generated by a given substance when it is completely oxidised. Calorific values are measured experimentally with a bomb calorimeter and can be calculated as the difference between the standard enthalpy of formation (also known as the standard heat of formation ΔH_f^Θ or $\Delta_f H^\Theta$; the change of enthalpy that accompanies the formation of 1 mole of the substance in its standard state from its constituent elements in their most stable form at 1 bar of pressure and 298.15 K or 25 degrees Celsius) of the oxidation products and the substance before oxidation. The gross calorific value includes the heat of condensation of water in the oxidation products. In contrast, the net (or lower) calorific value assumes that the enthalpy of vaporization of water (40.65 kJ/mol) is not recovered. It is useful in comparing fuels where condensation of the oxidation products is impractical, or heat at low temperatures cannot be put to use.

When specific data are unavailable, the gross calorific values in Table 5.1 are applied. The Table also gives densities for some common fuels for conversion from MJ to kg and back.

Data on standard enthalpy of formation are generally obtained from the thermochemistry data in the NIST Chemistry WebBook <http://webbook.nist.gov /chemistry/>. All elements in their standard states (e.g. oxygen gas) have a standard enthalpy of formation of zero, as there is no change involved in their formation.

Table 5.1. Default values for gross and net calorific values and density of some common fuels.

	gross calorific value MJ/kg	net calorific value MJ/kg	Density kg/l
agricultural biogas	23.7	21.4	0.00113
crude oil	45.8	43.2	0.86
Diesel	45.4	42.8	0.84
gasoline	45.1	42.5	0.75
hard coal	30.4	28.9	
hard coal, briquette	32.4	31.4	
hard coal, coke	28.9	28.6	
heavy fuel oil	43.7	41.2	1.0
kerosene	45.6	43.0	0.795
light fuel oil	45.2	42.6	0.86
lignite, briquette	20.9	19.5	
lignite, hard	17.8	16.8	
lignite, soft	9.5	8.4	
methanol	22.7	20.0	0.792
Naphtha	47.7	45.0	0.75
natural gas [1])	50.4 (40.3)	45.4 (36.3)	0.0008
petroleum coke	36.1	35.0	1.1 (0.650 to 1.3)

[1]) values in brackets: MJ/m^3

[**Changes relative to ecoinvent version 2:** The use of energy efficiencies for renewable energy inputs and the inclusion of waste heat has been abandoned. Boiler datasets such as "light fuel oil, burned in industrial furnace 1MW, non-modulating" are revised to have instead heat as an output, i.e. integrating with datasets such as “heat, light fuel oil, at industrial furnace 1MW", specifying the input of fuel in both MJ and other relevant physical units as product properties of the output. The conversion and re-linking of the datasets, including revising the datasets that currently demand inputs such as "light fuel oil, burned in industrial furnace 1MW, non-modulating" is done as a database-wide automatic routine.]

5.6.4 Density

Activity datasets for wood and semi-finished wood products are modelled per m^3. Since the density and the heating value of wood strongly depend on the moisture content, the water content on a dry mass basis (referred to as the u-value in ecoinvent version 1&2) is also given in the names of the activities and/or products. Some default values used for density of wood products are provided in Table 5.2.

Table 5.2 Default values for density of wood product

Wood type (water content on dry mass basis) [1]		density
		kg/l
Construction wood	Softwood, round wood [2] wet (70%)	0.765
	Softwood, industrial wood [3] wet (140%)	1.080
	Softwood air dried (20%)	0.540
	Softwood kiln dried (10%)	0.715
	Hardwood, round wood wet (70%)	1.105
	Hardwood, industrial wood wet (80%)	1.170
	Hardwood air dried (20%)	0.780
	Hardwood kiln dried (10%)	0.715
Energy wood	logs, softwood, 1 year dried(30%)	0.585
	logs, softwood, 2 years dried (20%)	0.540
	logs, softwood, in the forest (140%)	1.080
	logs, hardwood, 1 year dried (30%)	0.845
	logs, hardwood, 2 years dried (20%)	0.780
	logs, hardwood, in the forest (80%)	1.170
	wood chips, softwood, from sawmill (40%)	0.630
	wood chips, softwood, from forest (50%)	0.675
	wood chips, softwood, in the forest (140%)	1.080
	wood chips, hardwood, from sawmill (40%)	0.910
	wood chips, hardwood, from forest (50%)	0.975
	wood chips, hardwood, in the forest (80%)	1.170

[1]) Moisture given in weight-% related to the dry mass of wood.

[2]) round wood = entire trunk before cutting

[3]) industrial wood = smaller pieces, branches

[**Changes relative to ecoinvent version 2:** Names including u-values have been changed to "% water on dry mass basis".]

5.6.5 Price of products and wastes

The property "price" is accounted for all intermediate outputs in currency units per unit of the exchange.

Prices for outputs of transforming activities are provided in basic prices (i.e. without product taxes) obtained from the production facility or from statistical sources when the dataset represents several facilities. When statistical sources are not available, the prices are calculated from the prices of the intermediate inputs adding the average added value for the industry, as provided in national statistics. Prices for by-products/wastes may be negative, when costs of treatment activities have to be paid partly or fully by the supplying activity.

Prices for outputs of market activities are provided in purchaser's prices. To come from the basic prices to the purchaser's prices three elements are added:

basic prices + product taxes - product subsidies + trade margins + transport costs = purchaser's prices

Product taxes less subsidies are added as primary inputs (monetary elementary exchanges, see Chapters 6.4 and Annex C) to the market activity datasets, while the trade margins and transport costs are determined by the prices of the intermediate inputs to the market activities from the wholesale, retail and transport industries.

For exported products, the purchaser's price of the exporting area is also known as FOB (Free On Board). International transports costs (CIF = Cost Insurance and Freight) are then added to the import activity in the importing country, resulting in a "CIF" price at the border of the importing area corresponding to the basic price of that area. The imported product then contributes to the local market (consumption mix) and there receives the same purchaser's price as the products produced domestically in the importing area.

When niche markets exist, see Chapter 4.4.6, these will typically support higher prices than the corresponding general market segments. When part of a niche product is sold on the general market segment, this therefore involves a price reduction. Furthermore, the "mixing of niche product" activities, which transforms the niche products to be inputs to the general market segments, receive the niche products in purchaser's prices of the niche markets and supplies them in basic prices of the general market segments. Thus, the "mixing of niche product" activities will, besides changing the name of their products, imply a price reduction of the products, both because the general market segments do not support the higher price of the niche products, and because the activities transform the prices from purchaser's prices back to basic prices.

[**Changes relative to ecoinvent version 2:** The addition of price information is new.]

5.6.6 Allocation properties

ecoSpold reference: masterAllocationPropertyId (field 190); allocationComment (field 195); specificAllocationPropertyId (field 1150)

An allocation property is a property used for calculating allocation factors, either for a transforming activity dataset (master allocation property) or for a single exchange (specific allocation property).

The property *"true value"* is a property specifically added for allocation purposes. The "true value" property is set by the database service layer as identical to the price, unless the property "true value" is specifically provided in the original, manually edited dataset (the dataset with market model *undefined*). Thus, allocation by true value is a variant of the allocation using "price" as allocation property, introduced to correct for some problems identified in the latter approach in two specific situations:

- When there is a very high annual variation in the relative average prices of the co-products, the "true value" property may be set to the same ratio to the as the ratio of the average prices for the last three years.
- When the co-products have a shared functional property that should determine their relative value if not affected by market imperfections or perverse regulation, the "true value" property may be set to the same ratio as the amounts of this property. An example of this is the price of heat as a co-product from electricity production. Here, it is possible to argue that exergy, i.e. the ability of the products to perform work, is a shared property of the two products that reflects the true, functional value of the co-products, and that in a perfect market this would be reflected in the relative prices of the products. Thus, when both electricity and useful heat are products of the same activity, the true value property results in the same allocation factors for the two products as if the property "exergy" had been used, while the sum of the true value of the two products (i.e. true_value * amount) equal the sum of the revenue (price * amount) from these two products, so

that allocation based on the price can still be made for any other co-product. [real life calculation example to be provided]

For simple identification of activities for which true value properties are provided in the original dataset, the ecoinvent database automatically adds a tag “with true value” to such activities.

[**Changes relative to ecoinvent version 2:** While maintaining the same options as in the ecoinvent database version 2, the ecoSpold 2 format provides a more flexible approach to allocation.]

5.6.7 The designation “Defining value”

ecoSpold reference: TProperty definingValue (field 2312)

In the master file in which an exchange is defined, a property of the exchange can be designated as a “defining value”. This implies that its value is a part of the definition of the exchange and therefore has a fixed relation to the amount of the exchange that cannot be changed for individual instances of the exchange in different datasets.

[add example]

5.7 Use of variables within datasets

ecoSpold reference: mathematicalRelation (field 1060); isCalculatedAmount (field 1050); variableName (field 1040); Parameter name (field 1700); Parameter comment (field 1740); TProperty defaultvariableName (field 2315); Parameters variableName (field 1712); Parameters mathematicalRelation (field 1720); Parameters isCalculatedAmount (field 1725); Technology comment (field 510)

Values for exchange amounts and properties can be expressed as mathematical relations, using an ecoinvent-adapted version of the Open Document Formula Language (described in the documentation to the ecoSpold format: Schemas/AdditionalDocumentation at www.ecoinvent.org/fileadmin/documents/en/EcoSpold02.beta4.zip). For each field, where a mathematical relation is used, there is also a comment field, in which the mathematical relation is documented.

Variables for use in mathematical relations can be defined as specific parameters, valid within the individual dataset only. In addition, any exchange amount and property within a dataset can be used as a variable in mathematical relations of the same dataset. Exchange amounts and properties can be given a specific variable name, but also the unique identifiers (UUID’s) of each exchange amount and property can be used as a variable directly, using the REF function, i.e. REF('UUID').

Parameters and other variables can themselves be defined via mathematical relations including variables, i.e., nested variables are allowed, to the extent that circular references are not created.

In general, parameters are primarily used for discrete variables (e.g. aluminium/steel, hot/cold), while properties are used for continuous variables (e.g. elemental composition).

Variables are unique to each dataset, i.e. it is not possible to define global variables valid for more than one dataset. However, in combination with the option of parent/child datasets (see Chapter 4.2), also variables are inherited, which implies that relations between exchanges and/or properties are preserved from parent dataset to child dataset. Each variable in each child dataset can of course have a different value from the variable value in the parent dataset.

The use of mathematical relations allows entry of data directly copied from original data sources, in their original units, and therefore contributes to reduce data conversion as a source of error and provides a more transparent documentation of the calculations that have been performed upon the primary data.

Additional advice for data providers:

It is recommended to define variables in parent (reference) datasets first, before creating delta/child datasets. Variables can be applied to reduce the effort when creating and maintaining datasets for very similar activities, e.g. extrusion of different metals: Although separate datasets are still needed for extrusion of steel and extrusion of aluminium, the same generic dataset can be applied as a starting point, expressing the specific differences in exchanges as conditional upon the Boolean parameters "steel" and/or "aluminium", e.g., the electricity use per deformation stroke can be expressed as "Alu*0.115 + Steel*0.527" kWh, where the value will be 0.115 if Alu is true and Steel is false, and 0.527 in the opposite situation. All the exchanges that are identical to the two forms of extrusion then do not have to be entered twice.

[**Changes relative to ecoinvent version 2:** The option to use variables is new.]

5.8 Text variables

ecoSpold reference: Complex type TTextAndImage

Some ecoSpold fields of the type TTextAndImage (the fields general comment, allocation comment, geography comment, technology comment, and time period comment) allow the use of *text* variables.

Text variables are used to include, exclude or edit specific text strings within an inherited text field. This allows easy changes of parts of texts for the child activity datasets. See also Chapter 4.2 for more details on inheritance.

A text variable is defined in a parent dataset and included in a text string by placing the variable name in {{curly brackets}} For example, in the text string: "This dataset is includes the {{metal}} extrusion", the variable 'metal' may be given the value 'metal' in the parent dataset, but other appropriate values such as 'steel' and 'aluminium' in different child datasets. Thereby, only the difference between parent and child text has to be edited, while keeping the rest of the parent text intact.

5.9 No double-counting

5.9.1 Activity datasets

ecoSpold reference: includedActivitiesStart (field 145); includedActivitiesEnd (field 150)

The ecoSpold field includedActivitiesStart describes the starting point of the activity. For unit processes, the starting point may be described in terms of the nature of the inputs and the point of reception, e.g. "From reception of raw materials [possibly further specified] at the factory gate [possibly further specified]" or "Service starting with the input of [e.g. labour and energy]". For aggregated system datasets, the starting point is always "From cradle, i.e. including all upstream activities".

The ecoSpold field includedActivitiesEnd describes the included activities to the extent that this is not self-explanatory from the activity name, and ends with a description of the last activity and/or point of delivery, e.g. "until and including loading of the product on lorries".

Additional advice for data providers: In the text in the includedActivities fields, especially if raw materials inputs are specified, ensure that inputs are not described in such a way that it can be misunderstood whether the production and supply of these inputs are part of the activity described. For example "Machine infrastructure is included" or "Inputs of are XX are considered" can be misunderstood to mean that the production of the machine infrastructure and/or the input XX is part of the described activity, when they are in fact simply inputs to the activity, and recorded as such under exchanges. See the wording suggested above for good practice.

The clear description of the start and end of each activity reduces the risk of overlapping datasets or gaps between datasets. If temporal markets are defined (see Chapter 4.4.4), the sum of all temporal markets should equal the average market. For geographically distinct datasets for the same activity, the database validation procedures ensure that the sum of the production volume of all datasets for the same activity equals the global production volume. Double-counting is also generally avoided by the completeness of the database, which implies that any new activity dataset added to the database is effectively a disaggregation of an existing activity dataset, see Chapter 13.

[**Changes relative to ecoinvent version 2:** In some ecoinvent v2 datasets, the field includedActivities contains redundant information that should be removed when updating, for example information on which raw materials, infrastructure or transport is included or which emissions are included, both types of information already being provided in the information on the exchanges.]

5.9.2 General principles for elementary exchanges

Elementary exchanges (exchanges with the environment) are only registered once and on the most detailed level for which information is available. Benzene emissions for instance are reported as such but not as "aromatic hydrocarbons", nor as "non methane volatile organic compounds". If benzene and total NMVOC emissions have both been measured and reported, the amount of benzene emitted is subtracted from the amount of NMVOC emission, to avoid double counting.

Elementary exchanges are classified with the help of compartments and sub-compartments. Compartments describe to where elementary exchanges are emitted (air, water, soil). Within these compartments, sub-compartments further distinguish issues relevant for the subsequent impact assessment step, e.g. population density.

Each elementary exchange is recorded only once. Hence, if appropriate, one may add up the elementary exchanges of all sub-compartments to get the total amount of an elementary exchange of the compartment. For example, one might add up the mean values of all "Carbon monoxide, fossil" emitted to "air/high population density", "air/low population density", air/lower stratosphere + upper troposphere", and air/unspecified" to get the total amount of fossil CO emitted to air.

The particulate emissions are reported in classes of <2.5 µm, between 2.5 µm and 10 µm, and >10 µm. In order to get the amount of PM10 emitted, the results of particulates emissions of <2.5 µm, and between 2.5 µm and 10 µm (named "Particulates, < 2.5 um" and "Particulates, > 2.5 um, and < 10um") need to be added.

The only exception to this rule is the reporting for some sum parameters for water pollutants, i.e., the four parameters BOD_5, COD, DOC, and TOC (see Section 5.9.7), and the (minor) double-counting of mass implied by reporting particulate metal emissions as both particulates *and* as specific metal emissions (see section 5.9.4), both in mass units.

5.9.3 Resources

The extraction of metals and other minerals in ores is recorded as the amount of target material that is contained in the ore. In metals mining often two or more metals are mined together. The corresponding resources are recorded on the level of individual resources, e.g. 0.12 kg “Phosphorus, in ground” and 0.03 kg “Fluorine, in ground”. The additional content of non-used (gangue) material is added as a separate input, e.g. 0.85 kg “Gangue, fluorapatite ore, in ground”, so that the total amount of extracted material (here 1 kg) is recorded.

Non-renewable energy resources like oil and gas are provided in weight or volume units and with the properties dry mass and energy content in energy units.

[**Changes relative to ecoinvent version 2:** In version 2, different ores are reported separately with their composition of different metals. For version 3, the nature of the ore (mineral/concentration) is now given as a property for each metal resource. The necessary translation from the old to the new format is performed as a central database maintenance task. Affected dataset authors and editors will be informed.]

5.9.4 Airborne particulates

Particulate emissions are separated according to the diameter class. Three categories are distinguished, namely less than 2.5 micron, between 2.5 and 10 micron, and more than 10 micron (see Table 5.3). With that, double counting of particulate emissions is avoided. It has to be noted that these classes do not coincide with the standard measurements which distinguish between less than 2.5 micron (PM2.5), less than 10 micron (PM10) and total particulate matter (TPM). The values recorded in the ecoinvent database are derived from the standard measurements with the calculation procedure explained in Table 5.3.

Tab. 5.3 Names and characteristics of particulate elementary exchanges as reported in the ecoinvent database.

Name	Formula	Remarks
Particulates, < 2.5 um	PM2.5	particulates with a diameter of less than 2.5 µm
Particulates, > 2.5 um and < 10 um	PM10-PM2.5	particulates with a diameter of more than 2.5 µm and less than 10 µm
Particulates, > 10 um	TPM-PM10	particulates with a diameter of more than 10 µm and less than 100 µm

PM2.5 particulate matter with a diameter of less than 2.5 µm
PM10 particulate matter with a diameter of less than 10 µm
TPM total particulate matter

Particulate metal emissions are inventoried as particulates *and* as specific metal emission, implying a (minor) double-counting of mass. An option that would avoid the implied double-counting of the mass would be to exclude the mass of the particulate indicators from the mass balance and to add an inventory item "mass of particulates not accounted for as individual substances" with the sole purpose of entering the mass balance. This option has *not* currently been implemented in the ecoinvent database.

As a first priority, particulate emission factors as well as information about its size distribution are taken from the particular information source. If no information is available about the size and/or its distribution, standard reference works are used according to the following fixed order:

1. The Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (CEPMEIP) Database, (Berdowski et al. 2002),
2. A Framework to Estimate the Potential and Costs for the Control of Fine Particulate Emissions in Europe (Lükewill 2001),
3. Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, Appendix B.1: Particle Size Distribution Data and Sized Emission Factors for Selected Sources (US-EPA 1986).

5.9.5 Volatile organic compounds - VOC

Because of its particular importance with respect to global warming, methane and non-methane volatile organic compounds (NMVOC) emissions are accounted separately.

Further specifications within the NMVOCs are applied as far as possible. Among the large number of polycyclic aromatic hydrocarbons, at least Benzo(a)Pyrene is recorded separately.

Dioxins and furanes are recorded as TCDD-equivalents. The equivalency factors of the NATO/CCMS weighting schema are applied (see for instance Frischknecht et al. 1996, part III, p. 27).

[Check with our toxicity editor that this is still the most up-to-date procedure]

[**Changes relative to ecoinvent version 2:**]

5.9.6 Other air pollutants

SO_X and NO_X emissions are reported as SO_2 and NO_2, respectively. When information is available, the shares of SO_3^- or SO_4^{2-} emissions, and NO emissions, respectively, are subtracted from the total SO_X and NO_X emissions, and reported separately. This differentiation is also made in the impact assessment methods.

Trace element emissions into air are recorded as chemical compounds if information is available. They are recorded as e.g. "kg Sodium dichromate". In all other cases just the amount of chemical element released is recorded. A differentiation according to currently used impact assessment methods is aimed at. No sum parameters such as "metals" are used.

5.9.7 Sum parameters for carbon compounds (BOD_5, COD, DOC, TOC)

In the ecoinvent inventories all four sum parameters BOD_5, COD, DOC and TOC[2] are recorded in parallel (i.e., without any reductions due to separately reported individual substances). If necessary (no sum parameter measurements available) they are calculated from the information given for individual water pollutants. For that purpose the stoichiometric oxygen demand for the oxidation is calculated to quantify the COD. The amount of TOC and DOC is determined from the carbon content of the individual substance and based on the recommendations of de Beaufort-Langeveld et al. (2003).

Missing data are added using best estimates. DOC = TOC in a filtered sample, and in general the rules of thumb COD (g O_2) = 2.7*TOC (g C) and BOD_5 = 0.5*COD can be applied to untreated waste water. The BOD/COD ratio depends on the biodegradability of the organic material. At full biodegradability BOD = COD. For domestic wastewater values up to BOD_5 = 0.75*COD can be found and for food industries BOD_5 = 0.9*COD. For wastewaters with low nutrient share of the carbon, such as from chemical plants and cleaned wastewaters, the ratio can be as low as BOD_5 = 0.2*COD and when having passed a nutrient elimination step BOD_5 = 0.05*COD.

All individual substances are additionally recorded in the inventory. For the assessment of aquatic eutrophication or other impacts, it is sufficient to select one of the above-mentioned sum parameters. No double counting occurs as long as only one parameter and no individual substances are considered in this assessment.

[add Table here or calculation aid to ecoEditor?]

[**Changes relative to ecoinvent version 2:** The worst-case assumption BOD = COD has been removed as recommendation.]

5.9.8 Other sum parameters (AOX, etc.)

Individual substances are subtracted from other sum parameters used in the analytics of water, such as AOX or total nitrogen.

[2] BOD_5 Biological oxygen demand in five days
COD Chemical oxygen demand
DOC Dissolved organic carbon
TOC Total organic carbon

5.10 No cut-offs

No strict quantitative cut-off rule is followed in the ecoinvent database. Datasets are as complete as the knowledge of the data providers allow.

No cut-offs are applied for recycling. Recycled by-products are treated as any other by-product.

If no specific information about the exact substance or its amount emitted is available, an educated guess is made based on plausibility considerations. In cases where such assumptions dominate the LCA result, further and more detailed investigations are carried out and some of the values reconsidered. If the rough assumption does not influence the result, it does not harm and is kept in the inventory.

The ecoinvent database does not operate with cut-off levels for minor inputs or outputs. In principle, all known inputs and outputs are recorded as such.

This approach does imply some risk of bias in the results if comparing activities or product systems where detailed information is available for one while not for the other. The ecoinvent Centre currently carries out research to minimise such bias by increasing the completeness of the reporting of specific toxic exchanges, as well as other exchanges that contribute significantly to the overall environmental impact of human activities.

[**Changes relative to ecoinvent version 2:** In version 2, cut-offs were applied to by-products for recycling.]

6 Completeness

This Chapter is concerned with completeness of individual datasets. The completeness of the database is discussed in Chapter 13 on “Embedding new datasets into the database”.

6.1 Stoichiometrics

If data availability is poor, stoichiometric balances are used to determine the raw materials demand. If no specific information is available, a 95% yield is assumed.

6.2 Mass balances

For each activity, the law of conservation of mass and energy applies. This implies that the mass and energy in and out of each activity is the same, when taking into account changes in stocks. Only for activities involving nuclear reactions these balances interact. This is also true for each element. Thus, separate mass and elemental balances apply to all activities except those involving nuclear reactions.

Dry mass and water mass are available (reported or calculated) for each resource input, for each intermediate exchange of products and wastes, as well as for emissions. This includes water resource use, and nitrogen and oxygen from air entering into activities involving combustion, photosynthesis and biological metabolism, and the air emissions of water vapour and oxygen and nitrogen from these activities as calculated from the reaction equations. For example, the oxygen demand for combustion is calculated from the oxides (notably CO, CO_2, SO_2, NO_2, and N_2O) in combustion exhaust. Thus, complete mass balances (sum of outputs minus sum of inputs) for the unit processes can be calculated and any deviations reported, either in the validation report or as an “unspecified output, from mass balance”. Note that a dry matter balance may include water when this is incorporated as or released from chemical reactions involving chemically bound H and O.

In addition to the dry matter balance, mass balances for selected chemical elements can be performed when specific information on the content of these elements is provided for all relevant inputs and outputs to an activity. Currently, this is only done systematically for fossil and biogenic carbon.

Conditional exchanges are not included in mass balances; see Chapter 11.4.

[**Changes relative to ecoinvent version 2:** Mass balancing is a new option, enabled by the option to add properties to all exchanges.]

6.3 Energy balances

ecoSpold reference: energyValues (field 180)

Energy content is not a required property of exchanges in the ecoinvent database. Therefore, it is also not possible to provide complete energy balances of all activities or product systems. The total fossil and nuclear fuel inputs and Cumulative Energy Demand (fossil and nuclear) may still be calculated from the resource inputs of fossil and nuclear fuels.

[**Changes relative to ecoinvent version 2:** Waste heat emissions and energy content of renewable energy resource inputs are removed.]

6.4 Monetary balances

Although there is no "law of conservation of money", a monetary balance applies to each activity, expressed in the so-called *accounting equation,* which is the foundation for the double-entry bookkeeping system. Thus, all revenue earned must also be spent, when taking into account changes in savings.

Using the price information reported for each intermediate input and output, monetary balances can be established for each activity. The balancing element accounting for the difference between the value of the outputs (revenue) of an activity, and the value of the inputs of intermediate products (including investments) to this activity, is the elementary input *"Expenditures on primary production factors"*, measured in monetary units, which may be calculated as the unspecified residual in the monetary balance. When more information is available, this may be divided in the following components:

- *Labour cost* (wages and other remunerations), possibly further sub-divided on income group or education level of the workers
- *Net tax* (taxes minus subsidies)
- *Net operating surplus* (entrepreneur's income or profit)
- *Rent* (payment to resource owners)

The first three of these together are called *value added*. In national accounting practice, rent is included with the net operating surplus and the term value added is used for the payments to the primary production factors *including* investments, although in formal terms rent does not contribute any added value to society and the value added of investments is already counted once in the industries supplying the investment goods. In national accounting, the value added of an activity is the same as its contribution to the gross domestic product (GDP).

To ensure their inclusion in the monetary balance, the *Expenditures on primary production factors* and/or its components all have "price" as a property, even when the amounts of these exchanges are already measured in monetary units. When expressed in the same units as the amount of the exchanges, the amount of the price property is 1. *Labour cost* may be reported in terms of working time and the price is then expressed per unit of working time. Even then, working time is added as a separate property, to facilitate summing up working time over several activities or for a product system.

An activity does not necessarily pay for all its inputs; some may be supplied to the activity "for free", e.g. as a public service such as road infrastructure or hospital services. The physical relationship (causality) is then not matched by a direct economic relationship. However, a service or a good supplied "for free", typically means that someone else has paid for the costs of this good or service, which is thus an economic externality; see Chapter 6.11. To avoid double-counting, such externalities are not reported as externalities in the ecoinvent database, but are instead included directly (internalised) as intermediate inputs to the activity. When internalising an economic externality, the activity that originally paid for the good or service is relieved of this cost, which instead adds to the total intermediate costs of the activity that previously received this input for free. The economic balance of this activity is maintained either by an equivalent amount being added to (internalised in) the price of the output or subtracted from the *Expenditures on primary production factors*, or more specifically the *Net tax*, which is equivalent to assuming that the cost is covered by a subsidy. Which of these solutions (internalising in price or internalising via subsidy) to implement, depends on what best reflects the actual monetary flows.

Note that internalisation is also relevant when the good or service is already covered specifically by a dedicated tax, reported under *Net tax* of an activity, since this tax is not linked to any physical inputs. In fact, any dedicated tax or subsidy, i.e. a tax or subsidy that is dedicated to be used for a specific activity, should be internalised in this way, to correctly model the physical causalities.

However, whether a "free" good or service is included as input to an activity or not is sometimes dependent on a judgement of what constitutes a physical causality. For example, it is obvious that road infrastructure is to be included as an in input to road transport even when it is not paid for directly by the vehicle operators, rather than being a stand-alone final consumption item (as it is in many national accounts), but it may be less obvious whether or to what extent the road transport dataset should have an input of health care in proportion to the additional health care required to treat victims of road accidents, or an input compensating for the time lost in queuing from other users of the same infrastructure. For details of such modelling decisions, the database user must consult the relevant individual datasets. In general, the ecoinvent database strives to include (internalise) all well-documented physical causalities, disregarding whether they are matched by a direct economic relationship.

[**Changes relative to ecoinvent version 2:** The option to make a monetary balance is new, and is related to the requirement that price information is added to all intermediate exchanges.]

6.5 Elementary exchanges

In the ecoinvent database no predefined list of elementary exchanges is applied. Completeness in elementary exchanges is aimed for. Specific development projects are performed by the ecoinvent Centre to fill gaps in the data.

6.6 Water

Water enters as a resource input like any other resource, specified by its location or origin (distinguishing groundwater, surface water, sea water, rain water, water bound in extracted minerals, and water bound in biological material harvested in the wild). The quality of the water resource can be further specified by its properties. Relevant properties may be COD, BOD, TSS, TDS, and faecal coliform bacteria.

The input of water can be balanced with an equivalent output to different environmental compartments (air, soil, groundwater, ocean and surface water, see Chapter 9.4.2). Note that any pollution/contamination of the emitted water is specified as separate exchanges (including e.g., COD, BOD, faecal coliform bacteria, and temperature, when relevant).

6.7 Land occupation and transformation

Land occupation and land transformation receives increasing attention in life cycle inventory analyses and life cycle impact assessment methods. It is especially important for agricultural and forestry products.

Table 6.1 shows the land use classes used for the ecoinvent database. The land use classes and the descriptions in the table are mainly taken from Alkemade et al. (2009) and Koellner & Scholz (2008).

[It is currently being investigated if continuous indicators such as NPP can be used as the basic variables, so that the land use classes are only provided as default options (i.e. each of these with their specific description in terms of the continuous variables). This would allow data providers to define new land use classes as long as they define them in terms of the underlying variables.]

Table 6.1. Land use classes used in the ecoinvent database. Default use period for depreciation of the initial land transformation (n.r. = not relevant). Table continues on next page.

Land use class	Description	Default use period
Unspecified		1
Unspecified, natural (non-use)		n.r.
Forest, unspecified	Tree cover >15%.	80
Forest, primary (non-use)	+ Minimal disturbance, where flora and fauna species abundance are near pristine.	n.r.
Forest, secondary (non-use)	+ Areas originally covered with forest or woodlands, where vegetation has been removed, forest is re-growing and is no longer in use.	n.r.
Forest, extensive	Forests (tree cover >15%), with extractive use and associated disturbance like hunting, and selective logging, where timber extraction is followed by re-growth including at least three naturally occurring tree species, with average stand age >30 years and deadwood > 10 cm diameter exceeds 5 times the annual harvest volume.	100
Forest, intensive	Forests (tree cover >15%), with extractive use, with either even-aged stands and clear-cut patches exceeding 250 m length, less than three naturally occurring species at planting/seeding, average stand age <30 years or deadwood less than 5 times the annual harvest volume.	80
Wetland, coastal (non-use)	Areas tidally, seasonally or permanently waterlogged with brackish or saline water. Includes mangrove and marshland. Excludes coastal land with infrastructure or agriculture. Often rich in biodiversity.	n.r.
Wetland, inland (non-use)	Areas partially, seasonally or permanently waterlogged. The water may be stagnant or circulating. Includes bogs. Often rich in biodiversity.	n.r.
Shrub land, sclerophyllous	Near pristine shrub-dominated vegetation (e.g., savannah). Often rich in biodiversity.	100
Grassland, natural (non-use)	Grassland vegetation with scattered shrubs or trees (e.g., steppe).	n.r.
Grassland, natural, for livestock grazing	Grasslands where wildlife is replaced by grazing livestock.	20
Pasture/meadow, man made	Forests and woodlands that have been converted to grasslands for livestock grazing.	30
Pasture/meadow, man made, extensive	Meadows mechanically harvested 2 or 3 times per year, no artificial fertiliser applied.	20
Pasture/meadow, man made, intensive	Meadows mechanically harvested 3 times or more per year, fertiliser applied.	50
Arable	Cultivated areas with cereals, legumes, fodder crops, root crops, or vegetables. Includes aromatic, medicinal and culinary plant production and flower and tree nurseries. Excludes permanent pastures.	1
Arable, fallow (non-use)	Previuosly cultivated areas, not yet under forest cover. Often rich in biodiversity.	n.r.
Arable, non-irrigated	Annual crop production based on natural precipitation (rainfed agriculture).	1
Arable, non-irrigated, extensive	+ Use of fertiliser and pesticides is less than economically optimal.	1
Arable, non-irrigated, intensive	+ Fertiliser and pesticides at economically optimal level.	1
Arable, irrigated	Annual crops irrigated permanently or periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops could not be cultivated without an artificial water supply. Does not include sporadically irrigated land.	1
Arable, irrigated, extensive	+ Use of fertilizer and pesticides is less than economically optimal.	1
Arable, irrigated, intensive	+ Fertiliser and pesticides at economically optimal level.	1
Arable, flooded crop (rice)	Land developed for rice cultivation. Flat surfaces with irrigation channels. Surfaces regularly flooded.	1
Arable, greenhouse	Crop production under plastic or glass.	1
Field margin/hedgerow	Land between fields with natural vegetation.	20
Permanent crop	Perennial crops not under a rotation system which provide repeated harvests and occupy the land for >1 year before it is ploughed and replanted; mainly plantations of woody crops.	20
Permanent crop, non-irrigated	Perennial crops production based on natural precipitation (rainfed agriculture).	25
Permanent crop, non-irrigated, extensive	+ Use of fertilizer and pesticides is less than economically optimal.	30
Permanent crop, non-irrigated, intensive	+ Fertiliser and pesticides at economically optimal level.	25

Table 6.1., continued. Land use classes used in the ecoinvent database. Default use period for depreciation of the initial land transformation (n.r. = not relevant).

Land use class	Description	Default use period
Permanent crop, irrigated	Perennial crops with artificial input of water.	15
Permanent crop, irrigated, extensive	+ Use of fertilizer and pesticides is less than economically optimal.	20
Permanent crop, irrigated, intensive	+ Fertiliser and pesticides at economically optimal level.	15
Heterogeneous, agricultural	Agricultural production intercropped with (native) trees. Trees or shrubs are kept for shade or as wind shelter.	100
Urban/industrial fallow (non-use)	Areas with remains of industrial buildings; deposits of rubble, gravel, sand and industrial waste. Can be vegetated and rich in biodiversity.	n.r.
Urban, continuously built	Buildings cover most of the area. Roads and artificially surfaced area cover almost all the ground. Non-linear areas of vegetation and bare soil are exceptional. At least 80% of the total area is sealed.	80
Urban, discontinuously built	Most of the area is covered by structures. Buildings, roads and artificially surfaced areas, associated with areas with vegetation and bare soil, which occupy discontinuous but significant surfaces. Less than 80% of the total area is sealed.	80
Urban, green area	Areas with vegetation within urban fabric. Includes parks with vegetation.	80
Industrial area	Artificially surfaced areas (with concrete, asphalt, or stabilized, e.g., beaten earth) devoid of vegetation on most of the area in question, which also contains buildings and/or areas with vegetation.	50
Mineral extraction site	Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for riverbed extraction.	20
Dump site	Landfill or mine dump sites, industrial or public.	30
Construction site	Areas under construction development, soil or bedrock excavations, earthworks.	1
Traffic area, road network	Motorways, including associated installations (stations).	100
Traffic area, rail network	Railways, including associated installations (stations, platforms).	100
Traffic area, rail/road embankment	Vegetated land along motorways and railways. Often rich in biodiversity.	50
Bare area (non-use)	Areas permanently without vegetation (e.g., deserts, high alpine areas).	n.r.
Snow and ice (non-use)	Areas permanently covered with snow or ice considered as undisturbed areas.	n.r.
Inland waterbody, unspecified	Freshwater bodies.	100
River, natural (non-use)	Natural watercourses.	n.r.
Lake, natural (non-use)	Natural stretches of water.	n.r.
River, artificial	Artificial watercourses serving as water drainage channels. Includes canals.	100
Lake, artificial	Reservoir in a valley because of damming up river.	100
Seabed, unspecified	Area under seawater.	30
Seabed, shallow water, natural (non-use)	Natural coastal surface under 0 - 80 m water. Rich in biodiversity.	n.r.
Seabed, shallow water, used	Surface under 0 - 80 m water used (e.g., fisheries for dredging, sediment dumping, marine infrastructure).	30
Seabed, continental shelf, natural (non-use)	Natural surface under 80 - 200 m of water.	n.r.
Seabed, continental shelf, used	Surface under 80 - 200 m water used (e.g., oil drilling, mining).	20
Seabed, deep ocean basin floor, natural (non-use)	Natural surface under more than 200 m of water.	n.r.
Seabed, deep ocean basin floor, used	Surface under more than 200 m water used (e.g., for deep sea mining).	20

[**Changes relative to ecoinvent version 2:** New land use classes have been added, and some previously separate categories have been aggregated. The definitions of the land use classes have been improved.]

We distinguish between direct and indirect land use effects, both of which are described in the following sub-chapters. *Direct land use effects* are the consequences of what you do to the land, i.e. land use in its narrow sense. *Indirect land use effects* are the consequences of the occupation of land, regardless of what you do to it, i.e. what have been called the competition effect (Lindeijer 2001), and which we call land tenure effect.

6.7.1 Direct land use effects

Direct land use effects are inventoried through the use of data on:

- *Land occupation* for the current land use (e.g., the operation of a power station hinders the occupied land from changing to a more natural state).
- *Land transformation* (from previous land use and to current land use, e.g., a new assembly plant for airplanes requires the conversion of a former natural resort to industrial land; a gravel-pit is converted to a natural resort by active re-cultivation).

For land occupation, both the area and the duration required for the production of a certain amount of products and services are important. Therefore, land occupation is recorded in area*time (m^2*year). Clearly defined and relatively short temporary changes in the land use are also recorded as land occupation (e.g. the construction of underground natural gas pipelines, which temporarily converts agricultural land to an excavation site). For these construction activities as well as for active restoration activities after decommissioning, the land use category "land occupation, construction site" is applied.

A land transformation consists of two entries:

1. Land transformation, from *land use class X*, and
2. Land transformation, to *land use class Y*.

Example: "Transformation, from forest", in m^2 and "transformation, to mineral extraction site", also in m^2.

Land transformation thus records a state before and after a transformation. A transformation typically takes place *at the start* of the activity, but may also occur *during* the activity (open pit lignite extraction) and in selected cases *at the end* of the activity (for road construction, power plant erection, active mine restoration, land abandoned and subjected to natural succession, etc.). Usually, the transformation at the end is not considered, i.e. when it can be assumed that the land use is not likely to change at the end of the activity (no transformation from “industrial area” to “unknown” at the end of life of a factory, transport infrastructure, or agricultural land.

For particular activities the land use class before starting the activity may well be known. However, it is often difficult to assess in detail all the land use classes which have been converted by the activities recorded within the ecoinvent database. If the land use class before the operation phase of the activity is not known, land transformation is recorded with "transformation, from unknown". With that, the sum of all "transformation, to ..." equals the sum of all "transformation, from ...". From these values the net transformation of land use classes can be calculated.

If, for instance, the total amount of m^2 "transformation, from forest" is larger than the amount of m^2 "transformation, to forest", calculated for the production of 1kWh of low voltage electricity, the production of this kWh reduced the total net amount of forest area.

The land transformation relates to the time period covered by the dataset. Many datasets in the ecoinvent database relates to time periods of one year, and in any case shorter than a production cycle (e.g. for forests) or the life time of the infrastructure. Thus, the recorded land transformation reflects the proportional share of the transformation for the activity over the recorded time period. Table 6.1 shows the assumed lengths of production cycles (default use period) applied in the ecoinvent data v3.0, if no specific information is available. The inverse of these periods reflects the proportion of the land area occupied for one year that is assumed to be transformed at the start of the year.

Active restoration at the end of an extraction activity is modelled as a separate unit process ("restoration, gravel-pit", "restoration, copper mine"). This activity includes technical requirements such as diesel for construction machines, seeds, etc. Additionally, land transformation to the final land use class, and from the land use class during the activity are recorded in these datasets (e.g., "transformation, from mineral extraction site", and "transformation, to pasture and meadow"). Such restoration activities may be required by an infrastructure production activity (although this modelling is only done in special cases such as a power plant: "restoration, power plant") or by the production activity itself (in case land transformation and restoration takes place during the activity, e.g., lignite extraction).

While land occupation and transformation are generally included as an input to the infrastructure production activities, agricultural and forest areas are recorded as inputs to the operation activities as long as they do not include buildings. Land use by buildings, greenhouses and the like are recorded as inputs to the infrastructure dataset.

The above described approach is illustrated with the following simplified example of gravel extraction:

- total area 1'000'000 m2,
- gravel-pit used during 20 years,
- 10'000'000 metric tons of gravel extracted per year,
- 2 years of restoration activities,
- diesel consumption of 500 metric ton (21.3 TJ) per year during extraction and of 100 metric ton (4.3 TJ) during restoration.

The inventory for the two activities "gravel production" and "recultivation, gravel-pit" are shown in Table 6.2. Land occupation is calculated by dividing the total area by the total amount of gravel extracted per year. Land transformation is calculated by dividing the total area by the total life time production: 1'000'000 m^2 / (20 year * 10'000'000'000 kg / year) = 5 * 10^{-6} m^2/kg). The requirements for restoration are also evenly attributed to the life time production of the gravel-pit. Restoration leads to a forest (assumption). This restoration activity is not included in the inventory of forestry products (e.g., timber). For future timber production, the correct land transformation before starting that activity would then be "transformation, from forest" and "transformation, to forest" (in contrast to timber production modelled in ecoinvent, where "transformation, from unknown" has been used). In the column "LCI result" one can see that the total area transformed is 5.0 * 10^{-6} m^2 per kg gravel extracted and that the net transformation is from "unknown" to "forest". The two transformations "to mineral extraction site" and "from mineral extraction site" cancel each other out.

Table 6.2 Example of unit process raw data including land transformation and land occupation

			unit process raw data		LCI result
			gravel	recultivation, gravel-pit	Gravel
			1 kg	1 m^2	1 kg
Resource use	Occupation, mineral extraction site	m^2year	0.0001		0.0001
	Occupation, construction site	m^2year		2	0.00001
	Transformation, from unknown	m^2	5.00E-06		5.00E-06
	Transformation, to mineral extraction site	m^2	5.00E-06		5.00E-06
	Transformation, from mineral extraction site	m^2		1	5.00E-06
	Transformation, to forest, secondary (non-use)	m^2		1	5.00E-06
Technosphere Inputs	recultivation, gravel-pit	m^2	5.00E-06		5.00E-06
	diesel	MJ	0.0021	4.3	0.0023
	...	...			
Output	gravel	kg	1		1
	restoration, gravel-pit	m^2		1	

[**Changes relative to ecoinvent version 2:** Transformation at the end of an activity is now added also for land abandoned and subjected to natural succession.]

6.7.2 Indirect land use effects

[More details to be added after experimentation with this potential feature]

Indirect land use effects are captured in ecoinvent by adding land tenure as an input to the land using activity. This land is then provided by a local or global land market, defined in the same way as other markets in ecoinvent. The input to the land market is all the different land classes available for this market, including newly transformed land, and efficiency improvements on outputs from current land uses (which substitute for land). Land tenure is measured in productivity-equivalent m^2*year [The reference productivity for this measure has not yet been decided. One option is the global average wheat yield (0.27 kg wheat / m^2*year). Another option is the global average potential NPP. These references have slightly different rationales and implications.]

Large uncertainties will exist (and are documented) for estimating market boundaries and reactions for land tenure, but the current modelling is still an improvement compared to ignoring the indirect land use altogether. The same default modelling rules are applied as for all other market activities in ecoinvent (e.g. that unless local market boundaries can be justified, a global market is assumed, etc.).

[**Changes relative to ecoinvent version 2:** The inclusion of indirect land use is new. **[**In version 2 datasets, tropical wood from clear-cut is modelled as co-product of land transformation from forest to agricultural land: This may need to be revised?]]

6.8 Noise

[text to come]

6.9 Incidents and accidents

Accidents are unexpected, unusual, unintended and unpredictable events, and are not included in the ecoinvent database. Examples of accidents which are not considered are the serious accidents in nuclear power plants, e.g. Chernobyl, which might have very dramatic impacts, but which occur only seldomly.

On the other hand, incidents that can be calculated probabilistically and occur so frequently that the annual average is not influenced significantly by each individual incident, are considered in the ecoinvent activity datasets. An example of an incident is an oil spill due to rupture of a transport pipeline. Such spills occur frequently and are reported regularly.

Enterprises with additional safety measures may have lower occurrences of incidents and this may warrant a separate dataset for such enterprises.

6.10 Litter

Although litter is by its nature an exchange to the environment, since it does not undergo any further treatment, recording litter as such would imply the addition of many new elementary exchanges with little added value for the impact assessment. Therefore, the further fate of litter in nature is added as human treatment activities, similar to surface landfills and/or aquatic deposits.

6.11 Economic externalities

Economic externalities are costs paid or benefits received by parties not operating or in control of the reported activities, and not part of the price of the products.

Examples of such external costs for e.g. a road transport activity are the use of public infrastructure, time lost in queuing by other users of the same infrastructure, and accident and health services, to the extent that this is not covered by insurances or specific taxes paid by the transport activity. Examples of external benefits (typically reported as negative costs) are e.g. the free provision of infrastructure ("free rider" situations), education and other public services. External benefits are most often related to public production or voluntary private provision of such services. It is also possible to find examples of private goods and services where it is simply impossible for the supplier to ensure that all parties that benefit from the good or service actually pay for this.

An external cost of one activity is typically an external benefit provided by another activity and vice versa. In the ecoinvent database such externalities are therefore included directly (internalised) as intermediate inputs to the activities, see Chapter 6.4, rather than being separately reported as economic externalities.

6.12 Social externalities

Social externalities, i.e. changes in social pressures that may affect human well-being but are not of a biophysical or economic nature (i.e. not covered via the use of natural resources, emissions, or transfer of economic costs and benefits) may be added as elementary exchanges.

Examples of social externalities are occupational health issues (lost work-days), excess work (hours worked in excess of 48 per week), work-place stress, un-organised labour, and injuries (not limited to work-related injuries).

Positive social externalities can be e.g. provision of access to pensions and social security, where these benefits are not provided by the public authorities, efforts to alleviate poverty by provision of products that are targeted the poor, recruitment of workers in long-term unemployment, and support to terminated workers.

In contrast to the economic externalities described in Chapter 6.11, social externalities are not paid for or provided by other activities, e.g. the lost work-days are not compensated, but are simply lost. This implies that the same issue can sometimes be an economic externality and sometimes a social externality. For example, education provided for free can be an economic externality, since it is paid for by someone and provided by a specific activity, while lost education opportunities (e.g. due to child labour) can be a social externality.

Data on social externalities are currently not included in the ecoinvent database, but we encourage data providers to suggest systematic inclusion of new indicators for social externalities.

7 Good practice for documentation

7.1 Detail of documentation

ecoSpold reference: generalComment (field 120); includedActivitiesStart (field 145); includedActivitiesEnd (field 150); Technology comment (field 510); samplingProcedure (field 3030); percent (field 3110); extrapolations (field 3040); Exchanges comment (field 1110)

The data used to describe the exchanges of a particular activity are discussed within the context of values from various sources. Values are generally not supplied without comment.

Comments and references to sources (see Chapter 7.5) are given on the most detailed level possible (i.e. attributed to the particular exchanges of an activity, attributed to a particular property of an exchange, if possible and relevant), describing the individual values and their estimation. Comments and references that are general to more than one entry are provided in the comment field most relevant for the nature of the value. The “technology comment” field is used for comments and references general to the specific technology and the "general comment" field for comments and references of more general nature that cannot be placed in any of the more specific comment fields.

In general, the information in the dataset should be sufficient to judge the appropriateness of a dataset for a specific application. Background information that is common for many datasets are available on www.ecoinvent.org under the web-page for the ISIC activity class in question (see Chapter 9.7) or sub-pages to this, as indicated in the "general comment" field of the dataset.

Additional advice for data providers:
Information that is required to judge the appropriateness of a specific dataset for a specific application shall be placed in the dataset. The web-pages only contain less essential background information common to several datasets. This implies e.g. that the dataset should not contain references such as “For exceptions, see [web-page]”.

[**Changes relative to ecoinvent version 2:** The content of the reports from version 2 are placed partly in the datasets, partly on web-pages with the same structure as the ISIC activity classification. Web-pages will also be available for methodological issues, structured in the same way as this data quality guideline. In some ecoinvent v2 datasets, the *General comment* field contains redundant information that should be removed when updating, for example: “Inventory refers to the production of 1 kg …”, which is already given in the exchange information for the reference product.]

7.2 Images

ecoSpold reference: datasetIcon (field 200); Complex type TTextAndImage

[While being supported by the ecoSpold format, the ecoinvent database does not currently support images.]

7.3 Copyright

ecoSpold reference: isCopyrightProtected (field 3540)

When supplying a dataset to the ecoinvent database, the data provider confirms that the data are free from prior copyright, and makes a non-exclusive transfer of the right of use to the ecoinvent Centre.

In general, all ecoinvent datasets are subject to copyright. However, with the assistance of sponsors it has become possible for some ecoinvent datasets to be provided as open access datasets, which can be freely shared, see Chapter 7.4.4. Use of these open access datasets is still subject to the normal rules for citation.

7.4 Authorship and acknowledgements

ecoSpold reference: Person (fields 3600-3670)

7.4.1 Commissioner

The ecoSpold data format does not have a separate field for information on the commissioner for a specific dataset, i.e. the person or organisation paying for the data collection.

When such information is available, it is placed in the *General comment* field, which may refer to an entry in a *Person* field (can also be used for organisations).

7.4.2 Data generator

ecoSpold reference: personID (field 3500)

The data generator is the person or organisation that collected, compiled or published the original data. This may or may not be the same person as the author (see 'DataEntryBy'; Chapter 7.4.3).

The intention of this field is to acknowledge and reference the origin of the data and the person or organisation that performed the majority of the work in data collection. Minor changes and adjustments by subsequent authors do not make these persons data generators, unless this involves a new publication of the entire dataset in a context outside the ecoinvent database.

7.4.3 Author (Data entry by)

ecoSpold reference: personID (field 3400); qualityNetwork (field 3410)

The field dataEntryBy refers to the author of the dataset, i.e. the person that entered data into the database format and provided it to ecoinvent and thereby is the person responsible for the data. The dataset author may or may not be different from the data generator; see Chapter 7.4.2. The author may make minor modifications or adjustments to the datasets to fit the data to the ecoinvent requirements, without this implying that the author then also is the data generator.

Authors are subject to authorisation by the ecoinvent database administrator before being allowed to upload datasets to the ecoinvent validation and review procedure. The uploaded data are automatically stamped with the identity of the author. As part of the upload procedure, the author confirms the transfer of the right of use to the ecoinvent Centre, see Chapter 7.3.

7.4.4 Open access sponsors

A part of the ecoinvent database is made freely available to the public. The free public access to the datasets in this part of the ecoinvent database is made possible through sponsorships. The sponsored datasets are free of copyright (see Chapter 7.3), but are subject to the normal rules for citation (see Chapter 15.5).

The sponsored datasets are labelled with the following sentence in the general comment field: "The kind contribution of [sponsor name] has made it possible to make this dataset freely available to the public. The sponsors have no influence on the content and/or validation procedure for the sponsored datasets."

Datasets are made freely available for a minimum period of 3 years. The sponsored datasets stays in the free part of the database also after the termination of the 3-year period. Any later updates (i.e. improvements made after the 3-year period or new versions of the same dataset for later years) will only be made freely available if a new sponsorship agreement is made.

The ecoinvent Centre retains the right to refuse sponsors without stating any reason for this refusal.

Technical disclaimer: If parent/child relationships between datasets applies (e.g. the same dataset for several countries), the sponsorship applies either to the parent dataset alone, or to one specific instance of a child dataset.

7.5 Referencing sources

ecoSpold reference: Exchanges sourceId (field 1120); pageNumbers (field 1130); TProperty sourceId (field 2340); Source (fields 3100-3240)

Source references are centrally collected and managed in a master file for the entire ecoinvent database.

When the source is not a scientific article, book-chapter or separate publication, the title field is reused to refer to e.g. "Measurement documentation of company XY" (for measurements on site), "Oral communication, company XY" or "Personal written communication, Mr./Mrs. XY, company Z". Citations of large reference works include chapter numbers, table numbers and/or page numbers.

[**Changes relative to ecoinvent version 2:** References to sources are now placed directly in each dataset, and data sources are publicly available in the master file for sources.]

7.6 Version management

ecoSpold reference: majorRelease (field 3800); minorRelease (field 3805); majorRevision (field 3810) minorRevision (field 3815)

The ecoSpold format defines two version numbers for each dataset: Release and Revision, each with a major and minor version component.

The version defines the version of the ecoinvent database that the dataset is part of. A new version number is only entered by the database administrator when a new working database is created in preparation of the next official release (see Chapter 3). Both the major and minor version component can be changed when a new database is created. All datasets of one database must have the same version and once this version is entered on database creation it is not changed later on.

The internalVersion is specific to each dataset and is independent of the overall database version. The major version component reflects the amount of accepted changes to the dataset. It is increased automatically by the database software each time a reviewer accepts changes proposed by a data provider. It will only increase over time and must not be changed manually. The minor version component of the internalVersion describes versions of the dataset during the editing process before it is submitted for review. It is increased automatically by the ecoEditor software every time the data provider saves changes made to the dataset either locally or as a draft on the ecoinvent server. The minor version component is reset to “1” each time the major version component is increased (when changes to a dataset are accepted by a reviewer).

The internalVersion may also be used to notice concurrent editing of the same dataset by two data providers. If two data providers request the same dataset for editing, one will finish the editing before the other. If the reviewer accepted the changes of the first data provider, the major version component will have increased by the time the second data provider submits changes for review. The review process must then reject the second changes because they are not based on the current version of the dataset. The data provider would have to request the current version of the dataset for editing and enter the necessary changes again.

[**Changes relative to ecoinvent version 2:** The version management is more stringent and automatically controlled than in version 2.]

8 Language

8.1 Default language

ecoSpold reference: defaultLanguage (field 3810)

British English is used as the default language for all names and text fields.

8.2 Language versions

Language versions of datasets are produced by translating all text fields and storing the translated text fields with the appropriate 2 letter ISO 639-1 language code, as provided in the language master file.

The language versions are all stored in the same dataset, and can be viewed by choosing the corresponding language code as default when requesting to view a dataset (in the ecoEditor software or on the ecoinvent website).

Currently, systematic language versions are not available, but we encourage data providers to provide translations and initiate systematic translation projects.

[**Changes relative to ecoinvent version 2:** German names of activities and classifications from version 2 are not maintained in version 3. Some ecoinvent reports are still only available in German. After the text of these reports has been distributed over datasets and web-pages, as part of the revision of all background documentation, the ecoinvent Centre will decide on how to perform the translation of these texts.]

9 Naming conventions

9.1 General

It is strived for to use the most common technical nomenclature and units, and avoiding the use of abbreviations. All information in the name fields is written in full. Considering that the database is used by people from many different technical and non-technical fields, it is strived for to make the names generally understandable and provide adequate context, e.g. rather “electrical connector, peripheral component interconnect buss” than “bus, PCI”. No brackets are used, except when required by other conventions, e.g. in chemical formulas. Singular is used as far as possible, e.g. “barley grain”, not “barley grains”.

The lists of names for activities, intermediate exchanges, elementary exchanges, units, classifications and tags, geographical locations, macro-economic scenarios, and market models, are centrally collected and managed. The full list of names is available via www.ecoinvent.org and via the ecoEditor software. Likewise, master files are centrally collected and managed for persons, default properties and parameters, and sources.

9.2 Activities

ecoSpold reference: activityName (field 100); synonym (field 170)

An activity dataset is identified uniquely by its activity name, the geographical location (see Chapter 4.2.1), the time period (see Chapter 4.2.2), the macro-economic scenario (see Chapter 4.2.3), and the market model (see Chapter 4.13.2). The first four of these identifying fields, i.e. all except the market model, are represented by a universally unique identifier (UUID) for easy machine identification. This implies that the UUID of an activity dataset is the same in all market models, which facilitates the linking of the datasets in different market models, see Chapter 14. In addition, all activities are classified according to the ISIC classification with further sub-divisions made by ecoinvent (see Chapter 9.7).

Activity names are spelled with lower case starting letter, i.e. “lime production”, not “Lime production”.

The simplest form of an activity name is generated from the name of the reference product (see below) with the addition “production”, e.g. “lime production” after the product “lime”. Further specifications of the product, raw material or production route are added after a comma, e.g. “lime production, from carbonation”. The term “construction” is used instead of “production” for activities that have buildings, transport infrastructure, factories and facilities as their product outputs.

If the activity has multiple products, the activity can instead be named after the nature of the process, e.g. “air separation, cryogenic” with the products “oxygen”, “nitrogen” and “argon”.

When an activity is described in terms of the process of converting a raw material to a product, the order [process], [raw material], [detail of process] is preferred, e.g. “leaching of spodumene with sulphuric acid”, not “sulphuric acid leaching of spodumene”, thus avoiding to place the raw material in the beginning of the activity name.

Whenever possible, the “…ing” ending is reserved for services and avoided for activities with a material product.

For infrastructure, the name “factory” or “facility” is preferred to “plant”, except in traditional combinations such as “power plant”.

Dedicated treatment activities are preferably named “treatment of [material treated], [nature or output of the treatment]”, e.g. “treatment of waste paint, final disposal“, “treatment of cotton seed, cleaning, chemical dressing, bagging” or “treatment of slaughterhouse waste to tallow”.

Production and supply mixes end with the terms ", production mix" and ", supply mix" respectively. Market activities start with the term "market for ".

Activity datasets with the term "operation" as part of their name signifies activities that use specific infrastructures, e.g. "mine operation" as opposed to "mine construction". Operation datasets therefore always have inputs of infrastructure. Thus, "operation" is used as a synonym for "use". The term is used both for industrial activities and household activities.

The geographical and temporal locations of activities are described in separate data fields and are not required in the name field.

[Changes relative to ecoinvent version 2: The naming conventions are more stringent in some aspects. The unit is no longer an identifying field, i.e. the same dataset cannot exist with different units for the reference product. Different units can instead be applied for properties of the reference product. Datasets in version 2, which are found in duplicate units, have been merged to one dataset, choosing the most appropriate unit as the main unit and adding a property with the secondary unit.]

9.3 Intermediate exchanges / Products and wastes

ecoSpold reference: Exchanges name (field 1000); casNumber (field 1100); inputGroup (field 1500); outputGroup (field 1510)

Names of intermediate exchanges are spelled with lower case starting letter, i.e. "lime", not "Lime".

Product names begin with the most generic form of the product that is generally recognized as a product, e.g. "cement, blast furnace slag" rather than "blast furnace slag cement", but avoiding artificial names, e.g. not "fertiliser, nitrogen" but "nitrogen fertiliser". This should make searching for a specific product easier. The alternative name may be added as a synonym. It is difficult to make product names unambiguous. The general rules may be interpreted differently by different data providers, so that the two examples just provided may be reversed by different data providers. Therefore, it is always a good idea to search the database for different possible spellings and ordering of product names, especially before adding a new product and/or activity name to the database.

Following the product name, additional specifications are added if necessary for an unequivocal distinction. These are separated by commas, and in the following sequence: treatment level (like rolled, drawn or coated), additional description of the product characteristics or intended application, additional description of unit, additional description of provenience/raw material. Indication of the production route or specific product characteristics are only included if this is part of the marketable product properties, i.e. if there is a market or market niche where the production route or property is a part of the obligatory product properties, see Chapter 4.4.5. For example, the product "straw" is named as such, not with separate names for "barley straw" and "wheat straw", since the market for straw does not distinguish between these two products. Temporal markets, customer segments and market niches are reflected in the product name, so that each temporal and customer segment or niche has its own product. The product name includes as far as possible all relevant aspects of the obligatory product properties required by the supplied market, customer segment or niche. Additional description of the unit is only included when this is not obvious from the context. This is especially relevant when the unit is dimensionless, e.g. "unit", and this relates to a specific interpretation, e.g. "per pig place", which is then included in the name.

For dissolved chemicals, the traditional nomenclature of the chemical industry is to indicate the active substance and then add the water separately, so that e.g. 1 kg of "sodium hydroxide, without water, in 50% solution state", refers to the production of 2 kg NaOH solution with a water content of 50%, i.e., 1 kg pure NaOH plus 1 kg pure H_2O (by specifying "without water" we seek to avoid the possible confusion that occurred with the naming convention in ecoinvent v1 & v2 where the name of this dataset was "sodium hydroxide, 50% in H_2O").

The concentrations applied in the ecoinvent database are those typically found as commercial concentrations. To allow the user to model other concentrations than the default, the concentration may be defined as a variable, and the water content and other related inputs and outputs expressed in relation to this variable.

The concentration of the product has an influence on the manufacturing requirements (purification) as well as on the transport service requirements (double the amount of transport work is required for a 25% caustic soda dissolved in water as compared to a 50% caustic soda dissolved in water). The ecoinvent database may also in addition provide the same datasets as solutions with the actual solvent or carrier substance added, so that e.g. 1 kg "sodium hydroxide, 50% aqueous solution" refers to the production of 1 kg NaOH solution with a water content of 50%, i.e., 0.5 kg pure NaOH plus 0.5 kg pure H_2O. [To be added after conversion of current v2 datasets and experimentation: The specifics of this and how these datasets are linked and used as inputs to other production datasets.]

Treatment activities provide services to other activities to treat their material outputs, in particular wastes. Since the service and the input are intimately linked, the service output is named by the treated material, and the exchange is negative. Thus, the activity "treatment of slaughterhouse waste to tallow" has as its determining (reference) product – 1 kg "slaughterhouse waste" and as a by-product 0.4 kg "tallow". In this way, it is ensured that the output "slaughterhouse waste" from the slaughterhouse can link to its treatment process.

Market activities, production mixes, supply mixes, export and re-export activities have the same products as inputs and outputs, e.g. "market for barley grain" has "barley grain" as input and "barley grain" as output. For graphical presentations, the terms (consumption mix) for markets, (treatment mix) for markets for treatments, (production mix) for production mixes, (supply mix) for supply mixes, (export) for export activities, and (re-export) for re-export activities may be used as additions to the name, but are not formally part of the product name in the ecoSpold2 data format, where the information that the product output is a consumption mix, production mix, supply mix, export or re-export is carried in the separate field 115 specialActivityType.

The unit is described in a separate data field and is not required in the name field.

Special naming conventions for correction datasets are provided in Chapter 11.7.

[**Changes relative to ecoinvent version 2:** The naming conventions are more stringent in some aspects. The naming convention for dissolved chemicals has been revised. The naming convention for treatment services is changed.]

9.4 Elementary exchanges / Exchanges from and to the environment

ecoSpold reference: Exchanges name (field 1000); synonym (field 1470); casNumber (field 1100); inputGroup (field 1600); outputGroup (field 1610); formula (field 1670)

Naming of elementary exchanges takes pattern from the work of the SETAC working group "Data availability and data quality" (de Beaufort-Langeveld et al. 2003; Hischier et al. 2001). Sum formulas and IUPAC names are recommended when new substance names are proposed to be added to the list. CAS numbers are required, when available. Names of elementary exchanges are spelled with Capital starting letter, i.e. "Chlorine", not "chlorine", as opposed to names of intermediate exchanges.

The name for an element or a compound is the same for all environmental compartments.

Binding forms and oxidation states are considered in the name. The toxicology of chemical elements is dependent on the oxidation state. Some examples may illustrate this. Chlorine (oxidation 0) is a toxic gas. Chloride (oxidation = -1) is essential for the nutrition of human beings, but it might be toxic in high doses for animals and plants in rivers and lakes. Chromate (oxidation = 6) emitted to air is carcinogenic for humans when inhaled. Other forms of chromium (oxidation = 0, 2 or 3) are not. That is why the oxidation state of chemical elements and ions is considered in the description of the elementary exchange. Different oxidation states (e.g. chromium, chromites, chromate) are distinguished in the list of elementary exchanges.

Quite often chemical compounds are known under different names. A list of synonyms is available in the database.

The information provided on http://www.chemfinder.com is used as the default source of information for the definition of further elementary exchange names.

9.4.1 Land transformation and occupation

The differentiation between transformation and occupation is reflected in the naming of land use elementary exchanges. It takes pattern from the naming proposals of a Dutch project (Lindeijer & Alfers 2001):

- Occupation, *class, subtype*
- Transformation, from *class of occupation*
- Transformation, to *class of occupation*

The different levels of details in describing the land use class are separated by commas, e.g.:

- Occupation, arable
- Occupation, arable, non-irrigated
- Occupation, arable, non-irrigated, intensive

The highest possible level of information detail is always used and recorded in the inventories.

Names and definitions of the different land use classes are provided in Chapter 6.7.

9.4.2 Environmental compartments

ecoSpold reference: Compartment (field 1660)

Elementary exchanges in the ecoinvent database are identified by an exchange name (e.g. "Carbon dioxide, fossil"), its unit, a compartment and a sub-compartment.

Table 9.1 shows the compartments and sub-compartments which are used in the ecoinvent database. Compartment and sub-compartment names have a lower case initial letter. Compartments and sub-compartments can only be added and edited centrally via the ecoinvent database administrator.

Compartments describe the different environmental compartments, like air, water, soil and natural resource. Sub-compartments within these compartments make further distinctions which may be relevant for the subsequent impact assessment step.

The compartments "air", "soil", "water" and "food" describe the receiving compartment and are used for (direct) pollutants emissions, whereas the compartment "resource" is used for all kinds of resource consumption. For instance, water consumption is recorded as an input in the compartment / subcompartment "resource / in water". Land transformation and occupation is recorded as an input as well, in the compartment / subcompartment "resource / land".

Table 9.1 Categories and subcategories for elementary exchanges in the ecoinvent database

Compartment	SubCompartment	Definition	Assigned in general to
air (output to)	non-urban air or from high stacks	Emission in areas with a population density below 400 persons per km^2 or from stacks higher than 150 m	Resource extraction, forestry, agriculture, hydro energy, wind power, coal and nuclear power plants, municipal landfills, wastewater treatment, long-distance transports, shipping
	low population density, long-term	Emission which take place in the future, 100 years after the start of the activity	Emissions from uranium mill tailings
	lower stratosphere + upper troposphere	Emission from airplanes	Air transport, cruising
	urban air close to ground	Emission below 150 metres in areas with a population density above 400 persons per km^2	Industry, oil and gas power plants, manufacturing, households, municipal waste incineration, local traffic, construction activities
	indoor	Emission inside closed buildings and outside of dedicated fume hoods with intake speed >0,5 m/s	Use stage of products for indoor use
	unspecified		Only used if no specific information available
natural resource (input of)	in air	Natural resource in air, e.g. argon, carbon dioxide	Used for carbon uptake in biomass and gases produced by air separation.
	biotic	Biogenic resource, e.g. wood	
	in ground	Natural resource in soil e.g. ores; landfill volume	
	land	Land occupation and transformation	
	in water	Natural resource in water, e.g. magnesium, water	
soil (output to)	agricultural	Emission to soil that is used for or is suitable for the production of agricultural products that enter the human food chain.	Agriculture, agricultural biomass production
	forestry	Emission to soil that is used for plant production (wood, renewable raw materials), but which is not used or suitable for production of agricultural products that enter the human food chain (permanent forest land, marginal lands)	Forestry
	industrial	Emission to soil used for industry, manufacturing, waste management and infrastructure	Industry, land-farming of wastes, built-up land
	unspecified		Only used if no specific information available
water (output to)	ground-	Groundwater which will get in contact with the biosphere after some time	
	ground-, long-term	Emission which take place in the future, 100 years after the start of the activity	Long-term emissions from landfills
	ocean	Ocean, sea and salty lake	Offshore works, overseas ship transports
	surface water	River and lake	Discharge of effluents from wastewater treatment facilities.
	unspecified		Only used if no specific information available
Food (output to)	unspecified	Contamination in food products	Food products at the point of human intake
Economic (input of)	primary production factor	Labour cost, net tax, net operating surplus, rent	All net expenditures except those paid for goods and services purchased
Social (input of)	unspecified	Change in social pressure	All externalities affecting human welfare and/or productivity, not elsewhere covered

As recommended in USETOX < http://www.usetox.org/>, the border between urban and non-urban ((high and low population density) is the U.S. Census Bureau "urban area" definition <http://www.census.gov/geo/www/ua/ua_2k.html>. Approx. 50% of the global population lives in urban (high population density) areas.

Contaminants in food are described as an emission at the point of human intake. Until then, the contaminants are included as a property of the products.

For some subcategories a temporal differentiation was introduced. Emissions from landfills take place over a long time period after the waste placement. Emissions which take place 100 and more years after waste placement are named "long-term".

[The issue of how best to include long-term emissions is currently under consideration in a separate ecoinvent research project]

The subcompartment "agricultural" for soil pollutants is only used for releases on agricultural soil that is used or suitable for the production of food, fodder products, or animal feed, which enters the human food chain.

[**Changes relative to ecoinvent version 2:** Category/Subcategory (version 1&2) has changed name to Compartment/Subcompartment. Text description on emissions to soil, agricultural, has been brought in line with actual practice in ecoinvent 2 (biomass production on agricultural land has emissions to soil, agricultural). Resource has been changed to Natural resource. The sub-compartments Lake and River have been merged to Surface water. Some definitions have been made more precise. New compartments have been added for indoor air, food contaminations, economic and social exchanges.]

9.5 Synonyms

ecoSpold reference: synonym (field 170 and 1470)

Synonyms may be added for all names of activities and exchanges. We seek to make the synonyms lists as complete as possible.

Additional advice for data providers:
Synonyms are different names for the same item, *not* instances of the item. For example, *sheep husbandry* is a synonym for *sheep production*, while *Merino production* is not a synonym, but a specific instance referring to a particular kind of sheep.

9.6 Units

ecoSpold reference: Exchanges unit (field 1030); Parameters unit (field 1712); TProperty unit (field 2320)

The units shown in Table 9.2 (always in English language) are used. As far as practical, SI-units are applied, with the SI-prefixes shown in Table 9.4.

Exceptions are:

- The traditional measure ton, with the specification metric ton (= 1000 kg = 1 Mg), when used in the combination metric ton*km.
- The traditional area measure ar (a), as in hectar (ha), which should not be confused with the SI-prefix atto- or the popular abbreviation for year.
- Popular units for time (year, month, week, day, hour), written out fully, since multiples of the SI-unit seconds (s) appears awkward.

Table 9.2 Units used for activities and products

Unit	Term	Usage examples
m^2	square metre	Surface treatments, buildings, sites, boards, plates, reception surfaces,
ha	hectare (hecto-are) = 100 a = 10000 m^2	agricultural working activities
m^2*year		Roads, ventilation systems
kg/s l/hour kWh/s MW	kilogram per second litres per hour kilo Watt Hours per second mega Watt = MJ/s = 3.6 kWh/s	Capacity of weight Capacity of volume Capacity of energy conversion
kg/l	kilogram per litre	Density
m	metre	Cables, belts, chimneys, ducts, tape, welding, wells
metric ton*km person*km	metric ton*kilometre (Mg*km) person-kilometre	Transport services. The term vkm or vehicle-km (synonymous to km) is not applied
year*m	metre-year	Roads, railway track
unit	unit, piece, number	Infrastructure (exceptions: kg machine, m^2 or m^3 building), agricultural activities involving livestock units etc.
kWh	kilo Watt hour	Electricity
MJ	mega Joule	Final energy in boilers, useful energy at boilers, cooling energy
hour	hour = 3600 s	Usage time of equipment
year	year (annum)	Multi-product activities for the total production in an area or of a facility
l	litre = dm^3	Liquid products
m^3	cubic metre	Concrete and wood, wastewater, slurry, radioactive wastes, buildings; for natural gas, biogas, compogas, town gas: normal cubic metre = cubic metre of gas at 15 °C; 101.325 kPa (ISO 13443)
kg	kilogram	Building materials, basic chemicals, wastes (non radioactive), energy carriers from production to regional storage, (excl. electricity, natural gas), liquefied gases, tap water, decarbonised and deionised water, agricultural machinery, "kg SWU" (separative work unit) used for enrichment of uranium

Ideally, datasets that do not have a material output should not be provided in mass units, although this may sometimes be the only relevant function that can be referred to. Especially for datasets transferred from ecoinvent version 2, there are still some datasets that have the output of 1 kg, although this refers only to “processing of 1 kg of metal”, not to the metal material itself. We strive to rename the functional unit of these datasets whenever possible.

Currencies are reported in ISO three-digit code. As currencies change values over time, it is necessary to apply a subscript to indicate the year that the currency refers to, e.g. EUR_{2000} or EUR_{2003}. For large numbers, the SI-prefixes (see Table 9.4) have been used, e.g. MEUR = 1’000’000 EUR, GEUR = 1’000’000’000 EUR.

The units (basically SI units) used to describe elementary exchanges are shown in Table 9.3.

Table 9.3 Units used for elementary exchanges

Unit	Description	Type of exchange
Kg	kilogram	All chemical substances
kBq	kilo Becquerel	Radionuclide releases
m^3	cubic metre	Water as a resource, Gases as a resource; normal cubic metre = cubic metre of gas at 15 °C; 101.325 kPa (ISO 13443)
m^2	square metre	Land transformation
m^2*year	square metre year	Land occupation

Table 9.4 SI-prefixes

P	peta-	1.0E+15
T	tera-	1.0E+12
G	giga-	1.0E+9
M	mega-	1.0E+6
K	kilo-	1.0E+3
H	hecto-	1.0E+2

[**Changes relative to ecoinvent version 2:** Several changes in unit spellings. In ecoinvent v2, the units GVE and MSP were used: 1 GVE entspricht dem Futterverzehr und dem Anfall von Mist und Gülle einer 650 kg schweren Kuh in der Schweiz. 1 MSP is 0.15 GVE. These units are now changed to „unit“ and explained in the datasets. Mass units avoided for service products (e.g. rather 1 metre wire-drawing for steel, than wiredrawing of 1 kg of steel; using e.g. the extent of transport, transformation, shape, distortion, reduction, rather than the weight of the material treated). In version 2, some datasets also have outputs of kg of material removed (e.g. by drilling) and inputs of the material “lost” by this operation, which implies that to avoid double counting, the activity they are inputs to must have an input of an untreated object with the same weight as the treated object. Such datasets need to be changed so that the treatment activity has the full input of the material treated and an output of a treated object and the material removed. This should preferably be done in consultation with the original data provider and/or editor.]

9.7 Classifications

ecoSpold reference: classificationSystem (field 300), classificationValue (field 310), which together constitute the complex type TClassification, which is also used by productClassification (field 1540)

All activities are classified according to the ISIC classification (Rev. 4), <http://unstats.un.org /unsd/cr/registry/>, with some additional sub-divisions necessary for ecoinvent. The additional classes added by ecoinvent (listed in Table 9.5) are sub-divisions, using as far as possible the explanatory language from the original ISIC class.

The classification is used to identify the responsible ecoinvent editor (see Chapter 12.2) and can be used to create residual datasets for an industry, relative to data from national statistics (see Annex C).

Table 9.5 Additions to the ISIC Rev. 4 classification of activities, for use in the ecoinvent database

Class	Name
19a	Liquid and gaseous fuels from biomass
2011a	Manufacture of nuclear fuels
2420a	Smelting and refining of uranium
2710a	Manufacture of electric motors, generators, for liquid fuels
2811a	Manufacture of engines and turbines for liquid fuels, except aircraft, vehicle and cycle engines
2815a	Manufacture of furnaces and boilers for liquid fuels
2815b	Manufacture of permanent mount non-electric household heating equipment
3011a	Construction of drilling platforms
3510a	Electric power generation based on liquid fuels
3510b	Electric power generation, photovoltaic
3530a	Steam and air conditioning supply based on liquid fuels
3530b	Solar collectors operation
4100a	Construction of factory buildings for the metal industry
4220a	Construction of utility projects for electricity production, except for liquid fuels
4220b	Construction of utility projects for electricity production, for liquid fuels
4290a	Construction of infrastructure for petroleum refining and distribution
4322a	Installation of solar collector systems

For products, the optional CPC Ver. 2 classification is recommended < http://unstats.un.org/unsd/>.

For datasets transferred from version 2 of the ecoinvent database, the activity classification of version 2 is applied as an additional classification, but this classification system is no longer maintained by the ecoinvent Centre.

New, optional classification systems can be added on request to the ecoinvent database administrator.

[**Changes relative to ecoinvent version 2:** New classification systems for activities. Option to add more classifications for both products and activities. CPC remains to be added to the classification master file.]

9.8 Tags

ecoSpold reference: tag (fields 175 and 1450)

One or more tags can be added to any activity and to any exchange. Tags can be seen as an optional, user-defined classification system, to group specific activities or exchanges together.

Some pre-defined tags for datasets, used in the ecoinvent database, are listed in Table 9.6.

Table 9.6 Pre-defined tags for datasets, for use in the ecoinvent database

Name	Comment
branded dataset with logo	dataset for a named brand or from a named enterprise, with logo
branded dataset without logo	dataset for a named brand or from a named enterprise, without logo
complementary product	product needed for the proper functioning of a main product, but not part of this product, e.g. packaging or maintenance
consumption adjustment	dataset representing a change in consumption as a result of market constraints
goods transport	dataset representing a goods transport activity
household activity	dataset representing an activity taking place in private households
packaging	
quality difference adjustment	dataset representing downstream changes due to quality differences in products on the same market
single enterprise data	dataset representing one single, anonymous enterprise
with true value	dataset for which true value properties are defined (reserved; added by database)

Additional advice for data providers:
Tags can be added individually to an activity or an exchange. If the only change to a dataset is the addition of one or more tags, the dataset will not have to pass the full review procedure, but will only be reviewed by the editor for classifications. Even then, if you wish to add the same tag to many datasets or exchanges (or several, similar tags to many datasets or exchanges), this may be too cumbersome a procedure. For this situation, contact the ecoinvent database administration for a “fast track” procedure.

[**Changes relative to ecoinvent version 2:** The option to add tags is new.]

9.9 Geographical locations

The ecoinvent master file for geographical locations contains all countries, described in the Keyhole Markup Language (KML) used by e.g. Google Earth. Also some power grid regions and some regions (e.g. Europe) are included.

The designation GLO for global does not have a KML equivalent.

The designation ROW (Rest-Of-World) is a dynamic concept that exists in the situation when both a global dataset and one or more non-global datasets are available for the same activity, time period, and macro-economic scenario. The definition is specific to each activity and depends on what defined geographies are available for the specific activity name. It is defined as the difference between the global reference dataset and the datasets with defined geographies.

Additional advice for data providers:
New geographical locations, both point sources, line sources and area sources can be defined by the data providers. Since the ecoinvent database does not allow overlapping datasets, adding a dataset (whether point-, line-, or area-based), fully located within the geographical area of an existing dataset for the same activity, is effectively a

disaggregation of the existing dataset, and requires that the existing dataset is modified to represent the residual of the original dataset, in terms of geography, production volume, and otherwise.

[More text on how to create additional geographical locations]

9.10 Persons

Names and contact details on all persons referred to in ecoinvent datasets are centrally collected and managed in a master file. A name and an e-mail are the only required fields, but adding further address information is encouraged.

9.11 Other master files

Master files for the ecoinvent database are also available for default properties and parameters. Default properties include the elemental composition (Al_content, etc.), water content, density, dry mass, exergy, lifetime, etc.

Other master files are available for scenarios (see Chapter 4.2.3), market models (Chapter 4.14), languages (Chapter 8.2), and sources (Chapter 7.5). Only the latter can be amended by the data providers directly. The others are edited via the database administrator only.

Master files are used for validating datasets (see Chapter 12.1) and to create look-ups for the ecoEditor software (so that previous entries can be selected rather than created anew).

9.12 Variables

Variable names must start with a character (a-z). Variables may contain characters, numbers and underscores (_). Variable names are not case sensitive (calorific_Value equals Calorific_value)

10 Uncertainty

ecoSpold reference: Exchanges uncertainty (field 1200); Parameters uncertainty (field 1730); TProperty uncertainty (field 2330); Complex type Uncertainty

Uncertainty expresses the general problem that an observed value can never be exactly reproduced, but when an adequate number of observations have been made, certain characteristic features of their distribution can be described, such as mean and standard deviation. A *probability distribution* is the mathematical and/or graphical function giving the probability that an observation will take a given value.

Many different concepts are used to describe uncertainty. When applicable, we use statistical terms as defined in ISO 3534. *Uncertainty* is the general term we use to cover any distribution of data within a population, caused by either random variation or bias.

Variation is the general term used for the random element of uncertainty. This is what is typically described in statistical terms as variance, spread, standard deviation etc., see definitions below. It is the randomness of the observations, which allows a statistical treatment, since this describes the probability distribution of the observations.

Bias is the skewness introduced into a distribution as a result of systematic (as opposed to random) errors in the observations, e.g. when the observations are made on a specific sub-set of a non-homogenous population.

The population is the total number of items under consideration, from which only a sample is typically observed. The *arithmetic mean* or average value is the sum of the observed values divided by the number of observations. The *error* of an observation is the deviation of the observed value from the mean value, i.e the value of the observation minus the mean value. *Variance* is a description of variation defined as the sum of the squares of the errors divided by the number of observations less 1. The *standard deviation* (σ) is the positive square root of the variance. The *coefficient of variance (CV)* is the standard deviation divided by the mean value. The *median* (ε) is the value for which 50% of the distribution is smaller and 50% of the distribution is larger, also known as the 50% fractile. The *mode* or *most likely value* is the value that has the largest probability within the distribution.

In the ecoinvent database, the amount of each exchange is described by its *mean value* and its uncertainty is expressed as a 95% *confidence interval*. A two-sided confidence interval is the central part of a distribution that lies between two values chosen so that the interval includes a required percentage of the total population. For example, a 95% confidence interval includes 95% of the population, i.e. it excludes 2.5% of the population in both ends.

Table 10.1 shows how uncertainty information is reported in the ecoSpold 2 format, illustrated with some examples.

The choice of distribution has limited influence on the overall uncertainty of a product system, since the addition of a high number of independent variables each with their distribution will always approach a result with normal distribution. This is called the “central limit theorem”. The convergence to the normal distribution is surprisingly fast. For example, the distribution of the sum of ten uniformly distributed random variables is already indistinguishable by eye from an exact normal distribution. Since many real life phenomena are caused by a large number of independent random effects, the central limit theorem explains why we so often find real life data to be approximately normally distributed.

The normal distribution is a symmetrical distribution (as opposed to a skewed distribution, see the lognormal and triangular distributions below), which implies that the arithmetic mean, the median, and the mode all appear at the same place. An interesting feature of the normal distribution is that 68% of the data lies within one standard deviation either side of the mean, 95% of the data lies with two standard deviations of the mean, and 99.7% of the data lies within three standard deviations of the mean. Thus, it is easy to compare confidence intervals and standard deviations.

Table 10.1. Description of uncertainties in the ecoinvent database, examples

EcoSpold data field		Probability function / parameter	Formula / symbol	Example	Unit	Database input
2100	*Uncertainty type*	*Lognormal*				1
2101	meanValue	Geometric mean & median	μ_g	1'540	kg	1'540
2102	standardDeviation95	Square of the geometric standard deviation, basic uncertainty	σ_{gb}^2	2.7	-	2.7
2102	standardDeviation95WithPedigreeUncertainty	Square of the geometric standard deviation, basic uncertainty with pedigree uncertainty	σ_g^2	4.0		4.0
2110	*Uncertainty type*	*Normal*				2
2111	meanValue	Arithmetic mean	μ	1'540	kg	1'540
2112	standardDeviation95	Two times basic standard deviation	$2\sigma_b$	420	kg	420
2113	standardDeviation95WithPedigreeUncertainty	Two times basic and pedigree standard deviation	2σ	560	kg	560
2120	*Uncertainty type*	*triangular*				3
2121	minValue	Minimum value	B	930	kg	930
2122	mostLikelyValue	Most likely value	A	1'780	kg	1'780
2123	maxValue	Maximum value	C	1'910	kg	1'910
2130	*Uncertainty type*	*Uniform*				4
2131	minValue	Minimum value	A	1'210	kg	1'210
2132	maxValue	Maximum value	B	1'870	kg	1'870

The *lognormal distribution* is a specific probability distribution where the natural logarithm of the observed values follows a normal distribution. The lognormal distribution is also common in real life populations. One reason for this is that many real life effects are multiplicative rather than additive, and in parallel to the central limit theorem for additive effects, it can be shown that multiplicative effects will result in a lognormal distribution. Another reason is that real life populations typically cannot attain values below zero, and with a high variation this will result in a skewed distribution with a longer tail towards the higher values. The lognormal distribution is such a skewed distribution, although certainly not the only one. Because of its easy transformation into the normal distribution, it is often – and also in the ecoinvent database – used out of convenience, as an approximation for other more complicated, skewed distributions. Lognormal distribution has been used for nearly all exchanges in the ecoinvent database. As for the normal distribution, the confidence intervals are related to the standard deviation, but for the lognormal distribution, this relation is multiplicative: 68% of the data lies in the interval ε/σ to $\varepsilon\sigma$, 95% of the data lies in the interval ε/σ^2 to $\varepsilon\sigma^2$, and 99.7% of the data lies in the interval ε/σ^3 to $\varepsilon\sigma^3$, where the median (ε) is equal to the geometric mean μ_g. The *geometric mean* is the n^{th} root of the product of *n* observed values.

In addition to the distributions mentioned in Table 10.1, the ecoSpold 2 format provides fields for the following distributions:

- Beta distribution (minimum, most frequent, and maximum value), used often in Baysian statistics
- Gamma distribution (shape, scale, and minimum value), used for example in queueing models and climatology
- Erlang distribution (order, and mean value), often used for queueing models .

Finally, a generic "distribution" is provided, with fields minimum, maximum, and standard deviation 95, for backwards compatibility reasons. Most distributions can be transformed to be represented by each other.

The ecoSpold 2 format allows the entry of uncertainty information, not only for the amounts of exchanges, but also for exchange properties, parameters, and transfer coefficients. This allows the reporting of the uncertainty on the primary data, which is of particular interest when the exchange amount is calculated by a mathematical relation involving these properties, parameters or coefficients. The uncertainty of the exchange can then be calculated from the uncertainty on its components. Currently, this calculation is done manually by the data provider, but software support for this is planned.

In the ecoinvent database, two kinds of uncertainty are quantified for the amounts of the exchanges:

- Variation and stochastic error of the values which describe the exchanges, due to e.g. measurement uncertainties, activity specific variations, temporal variations, etc. This is expressed in the basic uncertainty. When relevant information to completely describe an activity in detail is unavailable, so that the exchanges are only reported in an unspecific way or at a high aggregation level of activities, the average data applied, with inadequate specification of important exchanges, will have a basic uncertainty that reflects the lack of knowledge on their precise nature.
- Uncertainty due to use of estimates, lacking verification, incompleteness in the sample, or extrapolation from temporally, spatially and/or technologically different conditions. For instance, if the electricity consumption of an activity that takes place in Nigeria is approximated with the dataset of the Rest-Of-World (ROW) electricity supply mix. These aspects of uncertainty are reflected in the additional uncertainty estimated via data quality indicators; see Chapter 10.2.

10.1 Default values for basic uncertainty

If the sample data are available, the probability distribution and standard deviation of the sample can be calculated directly. If the sample is small, an approximate standard deviation can be calculated from the range (the difference between the largest and the smallest observed value). For the normal distribution, the range is approximately 3, 4, and 5 times the standard deviation when the sample size is 10, 30, and 100, respectively. Life cycle data often result from a small number of observations, so it is reasonable to use the factor 3 when the number of observations is unknown.

Quite often the uncertainty of a specific value cannot be derived from the available information, when there is only one source of information, and this only provides only a mean value, without any information about the uncertainty of this value. A simplified standard procedure was developed to quantify the uncertainty for these (quite numerous) cases.

Basic uncertainty factors (coefficients of variance; CVs) are used for the kind of exchange considered. It is assumed that different types of exchanges differ in their uncertainty. For instance, CO_2 emissions show in general a much lower uncertainty than CO emissions. While the former can be calculated from fuel input, the latter is much more dependent on boiler characteristics, engine maintenance, load factors etc. The basic uncertainty factors (CVs) shown in Table 10.2 are based on expert judgements.

[The basic uncertainty factors in Table 10.2 may need to be revised since they have been assessed beforehand by a group of ecoinvent analysts. The experiences with variations found in the literature make it probable that these basic uncertainties tend to underestimate the "real" uncertainty. Especially for pollutants which are only seldom measured and which depend on impurities rather than on product properties the range found in the literature might be considerably higher. Furthermore sometimes uncertainties add up. This was observed for example for the emissions of heavy metals during fuel combustion or for the elements emitted with the wastewater streams from crude oil extraction.]

Table 10.2. Basic uncertainty factors (dimensionless coefficients of variance) applied for intermediate and elementary exchanges; c: combustion emissions; p: process emissions; a: agricultural emissions

input / output group	c	P	a	input / output group	c	p	a
demand of:				**pollutants emitted to air:**			
thermal energy, electricity, semi-finished products, working material, waste treatment services	1.05	1.05	1.05	CO_2	1.05	1.05	
transport services (tkm)	2.00	2.00	2.00	SO_2	1.05		
Infrastructure	3.00	3.00	3.00	NMVOC total	1.50		
resources:				NO_X, N_2O	1.50		1.40
primary energy carriers, metals, salts	1.05	1.05	1.05	CH_4, NH_3	1.50		1.20
land use, occupation	1.50	1.50	1.10	Individual hydrocarbons	1.50	2.00	
land use, transformation	2.00	2.00	1.20	PM>10	1.50	1.50	
pollutants emitted to water:				PM10	2.00	2.00	
BOD, COD, DOC, TOC, inorganic compounds (NH_4, PO_4, NO_3, Cl, Na etc.)		1.50		PM2.5	3.00	3.00	
individual hydrocarbons, PAH		3.00		Polycyclic aromatic hydrocarbons (PAH)	3.00		
heavy metals		5.00	1.80	CO, heavy metals	5.00		
Pesticides			1.50	inorganic emissions, others		1.50	
NO_3, PO_4			1.50	Radionuclides (e.g., Radon-222)		3.00	
pollutants emitted to soil:							
oil, hydrocarbon total		1.50					
heavy metals		1.50	1.50				
Pesticides			1.20				

The uncertainty factors in Table 10.2 reflect the expected coefficients of variance of large samples in a situation where the underlying sample data are not available.

For some ecoinvent datasets different approaches have been used. These approaches are described in the respective datasets.

10.2 Additional uncertainty via data quality indicators

In addition to the basic uncertainty, either measured or estimated from Table 10.2, an additional uncertainty from data quality indicators is added, based on a pedigree matrix approach, taking pattern from work published by Weidema & Wesnaes (1996) and Weidema (1998).

Data sources are assessed according to the five characteristics "reliability", "completeness", "temporal correlation", "geographic correlation", and "further technological correlation" (see Table 10.3). Each characteristic is divided into five quality levels with a score between 1 and 5. Accordingly, a set of five indicator scores is attributed to each individual input and output exchange (except the reference products) reported in a data source. Table 10.3 is called a pedigree matrix (after Funtowicz & Ravetz 1990) since the data quality indicators refer to the history or origin of the data like a genealogical table reports the pedigree of an individual.

An uncertainty factor (expressed as a contribution to the square of the geometric standard deviation) is attributed to each of the score of the five characteristics. These uncertainty factors are also based on expert judgements and are shown in Table 10.4.

[A separate ecoinvent project is ongoing to provide a better empirical basis for these uncertainty factors, and may lead to a revision of the pedigree matrix as well.]

The total uncertainty for the 95% interval – SD_{g95} (the square of the geometric standard deviation) is then calculated with the following formula:

[remove the 6^{th} element (sample size), as this is included in the basic uncertainty]

$$SD_{g95} := \sigma_g{}^2 = \exp^{\sqrt{[\ln(U_1)]^2+[\ln(U_2)]^2+[\ln(U_3)]^2+[\ln(U_4)]^2+[\ln(U_5)]^2+[\ln(U_6)]^2+[\ln(U_b)]^2}}$$

with :

U_1 : uncertainty factor of reliability

U_2 : uncertainty factor of completeness

U_3 : uncertainty factor of temporal correlation

U_4 : uncertainty factor of geographic correlation

U_5 : uncertainty factor of other technological correlation

U_6 : uncertainty factor of sample size

U_b : basic uncertainty factor

Table 10.3. Pedigree matrix used to assess the quality of data sources, modified from Weidema 1998)

Indicator score	**1**	**2**	**3**	**4**	**5** (default)
Reliability	Verified[3] data based on measurements[4]	Verified data partly based on assumptions ***or*** non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50%) relevant for the market considered ***or*** >50% of sites but from shorter periods	Representative data from only one site relevant for the market considered ***or*** some sites but from shorter periods	Representativeness unknown or data from a small number of sites ***and*** from shorter periods
Temporal correlation	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown ***or*** distinctly different area (North America instead of Middle East, OECD-Europe instead of Russia)
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials	Data on related processes on laboratory scale ***or*** from different technology

[3] Verification may take place in several ways, e.g. by on-site checking, by recalculation, through mass balances or cross-checks with other sources.

[4] Includes calculated data (e.g. emissions calculated from inputs to an activity), when the basis for calculation is measurements (e.g. measured inputs). If the calculation is based partly on assumptions, the score would be 2 or 3.

Table 10.4. Data quality uncertainty factors (contributing to the square of the geometric standard deviation) applied to convert the data quality indicators of the pedigree matrix in Table 10.3 into additional uncertainty.

Indicator score	1	2	3	4	5
Reliability	1.00	1.05	1.10	1.20	1.50
Completeness	1.00	1.02	1.05	1.10	1.20
Temporal correlation	1.00	1.03	1.10	1.20	1.50
Geographical correlation	1.00	1.01	1.02	1.05	1.10
Further technological correlation	1.00	1.05	1.20	1.50	2.00

[**Changes relative to ecoinvent version 2:** The pedigree matrix has been slightly revised compared to version 2, and entries added for score 4 of geographical correlation and score 2 of technological correlation. In the ecoinvent 2 datasets, it was not possible to store the basic uncertainty separately. Therefore, the basic uncertainties have been back-calculated from the calculated additional uncertainty and the data quality uncertainty factors.]

10.3 Limitations of the uncertainty assessment

The approach for the assessment of uncertainties does not take into account the following factors which also contribute to the overall uncertainties:

- Model uncertainty: The model used to describe a unit process may be inappropriate (e.g. using linear instead of non-linear modelling).
- Mistakes imposed by human errors, i.e. human errors included in the information source used or errors made by the data provider during modelling, and not caught by the subsequent validation and review (see Chapter 11).

10.4 Monte-Carlo simulation and results

[The procedure for calculating uncertainty for LCI results is currently being considered in the light of findings that a Taylor series expansion may be a more simple procedure providing equally correct results]

The uncertainty estimations are given for each data point on the unit process level. The 95 % confidence interval of cumulative LCI results is calculated with the help of Monte-Carlo simulation. The 2.5 % and the 97.5 % values, calculated with Monte-Carlo simulation, are shown for each individual elementary exchange of the LCI results.

The probabilistic mean values (i.e. the cumulative results determined with Monte Carlo simulation) differ slightly from the deterministic mean values (i.e. the cumulative results derived from the mean values of the unit process raw data only without use of the uncertainty factors). It was decided to show the deterministic mean values in the ecoinvent database. This has the advantage that the mean values of the LCI results are reproducible. Furthermore, the reliability of the mean values of the unit process raw data is judged to be much higher as compared to the roughly estimated geometric standard deviation.

For the time being no uncertainty values are shown in the impact assessment results. Current impact assessment methods (except i.e. Goedkoop & Spriensma 2000; Huijbregts 2001; Steen 1999) often do not provide uncertainty information. The contribution of the uncertainty in the damage factors to the overall impact assessment results is judged to be at least as important as the uncertainty in the LCI results. Showing uncertainty values on the level of LCIA results without considering the LCIA uncertainties would be misleading.

[It is currently being considered to require the inclusion of uncertainty also for impact assessment data]

11 Special situations

11.1 Situations with more than one reference product

In general, by-products can easily be distinguished from reference products and a joint production has only one reference product, while all other intermediate outputs are either by-products or wastes. However, in some situations, more stringent definitions and procedures may be needed to identify the reference product, and in some situations there are indeed more than one reference product, in which case additional modelling procedures are required. Additional advice for these situations is given below.

Additional advice for data providers:
In most situations, by-products can easily be distinguished from reference products. For example, cotton fibres cannot be produced in any other way than from cotton growing, while the by-product cotton seed is applied for oil production sold on the general market for vegetable oils where e.g. palm oil constitutes an alternative supply. In such situations, the documentation or justification is limited to the standard text “This by-product has an application for which an alternative unconstrained production route exists”. Often by-products are close to waste and are therefore not even fully utilised, for example straw.

In some situations, a more detailed justification and documentation is required. Examples can be found in the datasets [names of datasets with more detailed documentation].

If all the co-products have alternative production routes, and it is unclear which of these is the reference product, the following conditions may be helpful in identifying which of the co-products is the reference product. The reference product is the one for which a change in demand will affect the production volume of the activity. Thus, to be the reference product, a joint product, either alone or as part of a combination of co-products, shall simultaneously fulfil these two conditions:

i) It shall provide an economic revenue that exceeds the marginal cost of changing the production volume.

ii) It shall have a larger market trend (relative change in overall production volume) than any other joint product or combination of joint products that fulfil the first condition (taking into account the relative outputs of the co-products). The reason for this is that the joint product (or combination) with the largest market trend provides a constraint on the ability of the other joint products to influence the production volume of the co-producing activity.

Example: Given two co-products A and B with alternative production costs of 100 and 50 per simultaneous produced amount, respectively, the first condition is fulfilled by both products if the co-producing activity has a marginal production cost lower than 50 for the combined amount of A+B. In this case, the revenue from the co-product with the *largest* market trend will cover the cost of the other co-product, and thus determine the production volume. If the co-producing activity has a marginal production cost between 50 and 100, co-product A will be the reference product, because it is the only product that meets the first condition. If the co-producing activity has a marginal production cost between 100 and 150, only the combination of the two products fulfil the first condition. Note that in this situation of a combination of co-products, the reference product is the co-product with the *smallest* market trend in the combination, since in order for the market to be cleared (for all products to be sold) this co-product will be sold at the lowest price that is possible without bringing the revenue below the marginal costs, thereby providing a constraint on the production volume.

[This theoretical example may be supplemented by one or more examples chosen from the three such situations in the current database, namely joint extraction of oil and gas, the gold-silver-zinc-lead-copper mine, and/or oxidation of butane]

Condition ii) above implies that if more than one joint product or combination of joint products fulfil condition i), then only that joint product or combination which has the relatively largest change in overall demand (market trend) is actually a reference product. This again emphasises that as long as alternative production routes exist for the joint products, there is only one of the joint products that can be determining for the production volume at any given moment. It follows from the conditions above that the determining reference product is not necessarily the co-product that yields the largest revenue to the activity (although this will often be the case), and that the reference product is not necessarily the co-product that is having the largest increase (or decrease) in overall production volume.

That a co-producing activity can only have *one* reference product, except if there are more co-products from the activity that have no alternative production routes, is the most restrictive assumption possible with respect to reference products, and is in accordance with the only specific consequential model currently implemented in the ecoinvent database, namely the “small-scale, long-term” market model, see Chapter 14. The restrictive assumption follows from the long-term perspective of this model and its assumption that suppliers are price-takers (which means that they cannot influence the market price), so that the long-term marginal production costs of the alternative production routes for the respective co-products provide a constraint on the long-term market prices of the co-products, and thus their contribution to the overall revenue of the co-producing activity. Thus, a change in supply or demand for a co-product with an alternative production route will not lead to a change in its (long-term) price and it will not affect the overall (long-term) revenue of the co-producing activity. Note that the alternative production route may sometimes involve a product that has slightly different properties, as long as it has the same obligatory product properties as the product from the joint production, see Chapter 4.4.5.

The ecoinvent database is prepared for alternative consequential market models where the situation of more than one reference product per activity is more common than in the “small-scale, long-term” market model described above, see Chapters 11.4 and 14.6.2.

If more than one co-product from a joint production has no alternative production routes, all of these are reference products. [In the current ecoinvent database the only] Examples of this situation are argon, oxygen, xenon and krypton from air separation, and hexane and heptane from molecular sieve separation of naphtha. [In the latter case, the two co-products have the same application area and it may therefore be possible to express them as one product in equivalent units].

In consequential models, see Chapter 14.4.1, multi-product activities are not partitioned, but only scaled to the change in demand, and are therefore still multi-product activities. When there is more than one reference product, these joint products have no alternative production routes, and an additional output can therefore not displace any other production. Instead, the additional output leads to a specific increase in the marginal consumption activities, which must therefore be included in the model of the product system. This inclusion is achieved by providing for each reference product a direct link (with the activityLinkId, see Chapter 4.4.1) to the marginal consumption activities affected. See more details in Chapter 14.4.1 on how the database applies this information to include the marginal consumption activities.

11.2 Additional macro-economic scenarios

The ecoinvent database currently operates with one default reference scenario only: “Business-as-Usual”. This scenario can be described as the most likely if no other action is taken than already decided. As time passes, new decisions are incorporated into the Business-as-Usual scenario, which therefore eventually becomes identical to the actual situation. Datasets for current and historical years are therefore by definition “Business-as-Usual”.

For a macro-economic scenario to be meaningful, it must be implemented database-wide, i.e. for all activities, and be consistent, i.e. provide an overall description of a future economy in which all products produced are used and all income is distributed. Therefore, the introduction of new macro-economic scenarios in the ecoinvent database is only done centrally after a decision by the ecoinvent Centre. However, we do encourage potential data providers of macro-economic scenario data to suggest new scenarios and cooperate with the ecoinvent Centre in implementing these in the database.

Possible alternative scenarios could be “Optimistic” and “Pessimistic”, reflecting e.g. faster growth and technology development versus slower growth and technology development, relative to the Business-as-Usual scenario. See also Hornblow & Weidema (2007) for a review and classification of different possible scenarios.

Only datasets from the same macro-economic scenario are linked when calculating production, supply, or consumption mixes, attributional and consequential database implementations, and aggregated system datasets. If a global dataset for an activity is missing for a specific macro-economic scenario (once this is implemented in the database), the activity datasets for the reference scenario (Business-as-Usual) are used instead.

When more macro-economic have been implemented in the database, macro-economic scenario child datasets may be constructed for any time period and geographical location by entering the scenario name in a delta dataset and referring to the corresponding reference activity dataset or any geographical or temporal child dataset (using the "parentActivityId" field of the ecoSpold format).

11.3 Branded datasets

ecoSpold reference: tag (field 175)

A branded dataset is a dataset for a specific brand or a specific company, where the company or brand name is specifically mentioned as part of the activity and/or product name (see Chapter 9 for naming conventions). In addition to the brand and/or company name, the brand or company logo may appear as the dataset icon (Chapter 7.2). If a product is branded, a specific market activity is required for this product, and possibly a 'niche product to generic market' transforming activity (see Chapter 4.4.6). If a company name is part of the name of an activity, a global transforming activity is defined for this, and localised production sites may furthermore be specified.

Branded datasets are included in the ecoinvent database as part of an ecoinvent license or against additional payment from the owner of the brand or company. The financing thus obtained contributes to reduce the license costs of the database and/or increases the possibilities for ecoinvent to finance further data collection and development activities. However, the same data quality guidelines and the same independent review procedure apply to branded datasets as to any other ecoinvent dataset. In addition, branded datasets are on-site audited by an ecoinvent-approved auditor. The ecoinvent Centre retains the right to refuse branding of product datasets without stating any reason for this refusal.

Branded datasets may be unit processes ("gate-to-gate") or accumulated system datasets ("cradle-to-gate"; see Chapter 4.15) with or without confidential data (Chapter 5.2).

Branded datasets are given the tag "branded dataset with logo" or "branded dataset without logo", as relevant, for quick identification of such datasets in the database.

An ecoinvent dataset may represent a specific brand or company without being a branded dataset. The location of the enterprise or other information in the dataset may reveal this, but the name of the brand and/or company will not appear in the name of the dataset and the dataset icon will be brand neutral. Such datasets are given the tag "single enterprise data" for quick identification of in the database.

[**Changes relative to ecoinvent version 2:** Some version 2 datasets carry the name of a brand or company. Either these companies must pay (possibly for an updated dataset) or the datasets must be anonymised (the datasets in ecoinvent version 1&2 are not affected by this). Some version 2 datasets are representing single enterprise data without this being indicated in the name. Such datasets should be given the tag "single enterprise data" and the geographical location should be specified as closely as possible]

11.4 Constrained markets

[The specific implementation of constrained markets needs to be tested on real-life cases before decision on database-wide deployment of this feature, and may result in additional advice or restrictions on the application]

The typical assumption in LCI modelling is that markets are unconstrained and supply is fully elastic, so that an increase in demand is reflected in an equivalent increase in supply.

However, in consequential market modelling this assumption is challenged, and the supply may be modelled as more or less elastic, which implies that all or part of the increase in demand is not reflected in an increase in supply, but instead in a reduction in consumption elsewhere, typically in the application that has the least alternative costs from not using the product in question, and is therefore the most sensitive to changes in price (the marginal application).

For example, the market for sodium hydroxide is a constrained market, since its nearly exclusive production route of NaCl electrolysis is constrained by the demand for its reference product chlorine. The marginal application for sodium hydroxide is as a neutralising agent, where it can be substituted by sodium carbonate at the rate 0.755 kg per kg sodium hydroxide.

The share of the demand that is not met by increased supply is added to the market activity as a *conditional exchange*, i.e. an exchange that is only activated for particular, specified market models. The conditional exchange is added as a *negative by-product* output with the same name and unit as the reference product, and with a direct link to the affected consumption activity, see the example in Figure 11.1.

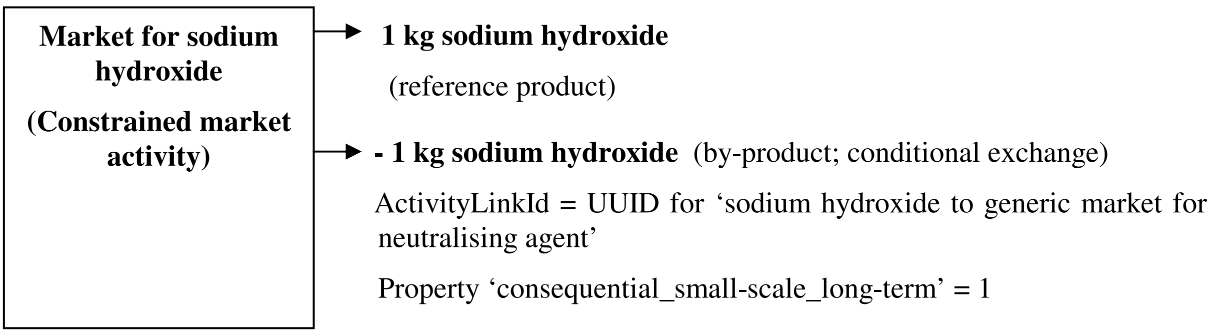

Figure 11.1. A constrained market (here for sodium hydroxide) where the share of the demand that is not met by increased supply (here: 100% = 1 kg) is added as a conditional exchange: a negative by-product with the same name and unit as the reference product, and with a direct link to the affected consumption activity (here the activity 'sodium hydroxide to generic market for neutralising agent'). The conditional exchange is normally ignored by the database calculations, but is activated (see Figure 11.2) for a particular market model via a dummy variable = 1 of a property with the name of the market model (here: "consequential_small-scale_long-term").

In general, such negative by-product outputs will be ignored by the database calculations, including mass and monetary balances for the activity. However, the negative output can be activated for use in a particular market model via a dummy variable, namely when the name of the market model in question (e.g. "consequential_small-scale_long-term") is added as a property of the negative by-product and set to 1. The database then interprets – for this particular market model – the negative by-product output as a positive input to the market activity, resulting from the reduction in consumption as modelled by the affected consumption activity, see the example in Figure 11.2. This input is then subtracted from the required market output before the remainder (if any) is distributed over the unconstrained suppliers to the market.

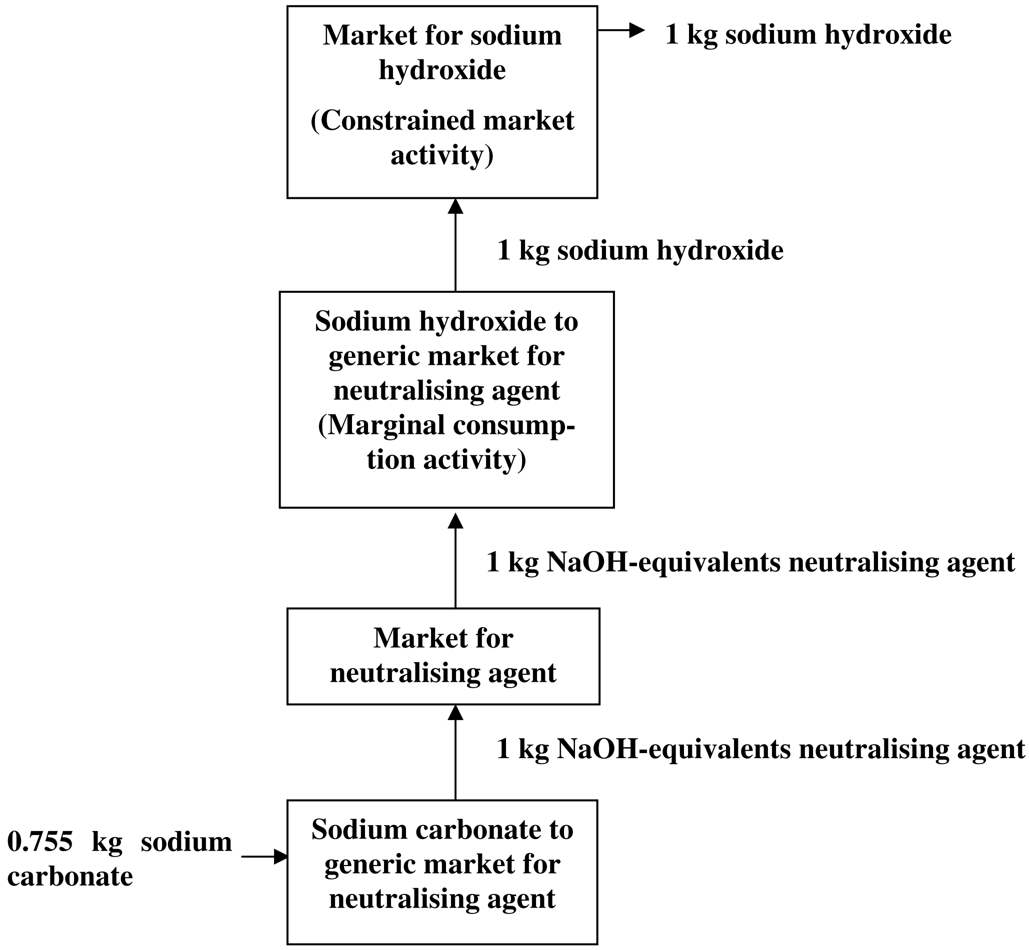

Figure 11.2. The database–generated consequential, small-scale, long-term model for the 100% constrained market in Figure 11.1. The reduction in consumption is obtained by reversing the consumption activity, in this case to have an output of sodium hydroxide, which then leads to an increased demand for neutralising agent. The neutralising agent is provided by sodium carbonate, the only unconstrained input to the market for neutralising agent.

This implies that different consequential market models may operate with different extents of constraints and different elasticities for each constrained market. This advanced functionality is not currently applied in the ecoinvent database, since only one consequential model (the "small-scale, long-term" model) is currently implemented.

Market constraints only lead to actual changes in consumption when there is no alternative production route for the product in its most generic application. Often, market constraints apply only to a niche application that puts very high requirements on the product so that no alternatives are applicable, while the same product may be easily substitutable in the more generic market segment. In such situations, the niche applications can be supplied by a constrained niche market (see Chapter 4.4.6), while the general market segment is defined with a more generic product name that reflects the less specific obligatory product properties that are required in this market segment, in such a way that the alternative production routes are included. For example, while the constrained market for sodium hydroxide may initially appear to lead to a reduction in consumption, the reduced amount of sodium hydroxide in the marginal application as "neutralising agent" simply leads to an increase in the consumption of the alternative supply to this more generic market, namely sodium carbonate production. This implies that in the consequential model described here, you will obtain the same result from a demand of 1 kg sodium hydroxide as from a demand of 1 kg NaOH-equivalents of neutralising agent or 0.755 kg of sodium carbonate.

For the "consequential, small-scale, long-term decisions" market model, only absolute, long-term constraints are considered. Empirical elasticities are generally not considered, since these typically represent short-term constraints only. There can be many different types of constraints to consider, notably regulatory or political constraints, and constraints in the availability of raw materials, waste treatment capacity, or other production factors. The ultimate market constraint is when there is only one supplier of the specific product (a monopoly). However, such situations are becoming more seldom as even the so-called natural monopolies, such as the railroads, telephone and electricity markets, which were long divided into regional monopolies, are now being opened up to competition. Still, patents and product standards may limit market entry of new suppliers, and transaction costs may be prohibitive for some potential suppliers to be involved in practise. Regulatory constraints typically take the form of minimum or maximum quotas on the activity or any of its exchanges, for example product quotas or emission quotas. The regulatory forced phasing out or in of specific technologies may also render these unavailable to respond to changes in demand. Taxes and subsidies may also constitute virtual constraints on production.

The justification for a market constraint is included in the comment field of the conditional exchange.

A specific situation of constrained markets occurs when an activity has more than one reference product, which happens when more than one of the products of an activity does not have an alternative production route. In this case, the activity only satisfies an increase in demand partly, namely with the same share of the demand as the share of the revenue obtained from the demanded product, see also Chapter 14.4.1. The missing part of the supply must therefore be obtained by reductions in use of the reference products in their marginal applications. The markets supplied by the reference products are therefore always constrained, and the missing shares of the supply are added to the market activities in the same way as described above.

The ecoinvent database is prepared for alternative consequential market models where the situation of more than one reference product per activity is more common than in the currently implemented "small-scale, long-term" market model, see also Chapter 14.6.2. For such models, by-products are declared as *conditional reference products* by the use of dummy variables in the same way as described above for conditional exchanges, namely by adding the name of the market model in question (e.g. "consequential_short-term") as a property of the by-product and setting this to 1. The database then interprets – for this particular market model – the by-product as a reference product, and treats the supplied markets as constrained, as described above.

[**Changes relative to ecoinvent version 2:** The option to model constrained markets is new.]

11.5 Import, export, market balances, and national balancing

ecoSpold reference: specialActivityType (field 115)

The basic concepts in national balancing of supply and use of products are illustrated in Figure 11.3. The national production and the import together constitute the supply, while the national consumption and the export constitute the use. Total supply of a product must equal total use when calculated in the same units (if in monetary units, also in the same valuation, e.g. basic prices, see Annex C) and when consumption includes losses and changes in stocks.

Part of the import may be separately described as destined for re-export.

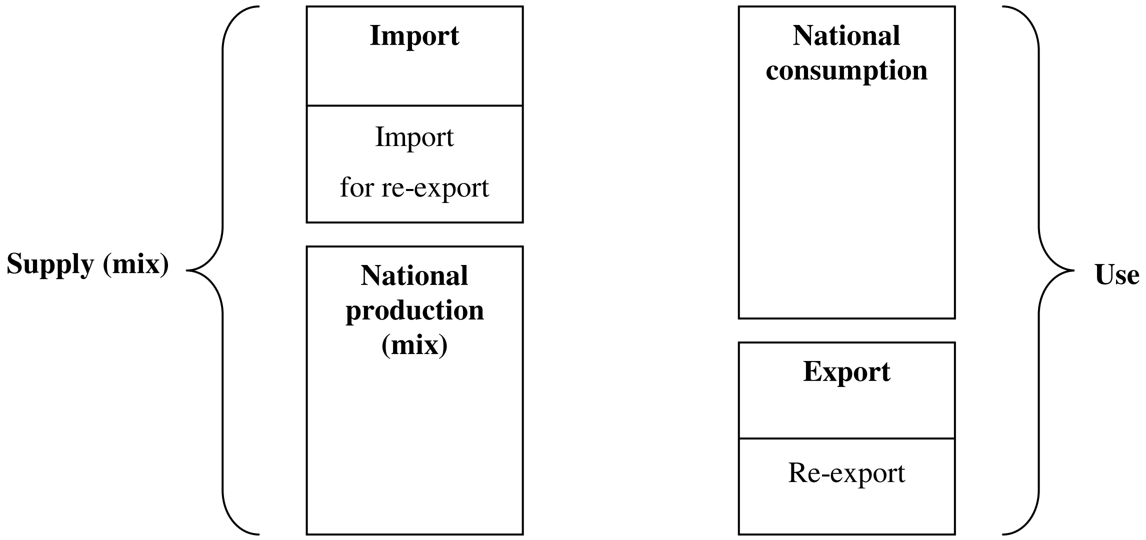

Figure 11.3. Basic concepts of national balancing of supply and use

In the ecoinvent database, supply and use are first of all balanced at the level of isolated markets, but balancing at the level of nations (or other administrative units), as in Figure 11.3, is supported. Administrative boundaries may or may not coincide with market boundaries. The following text first describes the linking of production and consumption of products in different market situations, and ends with a description of the additional modelling necessary to achieve a national balancing of products when the national boundaries are not identical to the market boundaries.

Figure 11.4 illustrate the most simple situation of a fully isolated market. This can be a single, global market, or it can be any other completely isolated market, without import and without export. Here, the product composition of the consumption mix equals that of the production mix.

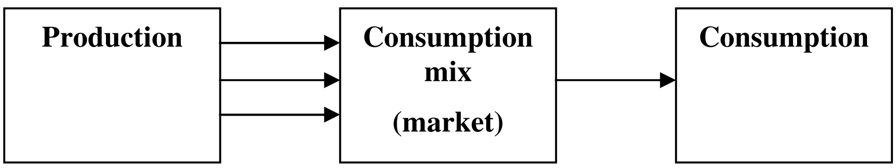

Figure 11.4. A fully isolated market. Composition of production mix and consumption mix is identical.

Figure 11.5 illustrates a partly isolated market where there is no import, but where there is export. In addition to the market activity for the geographical area, the exports from this market to other markets are specified as separate transforming activities "…, import from X" with the geographical specification of the receiving market and with direct links (specified in ecoSpold field 1520 ActivityLinkId) to the consumption mix of market X. The local consumption mix still has the same composition as the local production mix. This situation requires that the local production is flexible, so that an increase in local consumption does not influence the amount available for export. If this condition is not fulfilled, the market cannot be regarded as isolated, but is a part of a geographically larger market.

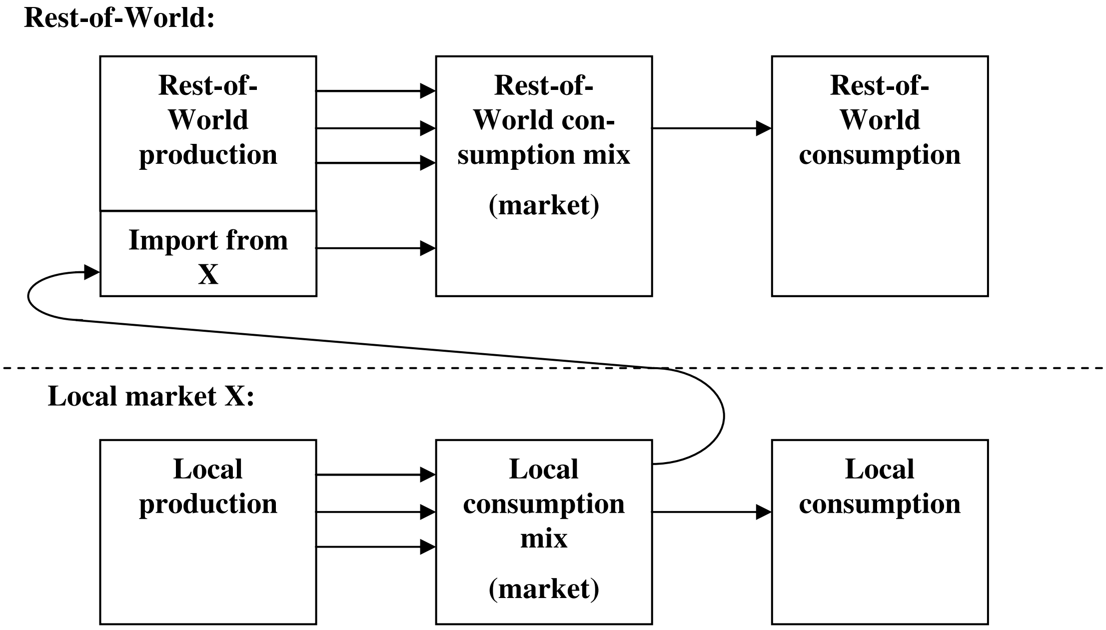

Figure 11.5. A partly isolated local market without imports but with exports. Composition of local production mix and local consumption mix is identical.

Figure 11.6 illustrates a national (or otherwise administratively delimited) isolated market where the import is administratively constrained, so that an increase in national consumption does not influence the import or only affects it in a specific proportion to the national consumption. The contribution of import is modelled as a separate transformation activity and added as a directly linked input to the market activity for the national area. If the import is affected in proportion to its share in the national supply mix, the national consumption mix is equivalent to the national supply mix. Note that the import activity here is an ordinary transforming activity, *not* a special import activity (ecoSpold field 115 specialActivityType), since the latter does not contribute to the auto-generated national consumption mix.

In general, administratively isolated markets are becoming less common over time. However, as long as the national administration decides on the extent and/or technology of imports and/or national capacity adjustments, it is relevant to regard the market as administratively isolated. Administratively isolated markets are typically found for products of strategic national interest, such as weapons, food, and electricity, and where the local administration seeks to protect national producers, such as often found for the service sectors.

In LCA, the national administrative influence on the electricity markets is of particular interest, because of the important role of electricity as an input in many product life cycles.

The documentation for a market being isolated, either due to the lack of imports and exports, due to the lack of imports but with exports from a flexible national production, or due to administrative restrictions, is provided in the Geography comment field (ecoSpold field 420).

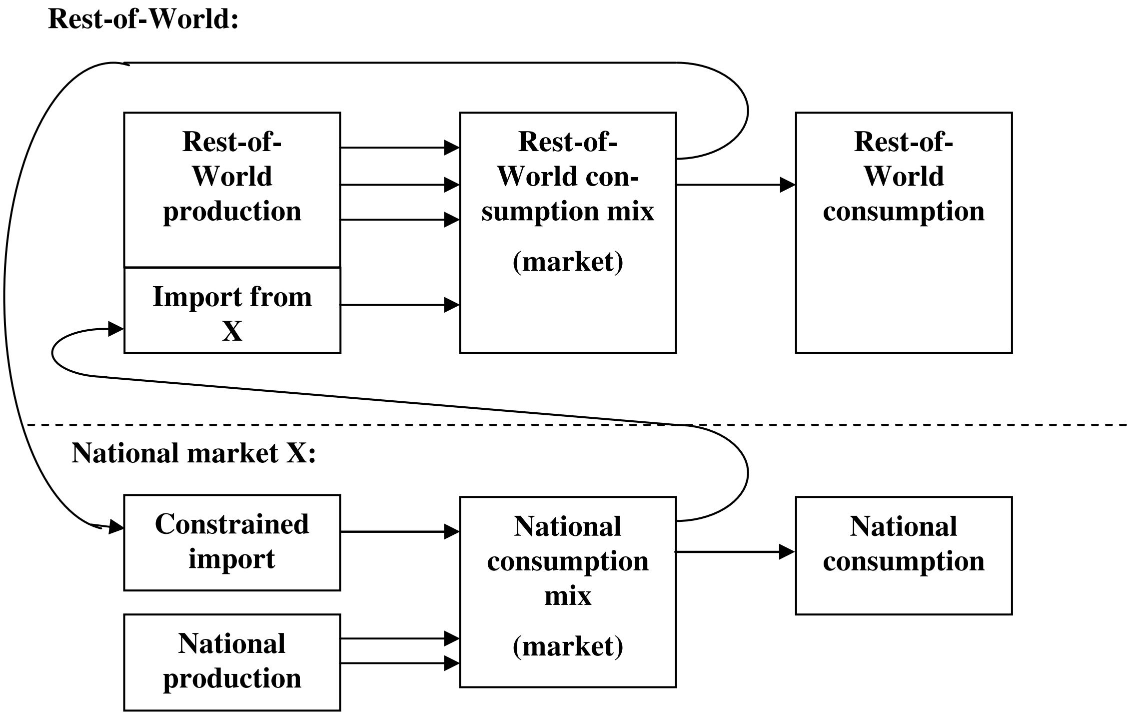

Figure 11.6. An administratively isolated national market, with constrained import.

A national balancing of the supply and use of a product, as foreseen in Figure 11.3, can be obtained by complementing the LCI modelling in Figure 11.6 with the dotted boxes of Figure 11.7:

- Export is modelled not only as import in the receiving market, but also as a national production mix that has the national area as its geographical location (dotted Export boxes in Figure 11.7). Such export activities have the specialActivityType "export" (ecoSpold field 115) to avoid that their products are contributing to auto-generated consumption mixes. To give the correct value of the export, the same activities and data that are included with the market activities are added directly to the export activity. This includes transport activities, production losses, wholesaler and retailer activities, and product taxes and subsidies.
- Import is specified with its actual contribution to the national supply mix, disregarding any administrative constraints, and is available also in the situation without any national, administratively constrained market. Import is therefore also modelled as a special import activity (ecoSpold field 115 specialActivityType) which does not contribute to the auto-generated consumption mix, but is solely for use in national balancing.
- Re-export is added. Re-export activities are modelled as a special re-export activity (ecoSpold field 115 specialActivityType) to avoid that their products are contributing to auto-generated consumption mixes.
- The national supply, combining the output from the special import activity and the output from the transforming activities within the national boundaries, may be modelled as a supply mix (ecoSpold field 115 specialActivityType), which does not contribute to the auto-generated consumption mix, but is solely for use in national balancing.
- The national use can be calculated as the consumption by activities on the national territory plus the national export and re-export activities.

Figure 11.7 illustrates the necessary additional activity datasets for national balancing and the way activities are linked in the two situations with and without a national, isolated market.

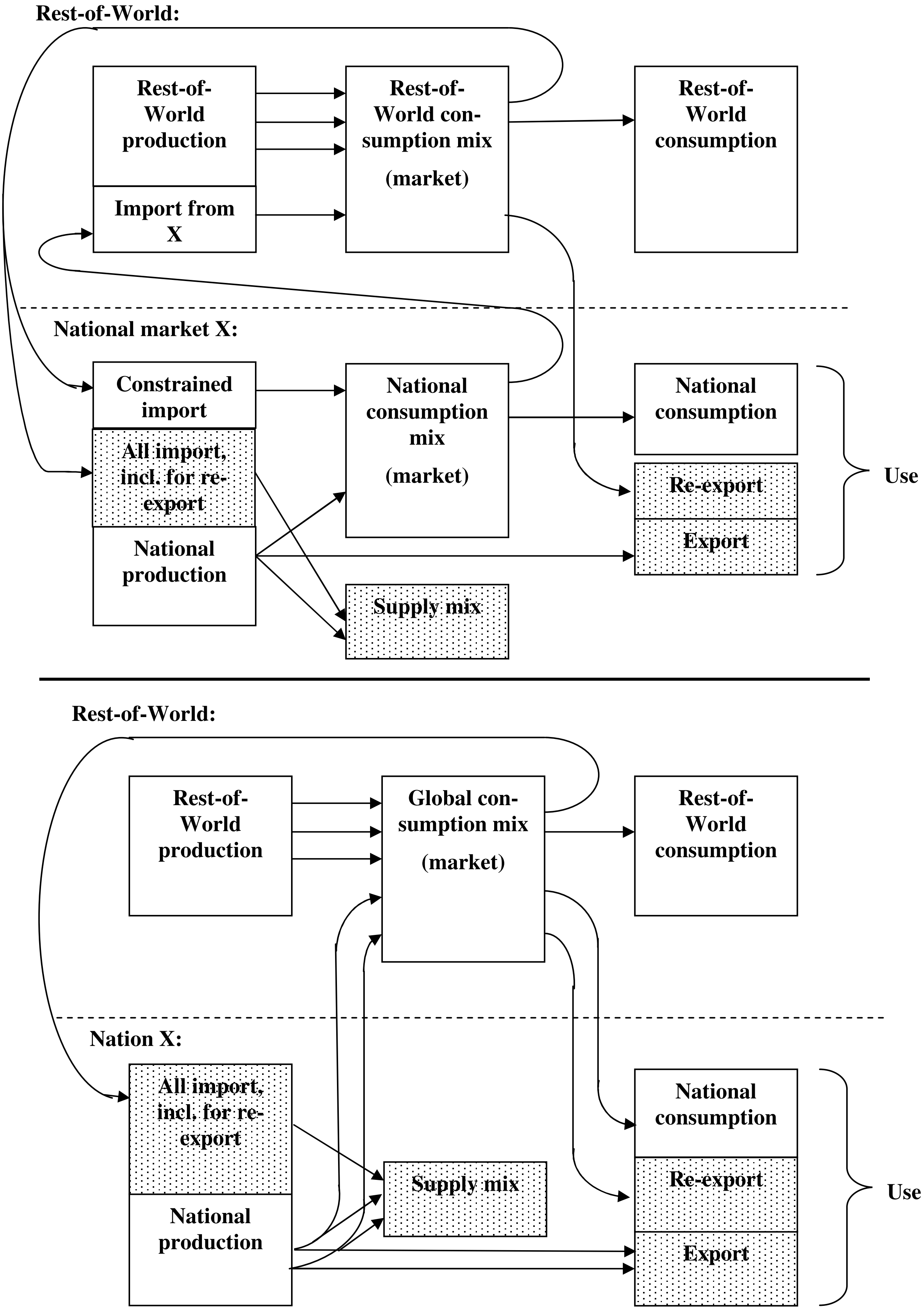

Figure 11.7. National balancing of supply and use in the situation with a partly and/or administratively isolated national market (top part of the Figure) and without (bottom part). The products of the dotted activities are not linked to any further activities in the database, but are included for national balancing only. However, because of their correct upstream linking, the products can be used as inputs in a specific model without causing any errors.

Additional advice for data providers:
Datasets for special import activities (ecoSpold field 115 specialActivityType) can only be uploaded to the database when the resulting national balance is correct, which implies that the datasets for national production, consumption, export and re-export must be added to the database before adding the special import activity.

[Add an example from the database to illustrate the entire sub-chapter]

[Changes relative to ecoinvent version 2: The clear distinction between market boundaries and administrative boundaries is new. The option for national balancing is new and is related to the (new) availability of production volume data for all activities. The editor for trade reviews all production mixes, supply mixes, import activity datasets, and market datasets (consumption mixes) from version 2, to ensure that they are consistent with the new, more precise definitions, and that they fulfil the new documentation requirements. Changes/additions are either performed or reviewed by the original dataset authors, when possible.]

11.6 Speciality productions

A *speciality production* is an activity that has a material for treatment as an input, but which is not a treatment activity (i.e. it has a positive reference product). The production volume of such an activity will be constrained by the availability of the material for treatment, and if the activity used all the material for treatment available, it would be a treatment activity. An example of a speciality production is pharmaceutical coal tar, shown in Figure 11.8.

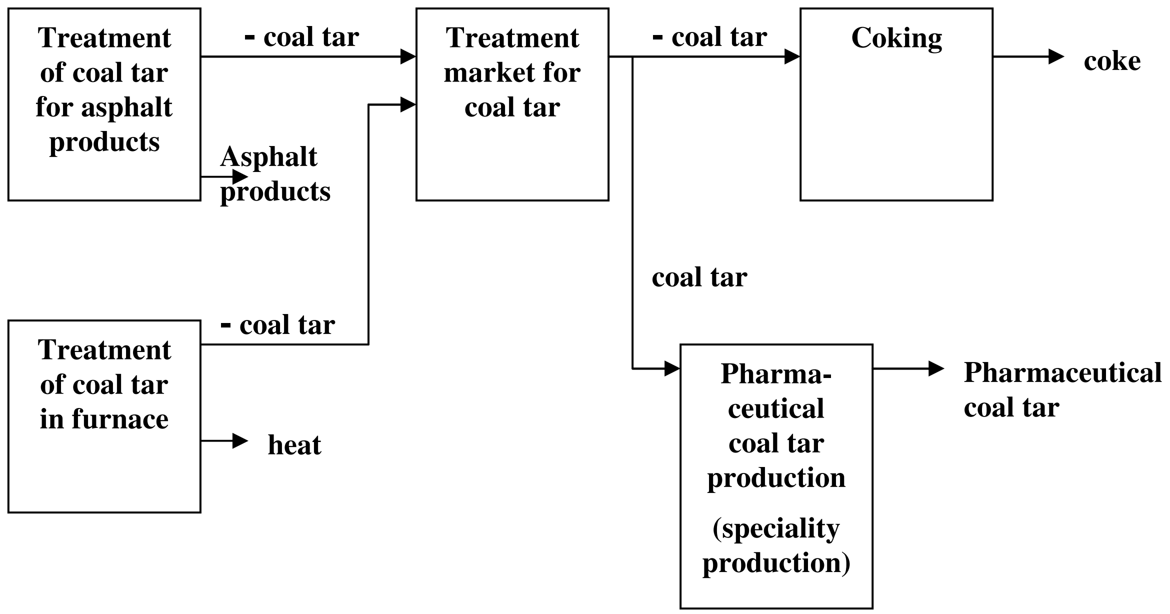

Figure 11.8. The database-generated model of the treatment of the by-product coal tar from coking with the speciality production of pharmaceutical coal tar.

11.7 Downstream changes caused by differences in product quality

Since products are defined in terms of their obligatory product properties only, see Chapters 4.4.5 and 9.3, they may differ in terms of non-obligatory properties, and these non-obligatory properties may influence the later, downstream activities in which the product is used or disposed of, so that these downstream activities have larger, smaller or different intermediate and/or elementary exchanges. This is illustrated in Figure 11.9 (left).

In a database context, where products with the same obligatory properties are mixed in the market activities, it is not practically possible to separately model the downstream use and disposal activities as dependent of the specific products used, since this would require these products to be modelled separately throughout their entire life cycle, also for those parts of the life cycle where there is no difference between the products (dotted intersections in Figure 11.9, left). Such a separate modelling would also not reflect the actual market situation, where the products are not necessarily perceived as different by the users. The difference may be something completely irrelevant to the user, such as a contamination that first shows up in the final disposal after several rounds of recycling.

In the ecoinvent database, use and disposal activities are therefore only modelled as average activities that use consumption mixes as inputs. For a product that has non-obligatory properties that make it environmentally better or worse in the use and/or disposal stages, these downstream differences to the average use and/or disposal activities are therefore added specifically and directly as *correction datasets* to the transforming activity that gives rise to the difference, i.e. that produces the product that deviates in relevant non-obligatory product properties from the other products on its market (Figure 4.9, right, upper part). In this way, the difference is included in the product system of that particular product, even when modelling all downstream activities as average activities.

At the same time as a correction dataset is added upstream, it is subtracted from the downstream average activity by placing it as a direct negative input to the downstream average activity, since the content of the correction dataset is already included once in the downstream activity (Figure 11.9, right, lower part). Thus, the same correction dataset is added upstream and subtracted downstream. The upstream positive input and the downstream negative input of the correction dataset is scaled to the production volumes of the two activities that the inputs are provided to. From the perspective of the average user, these two correction dataset therefore cancel each other out.

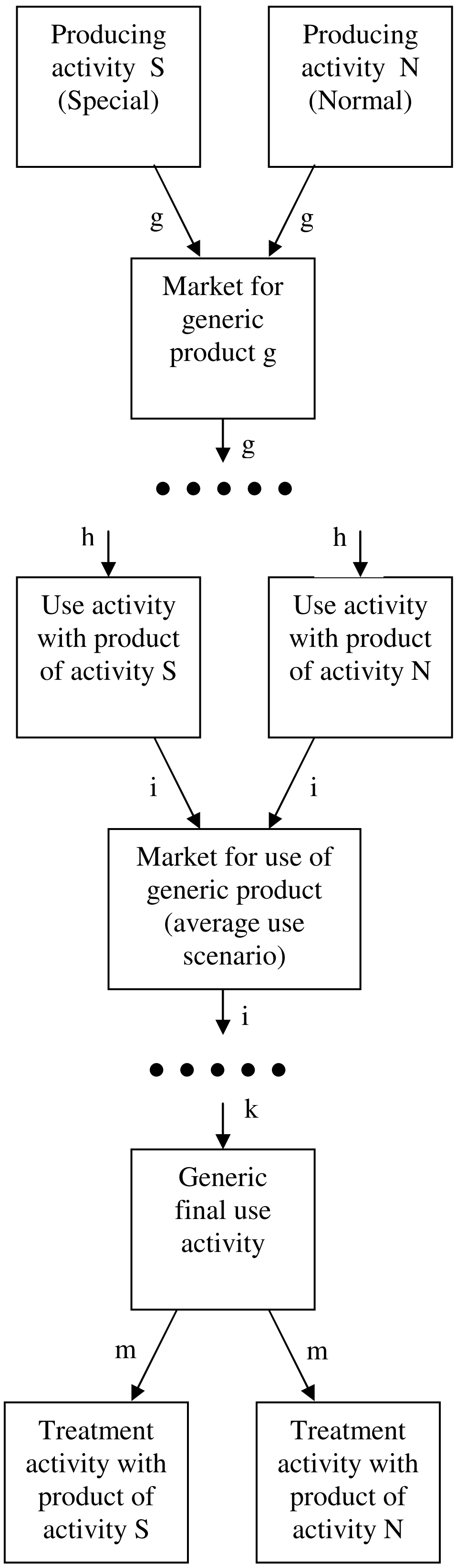

Figure 11.9 (left). The difference in non-obligatory properties of the products of activities S and N cause some downstream activities to be different.

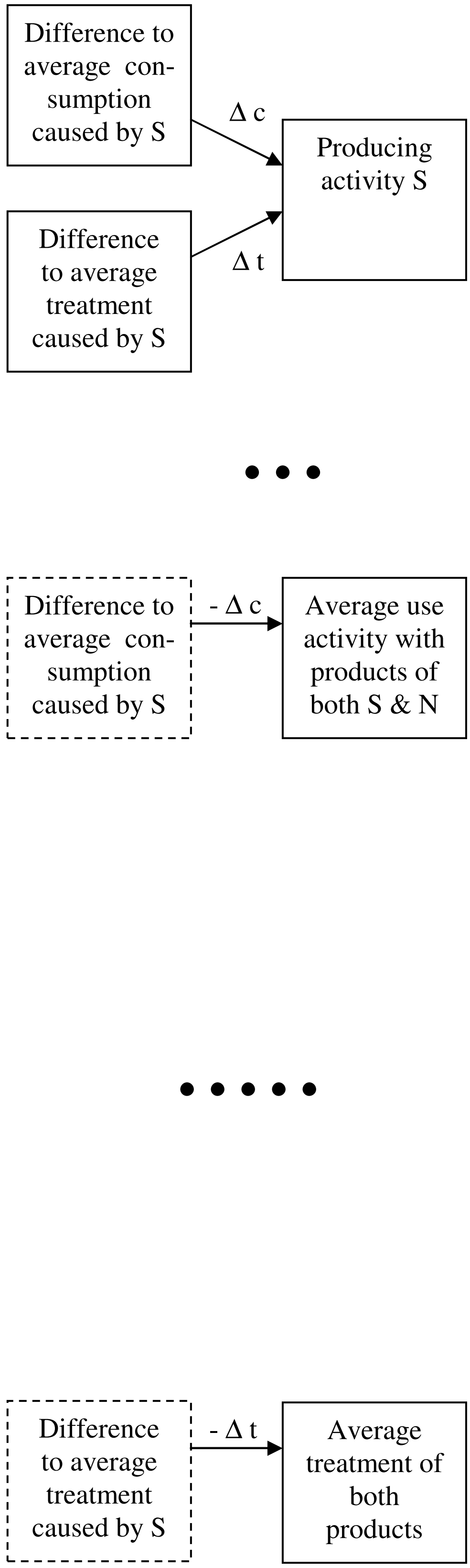

Figure 11.9 (right). Downstream activities are modelled as averages, and the differences are modelled with correction datasets, moving the differences up to the activities that cause them. Datasets with dotted lines are negative.

A correction dataset has the activity name and reference product "Difference to [downstream activity] caused by [transforming activity that gives rise to the difference], per [unit of reference product (of upstream or downstream activity)]". This reference product has neither mass nor any other properties, since a correction dataset represents a balanced sub-activity of the downstream average activity dataset, without a separate reference product.

Additional advice for data providers:
Correction datasets are most easily produced when all involved datasets (upstream and downstream) are scaled to their full production volumes, which also makes it most easy to check that the two corresponding correction datasets cancel each other out. The resulting correction dataset may then later be rescaled to any desired unit of reference product. If the deviating product causes differences in several parallel downstream activities, which is often the case at least for niche products and infrastructure products, it may be most practical to include the entire use and/or disposal activity in the correction dataset, so that these activities are completely subtracted from the downstream averages. Correction datasets can be added to any upstream activity that causes downstream differences, and is therefore not limited to production activities.

11.8 Packaging

Packaging is a complementary product, typically not included in the description and mass of the packed products. For example, 1 litre of the product "Milk, fresh, 3.5% fat by weight" reports the production of the milk alone, not its packaging, which is anyway variable. Milk is sold in glass bottles, plastic bottles and pouches, plastic-lines cartons, etc., each with their specific weights, production and disposal activities. Therefore, packaging is in general kept separate and added as a complementary input to (and waste output from) the receiving activity where the packed product is used or re-packaged.

When the type and weight of packaging is unknown, the default values from Table 11.1 have been applied.

Table 11.1 Default values for packaging for different products

[Table missing. Research is currently undertaken by the ecoinvent Centre to provide default data on packaging per product type, based on packaging statistics.]

[**Changes relative to ecoinvent version 2:** The addition of packaging as a complementary product is new. In version 2, packaging was generally not included with the products, except for some building materials which are available as packed and unpacked products. This needs to be re-structured according the revised guideline above.]

11.9 Final consumption patterns

[More details to be added after experimentation with adding household consumption and needs satisfaction datasets]

When household activities are modelled explicitly as transforming activities, with inputs of raw materials and outputs of products, final consumption becomes the satisfaction of needs. For example, the home grown potatoes are combined with purchased food products in the household activity "meal preparation" that has the product "meal" which combines with the meals from restaurants in a "market for meal", which finally may translate into the product "satisfaction of need for food", which together with all other need satisfactions combine in a final aggregate consumption/need satisfaction.

The modelling of final consumption/need satisfaction is complicated by the existence of many different consumer types, which assign different properties as obligatory for what is accepted as e.g. a "meal", so that it is necessary to operate with different markets and market niches for meals, which together with other specific preferences of the consumer types combine into final consumption or need satisfaction patterns per consumer type.

There are several suggestions on how to classify human needs. We apply the modification suggested by Weidema et al. (2005) to the Segal (1998) set of core economic needs, which has the advantage over other classifications that its applicability has been demonstrated in practical empirical work and that it provides a stronger linkage between consumption and affluence and its basis in products. The 11 need-based consumption groups are:

- Housing
- Food
- Leisure
- Social care
- Education
- Health care
- Security (including insurance)
- Communication
- Clothing
- Hygiene
- Other consumption not elsewhere classified (mainly “economic infrastructure” expenditures, such as interest etc. on financial investments, and economic affairs and services).

In national statistics, final consumption is typically recorded as the products directly or indirectly purchased by households. When recorded in this way, the household activities, e.g. the relation between shopping, car driving, fuel use and its emissions, are not included in the final consumption. However, at a more detailed level, statistics are available on the consumption patterns of different household types, depending on parameters such as household size, income level, dwelling type, etc. These data are interesting for understanding the driving forces behind consumption and for modelling changes in the household parameters. To take advantage of these data sources, the final consumption patterns from the statistics are translated into demands for the corresponding household activities per household type, thus integrating the household consumption patterns with those of the consumer types into one overall model of final consumption or need satisfaction.

11.10 Linking across time

11.10.1 Lifetime information / Stock additions

ecoSpold reference: Properties (field 1400); OutputGroup (field 1510)

In life cycle inventory modelling, long-lived products are typically represented by steady-state models, e.g. a car will typically be modelled with the current production technology, the average life time emissions and the current waste treatment technology, all divided by the lifetime of the car. Effectively, this means that - in this LCI modelling - the net additions to stock of these long-lived products are simply contributing as physical inputs to the waste treatment activities of the current year.

When lifetime information is available for a product and/or waste, and waste treatment datasets are available for the period that the product becomes waste, the waste treatment and the accompanying emissions can be placed at their correct point in time.

It is strived for to make lifetime information available for long-lived products and to make waste treatment datasets available for future periods, so that current net additions to stock of these products can be modelled as becoming waste at the correct period, and thus use the waste market that corresponds to this period.

The ecoinvent database automatically identifies by-products and wastes with a property “lifetime” in excess of one year as an addition to stock (ecoSpold field OutputGroup option 5 = StockAdditions), thus distinguishing this “future waste” from the waste outputs of the current year. For such stock additions, the database service layer identifies the years in which the stock will become waste (using the lifetime and any uncertainty information provided on this) and links this waste directly to the corresponding future waste treatment markets. If a treatment market is missing for a specific year, the corresponding treatment market for the nearest preceding time period is applied, although not prior to the reference year (2005).

In LCI modelling, it is the consumption activities that demand the necessary upstream production activities. Therefore, a similar automatic linking of the future *consumption activities* of long-lived products, as is implemented for waste treatment activities, cannot be made, since this would require that the consumption activities were *inputs* to the infrastructure activities in the same way as the waste treatments are. Thus, such dynamic modelling of the consumption activities of long-lived products still require additional, manual linking by the database user of the relevant accumulated systems datasets across time.

However, inputs to an infrastructure dataset (a dataset with a reference product having the property “capacity” or “lifetime_capacity”) may have a specific, direct link (using the activityLinkId) to a future activity. This may be relevant for maintenance activities or components of infrastructure that have a shorter lifetime than the composite infrastructure, e.g. windows in a building, or tyres on a car.

When linking to datasets of future years, only accumulated systems datasets are linked to, to avoid an endless calculation task, since practically all datasets within a time period are linked to each other, and linking to just one dataset from a future year therefore will involve the entire economy in that future year, with the additional possibility that datasets of this year also link to even more future years.

Applying the output category “stock additions” removes the requirement of direct equivalence between capital investments and waste in any given time period. When using the ecoinvent database in connection to data from national accounting, see Annex C, this allows to balance the complete economy for a given year, based on the actual investments in capital goods, and the actual waste amounts of that year, without any artificial requirement that these should match.

[**Changes relative to ecoinvent version 2:** In version 2, each dataset is only available for one time period, and all datasets are linked without regard to their indicated time period. In version 3, only datasets for the same time period are linked, except for the described situation of stock additions, which makes use of the new option to add lifetime as a numerical property to intermediate outputs, and if links across time are made using the activityLinkId.]

11.10.2 Long-term emissions

Emissions that occur over large time frames of substantially more than 100 years are assigned to specific subcategories (labelled "long-term"). Such long-term emissions occur in landfill sites (leaching), in uranium mining and milling sites (radon emissions) and – probably – final repositories of nuclear waste. For landfill emissions and uranium mining and milling sites timeframes of 60'000 and 80'000 years, respectively, are chosen. These activities release pollutants to “air, low population density”, to “water, river” and to “water, ground-“ during very long time scales. The ecoinvent database contains corresponding long-term subcategories in order to distinguish these long-term emissions from the ones occurring within the first 100 years.

[The issue of how best to include long-term emissions is currently under consideration in a separate ecoinvent research project]

11.11 Using properties of reference products as variables

When one or more exchanges of an activity dataset are expressed as mathematical relations involving a property of the reference product, and this property is not a fixed property (see Chapter 5.6.7), the value of the property may change depending on the setting of the property in the dataset that has the reference product as an input. Each setting of the property value effectively represents a different product. This can be seen as a special case of combined production (see Chapter 5.3) in which each such property represents a combined co-product, with the important difference that the properties are not traded separately from the product that carries the properties. Like for other cases of combined production, a sub-division of the co-producing dataset is required, so that the specific dependencies of each variable property are expressed in separate datasets. For example:

- If a dataset for impact extrusion of aluminium, with the reference product “impact extrusion of aluminium, cold”, has one or more of its exchanges defined as a mathematical relation to the property “number of deformation strokes” (variable name: “strokes”) of the reference product, two datasets are required: One with the reference product “strokes of impact extrusion of aluminium, cold” and one with the reference product “impact extrusion of aluminium, cold, property independent”, in which the first dataset contains all the mathematical relations that involve the property “strokes” and the second contains all the other exchange data that are not dependent on this (or any other) property of the reference product.
- If a dataset for waste incineration, with the negative reference product “waste”, has one or more of its exchanges defined as a mathematical relation to the property “cadmium content” of the waste, two datasets are required: One with the negative reference product “cadmium content of waste” and one with the negative reference product “waste, property independent”, in which the first dataset contains all the mathematical relations that involve the property “cadmium content” and the second contains all the other exchange data that are not dependent on this (or any other) property of the reference product.

For each new variable property of the reference product (i.e. a property included in a mathematical relation of another exchange), a new dataset is required (if there is at least one other activity dataset that has the reference product as an input with a different amount of the variable property). Each additive element (summand) of the mathematical relation can only contain one property of the reference product. In situations where multiple relations exist, composite properties can be used.

Figure 11.10 illustrates the original and the derived datasets and how these are linked to the activities that require the reference products. The variable property is added as a by-product with the name “[property name] of [name of reference product]” and the mathematical relation is changed to refer to the amount of this new by-product, while the original property is deleted from the reference product, which is renamed to “[name of reference product], property-independent”. All exchanges that were originally expressed as fixed amounts are re-formulated as mathematical expressions relating to the reference product, i.e. the fixed amount “40” translates to “40/A”, where A refers to the amount field of the reference product. In activity datasets that have the reference product as input, this input is also sub-divided in the same way, i.e. into a property-independent reference product and a “[property name] of [name of reference product]” using the specific property value of the receiving activity. The market activity dataset for the reference products is likewise sub-divided, with all other exchanges and properties remaining with the property-independent reference product, so that the new property-specific market activities have no additional exchanges besides the reference product.

Other datasets supplying the same reference product to the same market are subdivided in the same way. If such datasets do not have the same property of the reference product as a variable property, the exchanges of this dataset are interpreted as independent of this property, and their fixed amounts thus simply re-formulated as mathematical expressions relating to the re-named reference product.

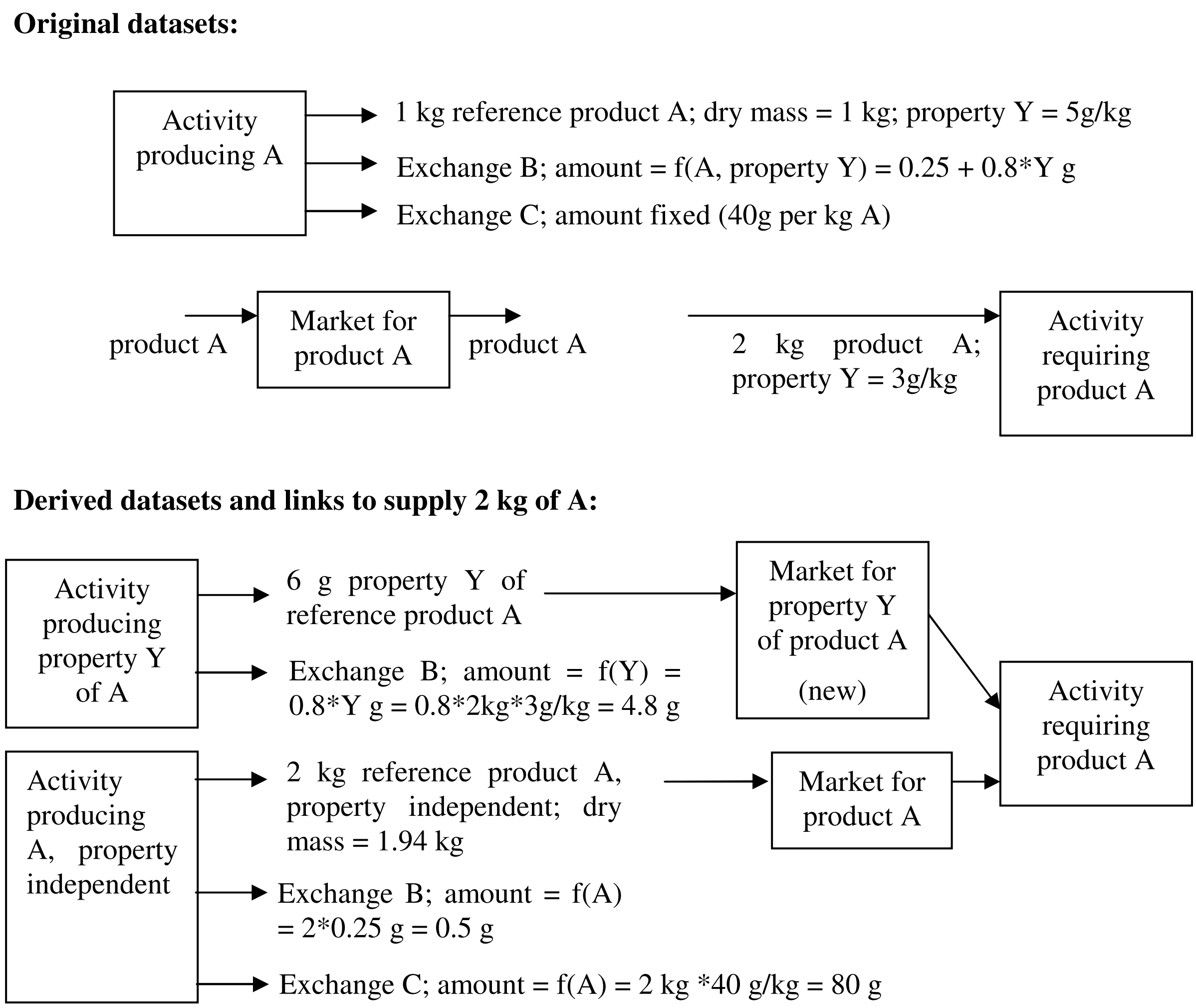

Figure 11.10. The original and derived datasets where a property Y of the reference product is used as a variable, and the original dataset requiring this reference product, but with a different value for Y, where the input is also subdivided. Note that the mass balance (and other balances) may be kept intact for the subdivided activities, (as illustrated by the change in dry mass of the reference product) when such adjustments are made during a manual sub-division, but since properties do not themselves have properties such as mass, such adjustments are not made when the sub-division is made automatically by the database service layer (see Chapter 14.1, linking rule no. 4). However, the aggregated systems results are not affected by this.

[Currently, the additional datasets and the linking has to be added manually, but it is planned to let the database service layer assist in creating the derived datasets for the variable properties of reference products and the specific linking from the activities requiring the inputs of these reference products, see Chapter 14.1, linking rules no. 3 and 4]

When the subdivision is performed by the database service layer, the subdivided datasets keep the same activity ID as the original dataset, which implies that the product name is required to distinguish the datasets from each other.

[**Changes relative to ecoinvent version 2:** In version 2, the situations described here were generally handled by adding completely separate, manually entered datasets for each instance of requiring activity.]

11.12 Market averages of properties

When a property of an output of an activity is not fixed (re. fixed properties, see Chapter 5.6.7), different transforming activities may supply the same product with different values for the same property. For example, different suppliers of lignite, even to the same market, may provide lignite with different sulfur contents.

This situation is more general than the specific situation described in Chapter 5.8.

As part of the linking of the different activities into product systems, see Chapter 4.14 and Chapter 14, the database service layer calculates the inputs to each market activity from different suppliers in proportion to their available production volumes, and calculates the resulting production volume of the market output. In addition, those product properties that are common to all the suppliers to the market are added as properties of the market reference product, and the values of these properties are calculated in proportion to the supplied production volumes.

These properties of the market outputs can be applied in further calculations. For example, the sulfur content of lignite may be used to determine the emission of sulfur dioxide in the activities that use the lignite as a fuel. To avoid circular references in the database, the calculated properties of the market outputs are not automatically transferred to the activities that use the market outputs, but remain available in the market datasets for information purposes and possible manual adjustments of the properties in these receiving activities. This transfer of information is of course only relevant when there are different values of a property among the suppliers to the same market and the receiving activity uses the property values in a mathematical relation.

11.13 Use of transfer coefficients

ecoSpold reference: transferCoefficient (field 1200); Complex type TTransferCoefficient

[Transfer coefficients is a feature of the new ecoSpold 2 format, but it has not yet been decided whether ecoinvent will accept datasets with transfer coefficients. The following description shall therefore be seen as informative for experimenting only.]

Transfer coefficients relate each input to an activity to the outputs of that activity. A transfer coefficient is the share of an input that contributes to a specific output. For example, an input of aluminium oxide to an electrolysis activity can have the transfer coefficients 52% to liquid aluminium, 1% to waste and 47% to carbon dioxide (the oxygen part). Together, the transfer coefficients for one input add up to 100%.

Transfer coefficients can be seen as a simple way of making a mathematical relation for an output, relating this output to its inputs. This implies that when transfer coefficients are used, the corresponding outputs are automatically calculated. For example, with an input of 1.92 kg of the aluminium oxide above, the output of liquid aluminium will be calculated to 1 kg (52%), while 0.019 kg (1%) will be added to waste, and 0.904 (47%) will be added to carbon dioxide (the carbon in the carbon dioxide will come from the carbon anode, which will also contribute to the waste, and any difference in oxygen to carbon will be balanced with an uptake or release to air).

When transfer coefficients are applied to all inputs to an activity, all outputs will be determined by these. Transfer coefficients can therefore not be applied at the same time as other mathematical relations for the outputs, and therefore also not when mathematical relations are used for situations of combined production (Chapter 5.3) or for variable properties of the reference product (Chapter 5.8).

Transfer coefficients may be useful in combination with mass balances, also at the level of individual elements, to calculate amount and composition of less well-known outputs, e.g. wastes, as residuals relative to other more well-known outputs.

Additional advice for data providers:

In the ecoEditor 2 (the software for supplying data to the ecoinvent database), both absolute and relative numbers can be entered for the transfer coefficients. The software automatically converts all entries relative to the sum of all entries for each input. This feature is useful when making transfer coefficients separately for one component or element of an input at a time.

[**Changes relative to ecoinvent version 2:** The option to use transfer coefficients is new.]

12 Validation and review

Validation is the automatic software routine to check that data are valid according to the internal rules set for the ecoinvent database.

Review is the manual inspection of the data and commenting on any discovered errors or anomalous data that require additional explanation or justification.

12.1 Validation

The automatic validation of ecoinvent data covers the

- accordance with the ecoSpold 2 data format,
- accordance with additional ecoinvent-specific rules, as described in this document,
- plausibility of the data,

and takes place in several steps:

The ecoEditor 2 software, used by most data providers to create and edit data for the ecoinvent database, secures the validity of the data against the ecoSpold 2 data format already during editing. Likewise, some validations of accordance with ecoinvent-specific rules can also be performed directly upon data entry, e.g. “Circular references are not allowed”.

[Other validation checks can be made off-line (i.e. without contact to the ecoinvent database) in the ecoEditor 2, upon user request, typically before storing an edited dataset, e.g. “An ISIC class must be chosen”, and “The field productionVolumeAmount must not be filled for the reference product of market datasets”. The latter is an example of a validation check that does not lead to a rejection if the dataset (i.e. it can still be uploaded to the database for review), but results in a warning to the user (here that “The entered value will be over-written by the database and should instead be placed in the comment field”).]

Other validation checks require contact to the working version of the ecoinvent database, because they require a check against data that already exist in the database, e.g., “Global dataset must exist before non-global datasets can be uploaded”, and “The name of a new geographical location must be unique (i.e. not already existing in the database)”. Such validation checks also apply for deletion of datasets, e.g. “A parent dataset cannot be deleted” (deletion of datasets can only be done by the ecoinvent editors, see Chapter 12.2, but can be suggested on the relevant talk pages, see Chapter 16.4.)

Validation checks that require contact to the database can either be performed via the ecoEditor 2 software when this is in on-line contact with the database, or by submitting the dataset to the ecoinvent database for validation via a web-browser. When using the ecoEditor on-line, the validation result will be inserted directly in the dataset (in the ecoSpold field 3340 Validation details). Only the latest validation result will be stored (i.e. any previous validation results will be over-written). If submitting a dataset via a web-browser, the validation result (a text message) will be returned by e-mail.

The plausibility checks generally do not lead to rejection of a dataset (i.e. it can still be uploaded to the database for review), but results in a requirement to justify the anomalous value in the adjoining comment field, if the anomalous value is maintained. An implausible entry without an adequate justification will be returned by the reviewer.

Plausibility checks generally compare the data entries to similar entries in similar datasets. Thereby, the completeness of the data is checked (missing exchanges or missing entries in fields where all similar datasets have entries); it is checked that the entries fall within expected ranges (relative to the amount of the reference product or relative to well-established relations between different amounts and/or properties of specified exchanges). Results of mass and monetary balances are also reported in the validation results.

The plausibility checks obviously relate to the existing database, specific clusters of similar datasets within the database, and knowledge about what are typical and important errors and relationships between individual data values within each cluster. This knowledge is built up over time, and is based on a continuous learning cycle of learning from past errors, software-supported explorative data analysis, interaction with expert knowledge, and cluster analysis. Thus, the plausibility checks will improve over time, and will be implemented in the ecoEditor 2 and the database software, as part of the continuous maintenance and updating.

[**Changes relative to ecoinvent version 2:** Validation is more extensive.]

12.2 Review of dataset and documentation

All activity datasets are reviewed by at least three experts prior to the storage of the datasets in the database.

12.2.1 Types of editors

There are three overall types of ecoinvent editors: activity editors, cross-cutting editors, and LCIA editors. Cross-cutting editors can further be sub-divided in geographical editors, inventory indicator editors, meta-data editors and language editors. Each of these types of editors will be described in the following:

Activity editors: Activity editors are responsible for reviewing of data for a specific industry, technology or other human activity. The activity editor is the main reviewer for a dataset; she/he is the first to receive a submitted dataset, and the last to accept it for final upload to the current beta-version of the database. Activity editors are typically leading (LCA) experts within their activity area. The activity editors divide the work between them according to the ISIC (Rev. 4, ecoinvent-amended) codes of the datasets. The main editor may re-assign a dataset to a co-editor with special expertise but still request to remain as main editor for the dataset. In this case, the dataset will first be reviewed by the co-editor and then by the main editor for overall consistency. An activity editor is in principle responsible for all datasets within an activity area, disregarding any geographical differences (exactly to ensure global consistency of activity datasets, i.e. across all geographies). When a dataset has been reviewed by the activity editor, it is passed on to the cross-cutting editors:

Geographical editors: A geographical editor is responsible for datasets that fall geographically within a specific country or other geographical area, ensuring that geographical variation in technologies are correctly and consistently captured and integrated across all datasets for that area. If the ecoinvent Centre cooperates with a national data collection initiative in a country, the geographical editor for that country will typically be appointed after suggestion by the national data collection initiative.

Inventory indicator editors: An inventory indicator editor is responsible for a specific emission (or group of emissions), e.g. particle emissions, or other environmental pressure indicators (e.g. resources, land use, noise, social aspects)[5], ensuring the consistency across all datasets.

Meta-data editors: A meta-data editor is responsible for ensuring the consistent use across all datasets of a specific database field (or group of fields) or master file entries, e.g. for name fields, statistical classifications, free documentation fields, supply-use data, geography fields, market models, scenarios, uncertainty fields, and product properties.

Language editors: A language editor is responsible for checking consistency and quality of translations within a specific language version of the ecoinvent datasets, and may maintain a vocabulary for

[5] Environmental pressure indicators are called ”Elementary Flows” in the ISO 14040 series, and “elementary exchanges” or “exchanges with the environment” in ecoinvent.

automatic pre-translations. Language editors will only receive datasets for review when they contain translated fields in their specific language.

LCIA editors: LCIA editors are responsible for impact assessment datasets, not activity datasets. In this way, they work in parallel to the activity editors. There are two kinds of LCIA editors: LCIA method editors and LCIA pathway editors. An LCIA method editor is responsible for the maintenance of the ecoinvent version of a specific LCIA method (CML, Ecoindicator, etc.). The LCIA method editors are both responsible for the correctness of the mapping of the environmental pressure indicators ("Elementary exchanges") between the ecoinvent inventories and the specific LCIA method, and for the correspondence of the numerical entries in the ecoinvent implementation with those of the original published method. An LCIA pathway editor is responsible for the consistency of the implementation of a specific impact category and/or pathway (for noise, water resources, etc.) across all relevant LCIA methods. LCIA editors are involved both when an LCIA method is updated by the method developer, and when new environmental pressure indicators are added to the ecoinvent database. The only cross-cutting editors which are relevant for impact assessment datasets are the language editors. Thus, when an impact assessment dataset has been reviewed by the LCIA editor(s), and it contains translated fields, it is passed on to the language editor.

12.2.2 The flow of a dataset through the editorial process

When a data provider uploads the dataset via the ecoEditor 2 software or via the ecoinvent web-site, the software stores it and assigns it to the relevant editor. For a transforming activity dataset this will be determined by the statistical classification assigned to the dataset by the data provider. For production and supply mixes and market activity datasets this is the editor for wholesale and retail trade. For import datasets and supply-use data, this is the meta-editor for supply-use data. For an LCIA method dataset this will be determined by the name of the method or impact category.

The original data provider (author) of a dataset can ask to be informed whenever there are other data providers that suggest modifying the dataset in question and can decide to take over the suggestion (and thus remain as author of the dataset) or comment on the suggested modifications before the dataset is passed on to the activity or LCIA editor.

The main editor may pass on the dataset and review responsibility to a co-editor if temporarily unavailable due to workload, holidays or illness, or if judging that the co-editor has more scientific expertise for the particular dataset in question. When passing on a dataset to a co-editor, the original responsible editor indicates whether the co-editor thereby becomes the responsible editor for this dataset or whether the original main editor remains as responsible editor, in which case the dataset will first be reviewed by the co-editor and then by the main editor for overall consistency. In case of conflicts of interests, any editor is required to pass on the dataset and review responsibility to a co-editor, and shall not demand to remain as responsible editor.

Having accepted the dataset for review, the responsible editor adds any review comments to the file. If a dataset is a delta/child dataset or a new version of an existing dataset, only those parts of the dataset are reviewed that are different from the parent or are affected by the changes. The purpose of the review is to check the dataset against the data quality guidelines in this document, to check that the result of the automatic validation has been adequately addressed, and to check the plausibility of the dataset against the "real life" activity that it is intended to represent. As part of the review, the editor may also compare the new dataset with an older version or a similar dataset. For delta/child datasets, the editor also considers whether entries correctly belong in the delta dataset, or should rather have been placed in the parent dataset.

If the review comments are of a nature that revision by the data provider is required, the commented dataset is returned to the data provider for re-submission. This procedure may continue until the responsible editor is satisfied with the quality of the submitted dataset.

When the responsible editor has accepted the dataset, the data provider is informed and the dataset now passes on to the cross-cutting editors. Depending on its content, the dataset can be passed on in parallel to several cross-cutting editors:

All activity datasets except global datasets are passed on to the relevant geographical editor.

Inventory indicator editors receive activity datasets if they contain data on their specifically monitored environmental pressure indicators (elementary exchanges). If the dataset is a new version of an existing dataset, it is only passed on if there are changes for the monitored indicators. More than one inventory indicator editor may be involved in the review of the same activity dataset.

Meta-data editors receive activity datasets if they contain information in one of the fields specifically monitored by them. If the dataset is a new version of an existing dataset, it is only passed on if there are changes for the monitored fields. More than one meta-data editor may be involved in the review of the same activity dataset.

Language editors receive datasets if they contain translated fields in their specific language. Datasets that have multiple languages may thus be passed on to several language editors in parallel. If the dataset is a new version of an existing dataset, it is only passed on if there are changes for the text or name fields, or when a new language has been added.

If responses are given by one or more cross-cutting editor, these responses are automatically accumulated into one review version, which is passed on to the data provider for corrections and resubmission. The resubmitted dataset is returned to the editors which have given comments. This procedure may continue until the cross-cutting editors are satisfied with the quality of the submitted dataset.

When the dataset has successfully passed the cross-cutting review, the data provider is informed and the dataset passes back to the responsible editor. If there has been changes made during the cross-cutting review, the responsible editor performs a final review. After this final review, the responsible editor uploads the dataset to the current working version of the database, and the data provider is informed.

Editors seek to process submitted datasets within 14 days of receipt, but may request a prolongation of the review period during peak load, in which case the data provider will be informed. The minimum time between submission of a dataset and its inclusion in the working database is one month, but will usually require more time due to several rounds of comments and replies between editors and data providers.

The review procedure is comparable to the critical review specified in the ISO standards.

It has to be emphasised that the responsibility for the contents of all datasets remains with the person and institute who supplies the data. The reviewer helps to improve the quality of datasets with his or her suggestions. But it is the final decision of the dataset author whether all proposals for corrections of the data are implemented, just as it is the decision of the activity editor whether a dataset can be included in the database or not. If an editor repeatedly returns a dataset, and this is regarded by the author as unfounded, the author may address a complaint to the ecoinvent LCI Expert Group that has the final decision authority on scientific matters raised by the Editorial Board or arising from complaints.

[**Changes relative to ecoinvent version 2:** Review is more extensive and now performed by domain experts.]

12.3 "Fast track" review for smaller changes

For adding tags to a dataset and for smaller corrections to a dataset (e.g. correcting spelling errors, adding, editing or deleting single entries that are obviously wrong), which do not require a full review of the entire dataset, a "fast track" submission procedure via the ecoinvent web-site <www.ecoinvent.org> is planned. This avoids the need to download and install the ecoEditor software if it is only single entries that are to be submitted for review.

The review procedure for such submissions is also streamlined, to limit the workload on the editors, and to reduce the time between submission and publication.

12.4 Confidentiality

Confidentiality concerns of a data provider and requests for confidentiality agreements should normally be referred to the ecoinvent database administrator. When the data provider has set the accessRestrictedTo different from the default “3 = ecoinvent”, the dataset will not even arrive at the editor’s desk, but will be redirected to and handled by the ecoinvent administrator directly. Confidential datasets are subject to the same data quality guidelines as any other ecoinvent dataset, but the review procedure will be performed under the direct management of the ecoinvent administrator that signs and/or manages the necessary confidentiality agreements, also in case of re-delegation of the review to independent reviewers.

The ecoinvent Centre accepts no responsibility for confidentiality agreements made directly between editors and a data provider.

12.5 On-site auditing

Branded datasets require on-site review by an ecoinvent-approved auditor. A visit to the factory and auditing of the books is required to determine that the activity is correctly and completely represented in the dataset. Audits are performed according to ISO 19011 and with Weidema et al. (2003) as technical basis. On-site audits may require the signing of a confidentiality agreement, and is always organised with the assistance of the ecoinvent administration.

13 Embedding new datasets into the database

The ecoinvent data covers all aspects of the societal economy, although in varying degree of detail. For any industry, there is at least one activity dataset representing unspecified products of that industry. For example, while the ecoinvent database contains a large number of individual pesticides, there is also an activity representing "pesticide production, unspecified" with the reference product "pesticide, unspecified".

This implies that any new dataset, which is not a delta dataset for a child to an existing dataset, is always a disaggregation of an existing dataset. For example, adding a new pesticide production would be a disaggregation of the activity "pesticide production, unspecified". The production volume of the "pesticide production, unspecified" would be reduced by the production volume and exchanges of the new, specified pesticide.

The disaggregation also ensures that the ecoinvent database remains complete and non-redundant, i.e. for any given activity there is only one dataset that is the relevant dataset.

For a data provider of a new dataset, this implies that at least two datasets are to be supplied at the same time: The new, specific dataset and the residual of the original, more unspecific dataset. These two new datasets together sum up to the original dataset. If the original dataset is not believed to represent the correct sum of the disaggregated datasets, a corrected version of the original dataset has to be submitted before or together with the disaggregated datasets.

[disaggregation is supported by the ecoEditor 2 in the final release version (not the current beta)]

A disaggregation of an activity also implies a disaggregation of its reference product. For example, the disaggregation of "knitted nets" into "knitted textile bags" and "fishing nets". Since the reference product of the original activity is an input to other activities in the economy, the datasets for these activities will also have to be adjusted, so that they instead of having inputs of the original reference product now have inputs of one or more of the disaggregated reference products. By default, the ecoinvent database assumes that all activities that had inputs of the original reference product will have inputs of all the disaggregated products in proportion to their new production volumes. This implies that the receiving activities are unchanged, except for the higher resolution in the intermediate input, and will provide the same results for their accumulated systems. However, this does not take advantage of the additional information provided by the new disaggregated activities. The food industry will still receive a part of their textile bags in the form of fishing nets, and the fishing industry will still receive too many textile bags. The authors and/or editors of the affected datasets are therefore informed about the availability of this additional resolution, and are asked to confirm the default distribution of the new disaggregated inputs, or to provide another distribution, thus allowing e.g. the food and the fishing industry to remove the unwanted inputs and place them on the correct disaggregated activity that now has become available. Such consequent changes, resulting from the availability of new resolution in an input, pass through the "fast track" review procedure, see Chapter 12.3.

[**Changes relative to ecoinvent version 2:** The completeness of the database is a new feature to be implemented. Datasets for unspecified products must be added to the database. This will be done in cooperation with the editor and the remaining active authors that have supplied data for each activity class.]

14 Market models and computation of accumulated system datasets

The ecoinvent database is not just an LCI data library but an LCI data network. The datasets of ecoinvent unit processes are interlinked. All intermediate goods and service inputs to a unit process, be it the consumption of electricity, the demand for working materials, the use of the road infrastructure, are linked to other unit processes that supply these intermediate goods and services. This means, that any change in one unit process influences the accumulated LCI results for almost all other unit processes. Depending on the magnitude of the change, this influence may be negligible for the majority of the datasets but it may also be significant to many or a few datasets.

The ecoinvent database stores the unit process datasets as unlinked, multi-product datasets, i.e. with inputs specified solely in terms of product names, without requiring specification of the supplying activities, and typically with more than one product output. This is the way the datasets are obtained and entered by the data providers and this is how the unit processes are normally presented to the end user.

For the purpose of calculating the accumulated system datasets, the database creates linked, single-product datasets from the unlinked, multi-product datasets, with the help of database-wide modelling rules. An unlinked, multi-product dataset and its derived linked, single-product datasets have the same universally unique identifier (UUID) and name (with extensions for subdivided datasets), and are distinguished by the field "Market model" (and for subdivided datasets by the reference product).

Two classes of market models are distinguished: *attributional and consequential*. Attributional market models create linked, single-product datasets by linking to average suppliers and partitioning (allocation). Consequential market models create linked, single-product datasets through linking to unconstrained suppliers and substitution (system expansion).

14.1 Rules common to both attributional and consequential models

It is a prerequisite for linking of any dataset that a specific geography, time and macro-economic scenario is declared in the relevant fields. Linking only takes place within this specific context (linking to same or larger geography and time, and same macro-economic scenario).

Some linking rules are identical for both classes of market models:

1) By-products/wastes that are identified as materials for treatment (see Chapter 4.8) are always moved to be negative inputs of the same activities, in order to include the treatment activities for the materials into the product systems. Since a negative input is the same as a positive output, this operation does not affect the mass, energy and monetary balances of the activities.

2) An intermediate input to an activity, which does not already have an activityLinkId, is always linked directly to the local market activity dataset that supplies this input as its reference product. The database service layer identifies the local market activity dataset based on the geographical location of the activity, matching this location with the available market for this location. Since markets do not overlap, there will generally only be one such market activity for each intermediate input. If the activity is defined for a geography or time that spans over more than one market, each of the market activities contribute in proportion to their production volume, implying that the database service layer will duplicate the intermediate input to match the number of supplying markets and subdivide the amount of the intermediate input over these in proportion to the production volume of each market.

3) For situations of variable properties of the reference product, the reference product is subdivided by the procedure described in Chapter 5.8,

4) For situations of combined co-products, the dataset is subdivided into an equivalent number of datasets, by the procedure described in Chapter 5.3. This procedure applies both to the datasets of combined production and the datasets generated from the variable properties, as described in the previous point.

The modifications described by these four rules are performed by the database service layer in the described order, before any other modification of and calculation on attributional or consequential datasets.

[Note that rules 3 and 4 may not be implemented in the first beta releases of the database service layer, which implies that such situation may initially still have to be handled by manual disaggregation]

14.2 Average current suppliers in attributional models

In the attributional market models, the inputs to each market activity are modelled as coming from all those transforming activities within the geographical area of the market activity, which have the market reference product as an output, in proportion to their available production volume.

The ecoinvent database automatically:

- Identifies these transforming activities, based on geographical matching,
- Adds an input to the market activity from each of these transforming activities,
- Adds the corresponding unique IDs of the transforming activities to the ActivityLinkId (ecoSpold field 1520) of the market inputs, thereby directly linking the inputs to the transforming activities,
- Calculates the amount of input from each transforming activity in proportion to its production volume, as indicated in the ecoSpold field 1530 productionVolumeAmount of each transforming activity, subtracting any production volume that is required by transforming activities via direct links (ActivityLinkId; ecoSpold field 1520) and therefore not supplied via the market,
- Sums up the production volumes, and adds the sum as the production volume of the output of the market activity.
- Calculates the production-volume-weighted averages of any properties that are common to all the transforming activities and places these averages as properties of the output of the market activity.

In combination with the rule for linking transforming activities to their local markets (rule 2 in Chapter 14.1), the above rule for linking market activities results in a database that is fully linked upstream, i.e. all inputs to all datasets are directly linked to their specific supplying activities.

14.3 Unconstrained suppliers in consequential models

In the consequential market models, the inputs to each market activity are modelled much in the same way as in attributional models, with the exception that market constraints are taken into account, so that only unconstrained suppliers are included.

This implies that before any of the above described operations, the database service layer first identifies if the market itself is described as constrained, see Chapter 11.4, i.e. whether any conditional exchange exist that should first be taken into account. If so, the conditional exchange, with its direct link to the affected consumption activity, is moved from being a negative output to be a positive input, and the amount of the conditional exchange is subtracted from the market output before the remainder (if any) is distributed over the unconstrained suppliers to the market.

The consumption activity affected by a conditional exchange has the constrained product as an input. In order for this product to serve as an input to the constrained market, the consumption activity must have the product as its reference product. The database service layer achieves this by moving – for the particular consequential market model in question – the specific product input of the consumption activity to be its negative reference product, moving also the original reference product to be a by-product (when an alternative production route exists, for which this product is a reference output) or an elementary exchange, thus quantifying the resulting reduction in consumption. The market demand for the specific input from the consumption activity thus translates into a reduction in the negative reference product output of the consumption activity. Note that the reduction in a negative output is a positive output, namely the input required by the constrained market. The technology level of the consumption activity is at the same time changed to “current”, to reflect that the consumption activity is now constrained by its constrained input.

Next, the unconstrained suppliers to the market are identified. These are the transforming activities, within the geographical area of the market activity, for which the market reference product is a reference output (i.e. not a by-product, since the volume of a by-product is per definition constrained by the corresponding reference products), and which has a technology level (see Chapter 5.5) that corresponds to the specific rule for the particular consequential market model, see Chapter 14.5.

For each of the identified unconstrained suppliers, the ecoinvent database then:

- Adds an input to the market activity, with the corresponding unique IDs of the supplier as ActivityLinkId, thereby directly linking the input to the specific supplier,
- Calculates the amount of input to the market activity in proportion to the production volume of the supplier, subtracting any production volume that is required by transforming activities via direct links and therefore not supplied via the market,
- Calculates the production-volume-weighted averages of any properties that are common to all the suppliers and places these averages as properties of the output of the market activity.

Note that the production volume of the market activities does not have any meaning in a consequential market model, and is therefore not provided in the consequential datasets.

As for the attributional linking rules, the above rules – together with the rule for linking transforming activities to their local markets – results in a database which is fully linked upstream, i.e. all inputs to all datasets are directly linked to their specific supplying activities.

14.4 Modelling principles for joint production

The linked, multi-product datasets are converted to single-product datasets with the help of database-wide modelling rules. Attributional market models create single-product datasets by partitioning (allocation), while consequential market models create single-product datasets through substitution (system expansion).

14.4.1 Allocation in attributional models

For attributional market models, the ecoSpold format allows recommended allocation factors to be separately recorded as properties of the outputs of a multi-output activity. Each multi-output dataset may include information about the recommended allocation factors. This information can be recorded per individual input and output. Each pollutant, each intermediate or resource input may therefore have its individual recommended allocation factor, if necessary.

The ecoinvent software system tests whether 100% of all exchanges of the unallocated activity are attributed to its outputs. This guarantees that no elementary exchanges are lost or counted twice.

Different attributional models of the ecoinvent database can be supplied. These may use the same allocation property for all multi-output datasets (e.g. price), or may use a combination of allocation properties depending on the nature of the multi-output dataset. [specific examples to be added]

For each attributional model, as many single-product datasets are created from each multi-product dataset as the dataset have products with the specified allocation property. For each of the single-product datasets, the original inputs and elementary outputs without the allocation property are multiplied by the ratio of the specified allocation property for the product (when multiplied by the amount of the product) relative to the sum of this (multiplied) property for all outputs. This procedure is called co-product “allocation”.

While mass inputs and outputs are balanced for each multi-product activity, the derived single-product datasets are only balanced for the applied allocation property, and only if the allocation is applied to all outputs. In general, mass balances are therefore not relevant for attributional market models.

The choice of allocation property depends on the purpose of the analysis. Allocation by revenue (price * product volume) is often applied with the argument that the (expected) revenue is the reason for the activity to operate. This is the same argument that is used for consequential market models, and in fact an attributional model with economic allocation is very similar to a consequential model without constrained markets and technologies, and where by-products are allowed to influence the production volume of the co-producing activities.

On the other hand, since an economically allocated model does not provide a correct mass or elemental balance for a product, it can therefore not be used to say anything about how much mass of a specific material or from a specific activity is part of the studied product. For this purpose, a model allocated by the mass of all outputs is more relevant. However, a mass allocated market model will not include electricity and services, and will therefore have limited relevance for assessing the total environmental impacts of a product.

The inability of market models with economic allocation to correctly reflect the elemental balances has led to the suggestion to add allocation corrections for the most environmentally important elements. An allocation correction for e.g. carbon is an additional dataset with a carbon input or output that is added to one allocated dataset of an activity and subtracted from the other allocated dataset of the same activity to correct the mis-allocation made by the economic allocation. The two allocation correction datasets cancel each other out, and the result is a model that gives correct mass balances for carbon. This exercise can be repeated for any other element. If this was implemented for all elements, the result would be a completely mass allocated model with elemental specification, which would then no longer have any economic rationale.

For a particular application, it may therefore be a question of finding an appropriate balance between these two incompatible rationales of economic causality and balanced mass flows. The ecoinvent database provides one such “compromise” implementation, which uses true value (a modified form of revenue) as general allocation property, but includes corrections to reestablish the mass balance for carbon. The rationale for this is that for carbon, in contrast to most other elements, the same substance as both input (capture of carbon dioxide from air) and output (carbon dioxide to air) has the same significant environmental impact pathway (change in the atmospheric concentration). For most other elements, the lack of an exact mass balance is a less obvious flaw, since the most significant environmental impact pathways are usually different for the inputs of resources and the emissions to the environment.

Before allocation, activities with a negative reference product (treatment markets and treatment activities) are combined with the activity that supplies the material for treatment, creating an aggregated activity dataset “…, with treatment of wastes and by-products”. Thus, such “treatment activities” are not allocated separately, and consequently, allocation properties are not relevant for treatment activities.

This aggregation is required to ensure an allocation at the point of substitution, as illustrated in Figures 14.1 to 14.2.

The allocated implementations of the intermediate aggregated activity datasets “…, with treatment of wastes and by-products” can be viewed by the database user.

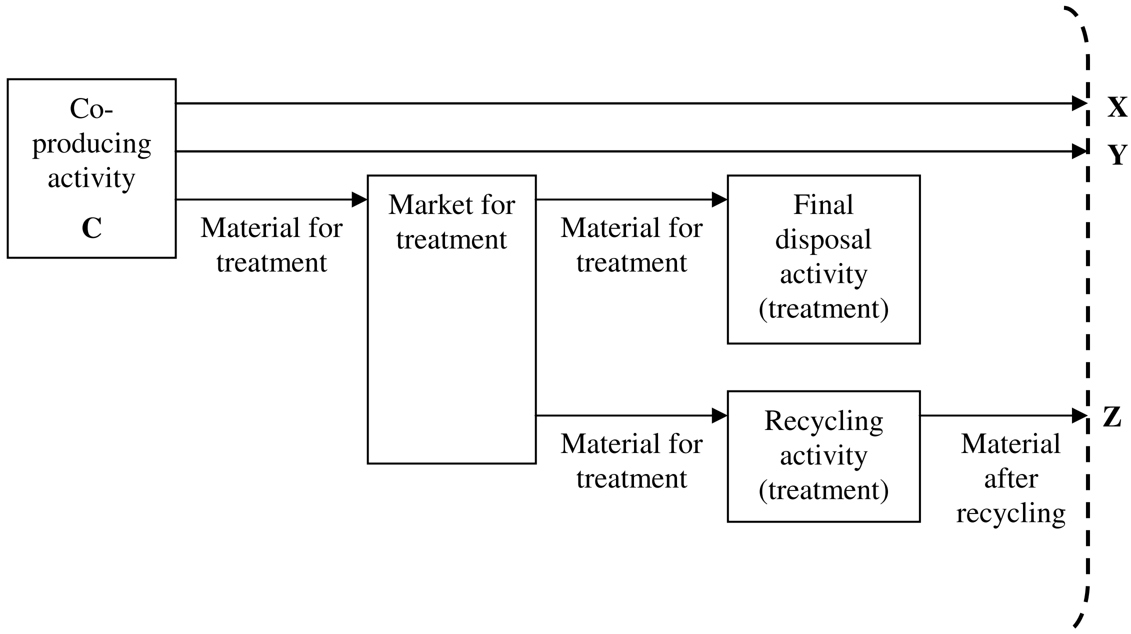

Figure 14.1. A co-producing activity (A) with outputs of two products (X and Y) and a material for treatment, with its treatment activities, of which one has a by-product Z. The dotted line indicates the system boundary at which allocation between X, Y and Z is performed. For the material for recycling, this is also the point of substitution, where the material can – without further treatment - substitute a reference product as an input to an activity.

By performing the allocation at the point of substitution, it is ensured that all treatment activities are attributed to the activities that produce the materials that need treatment, disregarding whether these are defined as wastes or by-products. The result of the allocation will be the same as if the treatment activities take place within the co-producing activity. Thereby it is ensured that the results of the allocation is unaffected by any choices of the degree of detail in modelling the activities, and that a result cannot be manipulated by moving a treatment activity inside or outside the co-producing activity.

Performing the allocation at the point of substitution furthermore ensures that the full value of the by-products is attributed to the product system that gives rise to these by-products, and that any value-correction therefore becomes unnecessary. Furthermore, the price of the by-product is always available at the point of substitution, since this is the point at which the product is exchanged and substituted with other products, while the price of a waste or by-product before or during treatment often can only be estimated, because it is not available as a market price, and if available may often be influenced by irrelevant properties of other wastes or by regulatory conditions.

Database representation after moving materials for treatment cf. Chapter 14.1:

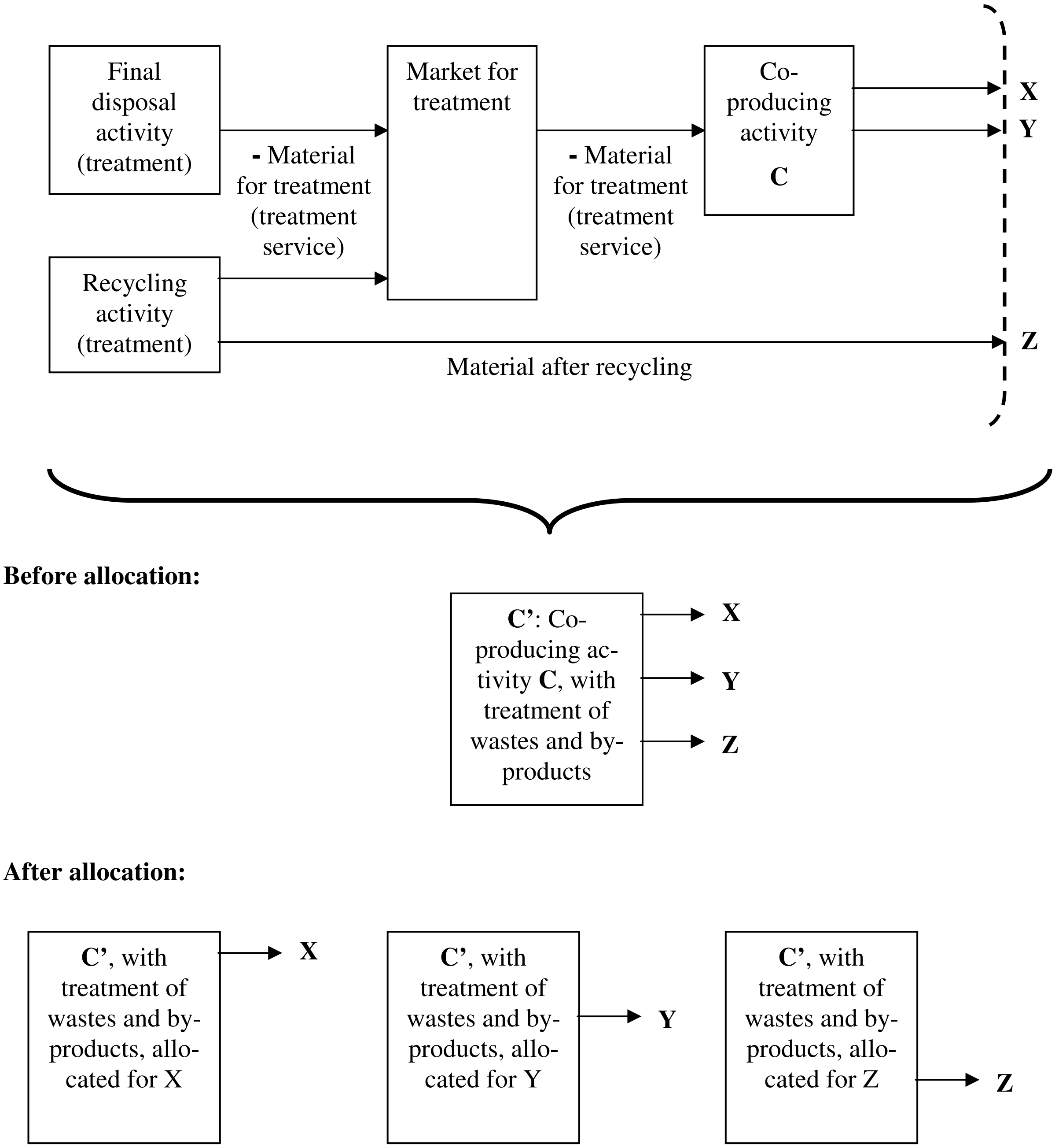

Figure 14.2. Top: The database representation of the system of activities in Figure 14.1 after the moving of materials for treatment to be negative inputs as described in Chapter 14.1. Middle: The same activities, now aggregated into one activity dataset. Bottom: The three resulting single-product datasets in which all other inputs and environmental outputs without allocation property are multiplied by the ratio of the specified amount * allocation property for the product X, Y or Z, respectively, relative to the sum of this weighted property for all outputs.

14.4.2 Substitution in consequential models

In the ecoinvent database, the substitution (system expansion) is implemented by moving the output of the non-reference co-products (also known as dependent co-products or by-products) from being outputs of the multi-product activity to be negative inputs of this activity, see Figure 14.3. This procedure for dealing with multi-product activities was originally presented by Stone (1984) for use in input-output analysis, where it has become known as the *by-product technology model*. For practical purposes the results of the by-product technology model is strictly identical to the more well-known, more widely used, but less transparent *commodity technology model* (Suh et al. 2010).

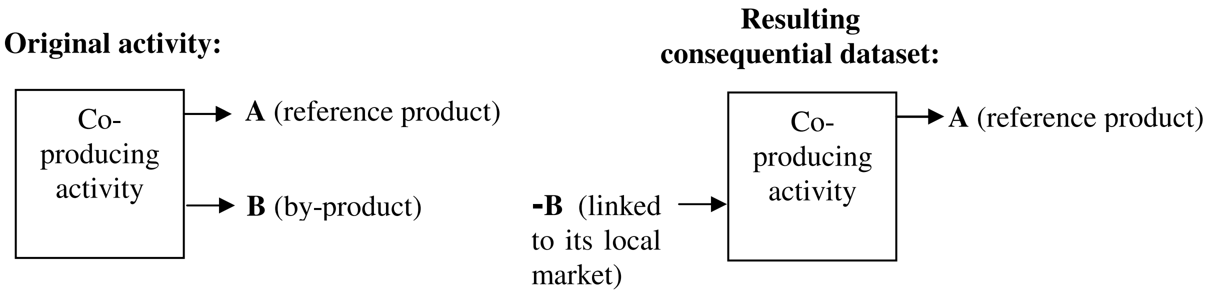

Figure 14.3. Original multi-product activity and the resulting database-generated consequential dataset.

This operation is performed automatically by the ecoinvent database service layer. Links to the by-product from other activities via activityLinkId will be ignored, which effectively means that the supply is shifted to the market for the by-product (B in Figure 14.3). Note that by-products and wastes for which substitutes are *not* available have already been placed as materials for treatment by the procedure in Chapter 14.1. This implies that for the remaining by-products there will always be an activity that supplies the by-product as its reference product, and which will therefore be displaced when an additional amount of the by-product from the co-producing activity is supplied to the market. The database service layer links the negative input to its local market, in the same way as described for all other intermediate inputs in Chapter 14.1.

When there is more than one reference product for an activity, which happens when there is more than one product output without an alternative production route, the multi-product dataset is duplicated into the same number of activities as there are reference products, since the described procedures are performed for each of the reference products separately, reflecting the consequences of an increased demand for each product separately. The following additional operations are performed to deal with this situation:

First, each of the new datasets are multiplied by the ratio of the revenue of its reference product relative to the revenue from all products of the multi-product activity. This is equivalent to the result of a revenue partitioning (allocation) of the multi-product activity, and is justified by the necessity for the prices of the joint products (that do not have any relevant alternative production routes) to adjust so that the market is cleared, i.e. so that all the products produced will also be sold. In this situation, a change in demand for one of the joint products will influence the production volume of the joint production in proportion to its share in the revenue of the joint production.

Since the change in the multi-product activity only partly satisfies the demand that gave rise to the change in its output, the missing supply to the market activity must be obtained by a reduction in use of the product in its marginal application (the application that has the least alternative costs from not using the product in question, and is therefore the most sensitive to changes in price). Such reductions in marginal use are therefore added as inputs to the market activities supplied by the multi-product activity to compensate for the missing supply from the multi-product activity.

Since the multi-product activity is not partitioned, but only scaled to the change in demand, it is still a multi-product activity, and the output of the other joint products thus increases proportionally to the induced change in the multi-product activity, and must therefore be dealt with as for the simple situation above. However, since the other reference products have no alternative production route, the additional output of cannot displace any other production, and therefore specifically influences their marginal consumption activities and further downstream lifecycles, and thus require the inclusion of these specific activities. This is achieved by linking the negative input of the other reference products directly (with the activityLinkId specified in the original multi-product activity) to the marginal consumption activities.

An example is provided in Figure 14.4 where the multi-product activity has two outputs with the revenue 75 for product A and 25 for product B. For ease of explanation we can assume that the output in mass units follows the revenue. The modelling now distinguishes between the two separate situations of an increase in demand for 100 units of A and an increase in demand for 100 units of B. The following text focuses on the situation of an increase in demand for 100 units of A. The modelling for an increase in demand for 100 units of B follows in complete parallel.

The increase in demand for A of 100 units leads to an increase in supply from the multi-product activity of 75 units of A and 25 units of B (the 75 being the ratio of the revenue of A relative to the revenue from A+B). Thus, we miss 25 units of A and have 25 units of B too much, compared to the initial demand. The missing 25 units of A are supplied from reduced consumption in its marginal application, while the surplus 25 units of B are additionally consumed in its marginal application. The two consumption adjustments are added to the constrained market for A and to the co-producing activity, respectively.

The database service layer automatically performs all the described linking; only the direct activityLinkIds for the reference products and conditional exchanges must be supplied in the original data. This is also the case for conditional reference products, see Chapter 11.4. The datasets for the co-producing activity, each with only one reference product, all have the same activityID as the original co-producing dataset, which implies that the name of the reference product is required to distinguish the datasets from each other.

[a real life example from the current database should be added]

Any implementation of the above described substitution (system expansion, by-product technology model) can be validated numerically by checking any of the mass, material and/or economic balances, since all of these balances shall be preserved during the transformations. As a positive output equals a negative input, the simple moving of the dependent co-products from positive outputs to negative inputs obviously preserves the balances. Since all the originally balanced unit processes are maintained intact (no partitioning), and simply scaled to accommodate the required change in product output, there is no way these unit processes can become unbalanced, except by error. Since the product system is a simple aggregate of these balanced unit processes, the same applies for the resulting product system. In this context it is important to note that treatment services for wastes, while possibly having a positive economic product flow, the mass of this flow must negative (the mass of the treated waste) to maintain mass balances correct. The same is true for the inputs to the multi-product activities representing changes in downstream activities caused by the other co-products. In general, any corrections made are always balanced by similar counter-corrections, to maintain balances intact.

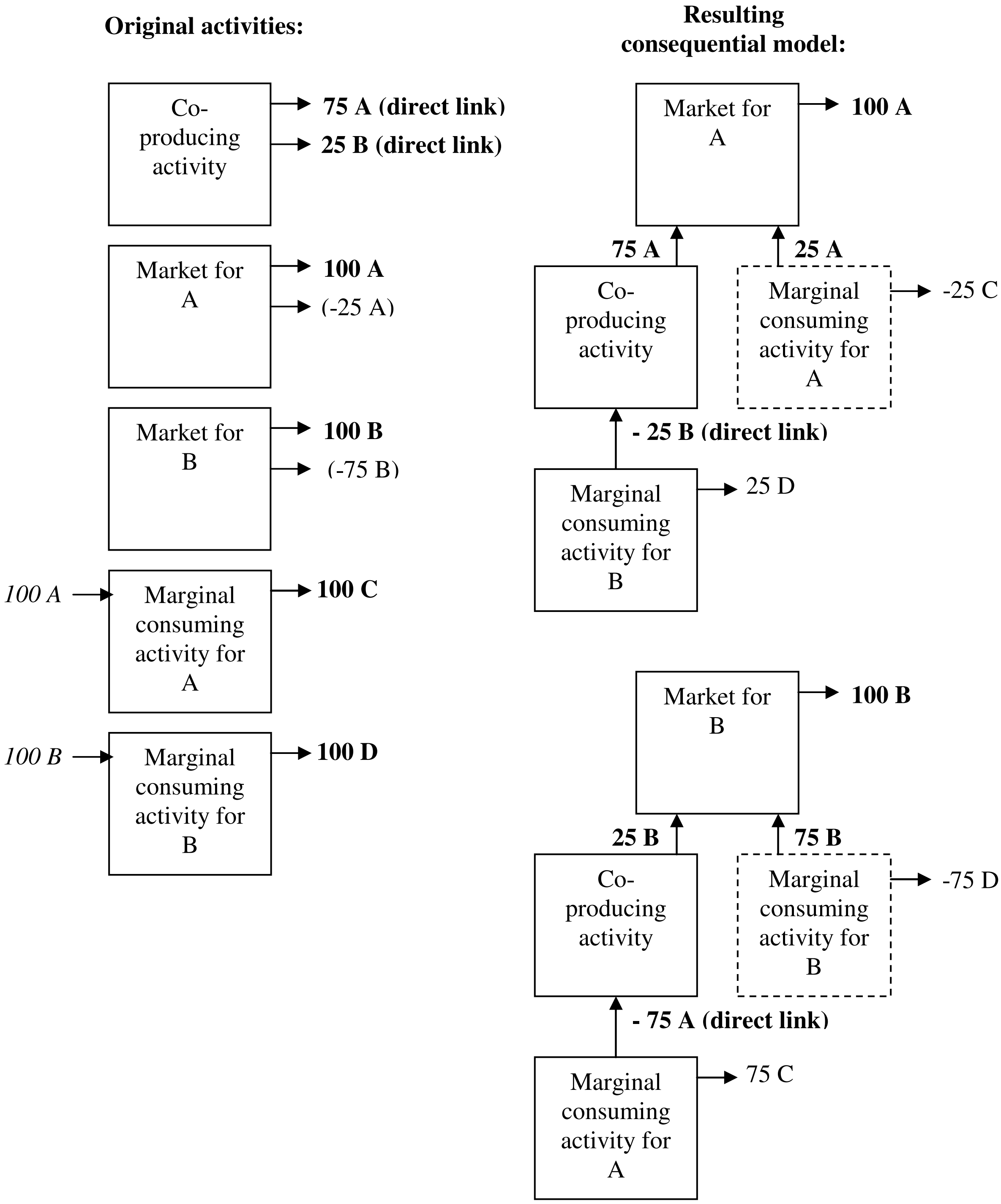

Figure 14.4. A co-producing activity with two reference products (A and B), and the resulting consequential model of an additional demand of 100 units of product A and B, respectively. Exchanges in bold are reference products. Exchanges in brackets are conditional market constraints that are not actually part of the original data but are auto-generated by the database. Activities with dotted lines represent activities that are reduced in volume.

14.5 Consequential and attributional datasets

The differences between the original, stand-alone datasets and the database-generated, linked, consequential and attributional datasets are illustrated in Figure 14.5 and 14.6. Note that Figure 4.5 takes as a starting point the situation where *inputs* of materials for treatment (identified by the database service layer as by-products/wastes that are not positive reference products of any activity in the same geographical area; see Chapter 4.8) to a treatment activity or to a speciality production (see Chapter 4.8) have already been moved to be negative outputs of these activities, so outputs A or C in Figure 14.5 and 14.6 may in this situation already have a negative amount.

The initial operations common to the generation of both consequential and attributional datasets are illustrated in this way:

- By-products/wastes that are identified as outputs of materials for treatment (outputs C, D and E in Figure 14.5) are moved to be negative inputs of the same activity, in order to include the treatment activities for the material into the product system. Since a negative input is the same as a positive output, this operation does not affect the mass, energy and monetary balances of the activity. For the attributional implementations, these treatment activities are combined with the co-producing activity, creating an aggregated activity dataset "…, with treatment of wastes and by-products", before this aggregated activity is allocated. This is required to ensure an allocation at the point of substitution, as explained in Chapter 14.4.1 and illustrated in Figures 14.1 to 14.2.
- Intermediate inputs to an activity, which do not already have activityLinkIds (inputs G and J in Figure 14.5), are always linked directly to the local markets that supply the inputs as reference products. The database service layer identifies the local market based on the geographical location of the activity, matching this with the available market for this location. This linking algorithm was described in detail in Chapter 14.1.

In consequential market models, by-products that can immediately – without further treatment – substitute a reference product as an input to an activity (output B in Figure 14.5; identified by the database service layer as a non-reference output which is the reference product of another activity in the same geographical area) are moved to be negative inputs of the same activity and linked to the local markets in the same way as described in the preceding paragraph for any other intermediate input. A negative input implies a reduction in output from the market and therefore a reduction in (displacement of) the other activities that supply the by-product to the market.

In attributional market models, a new allocated dataset is generated for each such by-product B. The allocation procedure is described in Chapter 14.4.1. The cumulative LCI results (see Chapter 4.15) of the multi-product activity (before allocation) are not available as ecoinvent LCI results. The allocated datasets have the same activityID as the original dataset, which implies that the product name is required to distinguish the allocated datasets from each other.

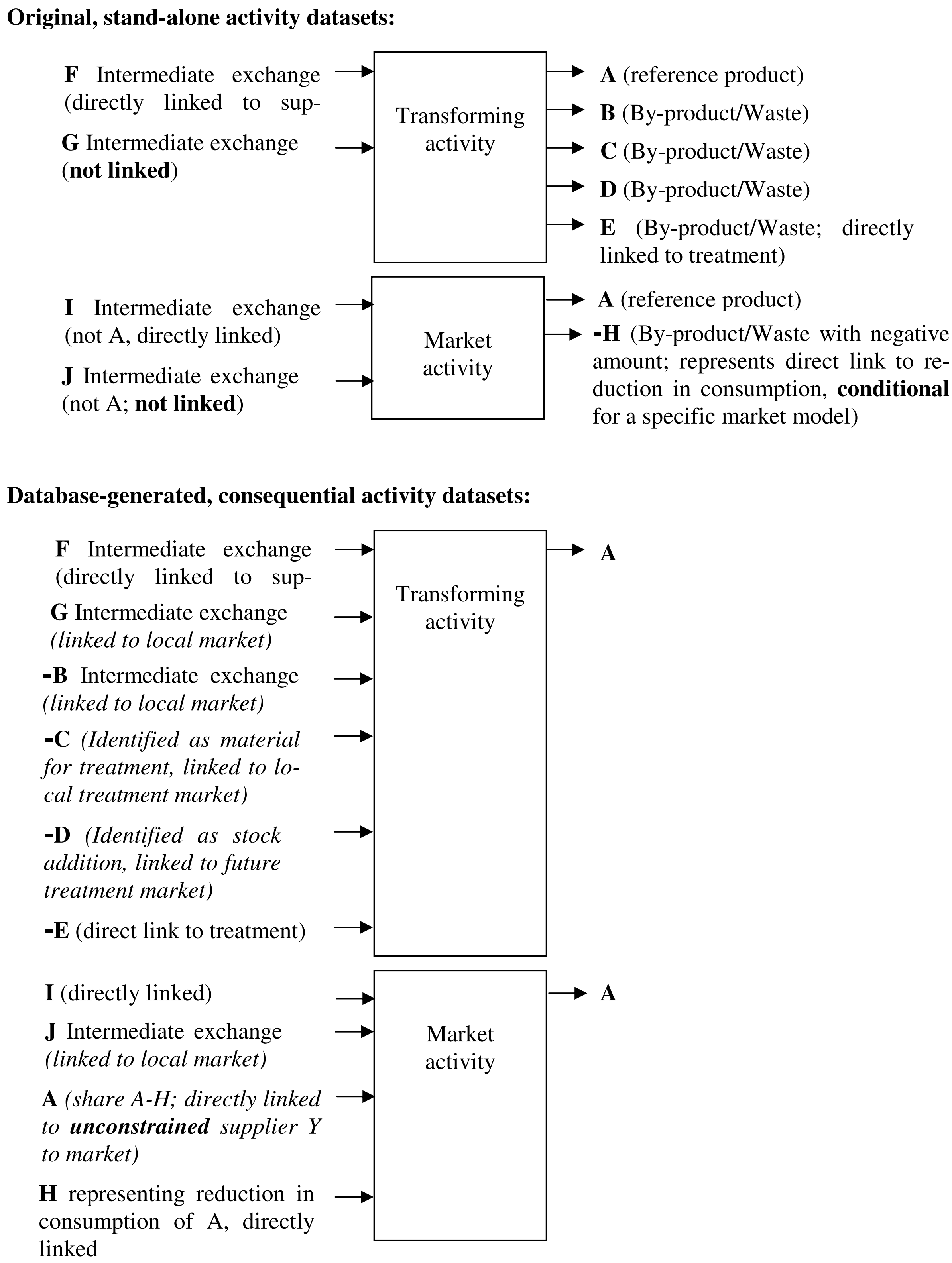

Figure 14.5. The intermediate exchanges in the original, stand-alone transforming and market activity datasets and the database-generated, linked, consequential implementations of the same datasets. To avoid unnecessary detail, two specific situations are not included: The situation of loss of product from market activities (Chapter 4.3) and the situation with more than one reference product in consequential models (Chapter 14.4.1, Figure 14.4). Text in *italics* represents database-generated changes, in addition to the moving of some outputs to be inputs with a sign reversal.

Database-generated, attributional activity datasets:

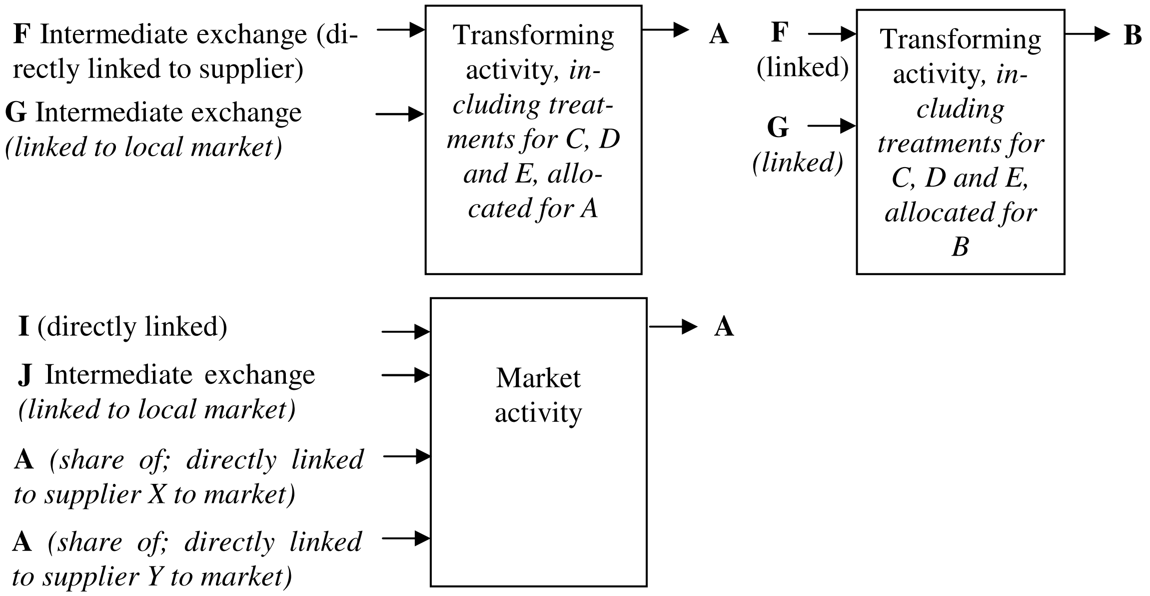

Figure 14.6. The database-generated, linked, attributional implementations of the original, stand-alone transforming and market activity datasets shown in Figure 14.5. To avoid unnecessary detail, the situation of loss of product from market activities (Chapter 4.3) is not included. Text in *italics* represents database-generated changes, in addition to the moving of some outputs to be inputs with a sign reversal.

In the original market activities the inputs of the reference product (product A in figure 14.5) are not specified. These inputs are added by the database service layer: Based on the geographical area specified for each market activity, the database service layer first identifies the transforming activities that are located within this geographical area. For the attributional market models, an input to the market is then added for each transforming activity (links to suppliers X and Y in Figure 14.6). For consequential market models, an input is added only for those transforming activities that are unconstrained (supplier Y in Figure 14.5), which are those for which the product is a reference output (i.e. not a by-product, since the amount of a by-product is per definition constrained by the corresponding reference products), and which has a technology level (see Chapter 5.5) corresponding to the specific rule for the particular consequential market model, see Chapter 14.5. For both attributional and consequential models, the amounts of inputs are added in proportion to the available production volumes of the transforming activities.

In consequential market models, any conditional exchanges (negative output -H in Figure 14.5), representing reductions in consumption of the specific market output (see Chapter 11.4), are moved to be positive inputs to the market activity, and are subtracted from the amount of the reference product A before the remaining amount of market output is distributed over the unconstrained suppliers, as described in the preceding paragraph.

[**Changes relative to ecoinvent version 2:** In version 2, all links between activity datasets were hard links, added by the data providers. The new feature of database-generated links allows a more flexible updating of the database, since all links can be automatically updated after the addition of new datasets, and the data provider does not need to consider linking datasets specifically. The modelling of materials for treatment is now more consistent. The option to produce consequential models of the database is new.]

14.6 Consequential models in the ecoinvent database

14.6.1 The "small-scale, long-term decisions" model

The name of the consequential model includes the two key characteristics *scale* and *time horizon* of the decisions that can be supported by this model. The scale and the time horizon are relevant because they delimit what suppliers, markets, products and technologies can be affected by the decision.

A *small-scale* decision is defined as a decision that does not affect the determining parameters of the overall market situation, i.e., the direction of the trend in market volume and the constraints on and production costs of the involved products and technologies. The consequences of the decision can thus be assumed linearly related to the size of the change and both an increase and a decrease in production volume will affect the same processes. As shown by Mattsson et al. (2001), even a change in the annual electricity demand by 1 TWh can still be regarded as small (marginal), since it affects the same technologies as a change of 1 kWh, which means that the effects are linearly related to the size of the change. The typical decisions studied by LCA can therefore be said to be small-scale.

The time horizon of a decision is defined as *long-term* if it affects capital investment (installation of new machinery or phasing out of old machinery) as opposed to short-term decisions that affect only capacity utilisation, but not capacity itself. However, even the effect of small, short-term decision can seldom be isolated to the short-term perspective, since each individual short-term purchase decision will contribute to the accumulated trend in the market volume, which is the basis for decisions on capital investment (long term changes). This is obvious in free market situations (where market signals play a major role when planning capacity adjustments) with a short capital cycle (fast turnover of capital equipment, as for example, in the electronics and polymer industries), but it is also true for markets with a long capital cycle (as for example, in the building and paper industries).

If a long-term investment is planned and announced well in advance of its implementation (as for example, the installation of a new pipeline), it may involve only long-term effects, namely the effects from installation and production on newly installed capacity. But such planned decisions are the exception. Most decisions will also lead to some immediate short-term effects, affecting the existing capacity, while at the same time affecting investments decisions and in the long run affecting the production from this newly installed technology. Since the technology affected in the short term will often be old technology (the least competitive technology which typically has a low capacity utilisation compared to newly installed technology) while the technology affected in the long term will often be modern technology, long-term product substitutions may thus often be seen to affect a mix of technologies (Mattsson et al. 2001). However, the short-term effect will typically be negligible compared to the long-term effect, simply because the long-term effect is typically more permanent, while the short-term effect only lasts until the next capacity change.

Consider a factory in which several production lines exist, some using an older technology, which is more polluting and more expensive to run, and some with a new technology (less polluting, less costly to run). Small, short-term fluctuations in demand will affect the capacity utilisation of the production line with the older technology (since this is the most costly to run), while the line with the new technology will be utilised as much as possible, and will therefore not be affected. If the demand increases beyond what can be covered by the current capacity, new machinery will be installed, and here the factory may choose to install the newest technology even though it is more costly to acquire, or it may decide to buy a cheaper, but more polluting technology. Whatever the choice, this can be said to be the long-term result of the change in demand and the additional environmental exchanges from the factory are now those coming from the newly installed machinery. It is therefore reasonable to ascribe these exchanges to the change in demand. Once the new machinery has been installed, further changes in short-term demand will still affect the older technology (since this is still the most costly to run). It is important to understand that even though the short-term fluctuation constantly will affect the older technology in the short-term, it is the accumulated changes in the short-term demands that make up the long-term changes, which eventually lead to the installation of the new machinery. The long-term effect of the demand is therefore the additional exchanges from the newly installed technology, and the short-term effects can be seen as a mere background variation for this long-term effect. Thus, the long-term effect should also be guiding for decisions that at first sight appear short-term, such as individual purchase decisions, and the product declarations that support such decisions.

The 'consequential, small-scale, long-term decisions' model generally assumes full elasticity of supply, just like the attributional models. This means that if the demand increases with one unit, the producers will react by increasing their supply with one unit, and conversely when the demand decreases. This makes it straightforward to trace the changes in the product system upstream, simply by following the increases in outputs of the upstream activities required to satisfy the increases in demand of the downstream activities.

The assumption of full elasticity of supply is in accordance with the theoretically expected long-term result of a change in demand on a unconstrained, competitive market, where there are no market imperfections and no absolute shortages or obligations with respect to supply of production factors, so that production factors are fully elastic in the long term, and individual suppliers are price-takers (which means that they cannot influence the market price), so that the long-term market prices are determined by the long-term marginal production costs (implying that long-term market prices, as opposed to short-term prices, are *not* affected by demand).

When suppliers are constrained or markets are imperfect (so that producers can influence the market prices), the assumption of full elasticity of supply should be modified.

Because the 'small-scale, long-term decisions' implementation considers long-term changes, the rule for the technology level of unconstrained suppliers depends on the market trend. If the market is generally increasing, stable, or slowly decreasing (at a rate *less* than the average replacement rate for the capital equipment), new capacity must be installed, typically involving a modern, competitive technology, and any change will affect the decision on this capacity adjustment. In a market that decreases rapidly (at a higher pace than what can be covered by the decrease from regular, planned phasing out of capital equipment) the affected suppliers will typically be the least competitive (often using an older technology).

The replacement rate for production equipment is determined as the inverse of the estimated lifetime of the equipment. For the 'consequential, small-scale, long-term decisions' implementation of the ecoinvent database, a general lifetime of 30 years and a consequent rate of replacement of 3.33% annually is applied. The market trend is automatically identified by the ecoinvent database service layer by comparing the production volume of the corresponding attributional market dataset for the current year with the same dataset covering a period 3 years later. If a dataset covering the period 3 years later does not exist, the following datasets are used for the comparison, in order of priority: 3 years into the past, 4 years into the past, most recent past year, assume stable market without comparing to any other year.

Thus, when the production volume of the reference product is decreasing more than 3.33% annually, the activity is identified as unconstrained if its technology level is “Old”, and when the production volume of the reference product is decreasing less than 3.33% annually, increasing, or stable, the activity is identified as unconstrained if its technology level is “Modern”. If there are no supplying activities with the required technology setting, the requirement for “Modern” is replaced by ”New”, and “Old” is replaced by “Outdated”, and if these do not exist, by the option “Current”.

In the ecoinvent database, market constraints are modelled by the use of conditional exchanges, see Chapter 11.4, i.e. exchanges that are only activated for a specified market model, and which represents the share of the demand that is not met by increased supply, but which instead is coming from a reduction in specified consumption activities. In general, the “small-scale, long-term” model implementation does not apply empirical elasticities, but only considers absolute constraints, as described in Chapter 11.4.

In the “small-scale, long-term” model implementation, a co-producing activity can only have *one reference product*, except if there are more co-products from the activity that have no alternative production routes. This follows from the assumption that suppliers are price-takers (which means that they cannot influence the market price), so that the long-term marginal production costs of the alternative production routes for the respective co-products provides a constraint on the long-term market prices of the co-products, and thus on their contribution to the overall revenue of the co-producing activity. Thus, a change in demand for a specific co-product with an alternative production route will not lead to a change in its (long-term) price and the change in demand will therefore not affect the overall (long-term) revenue of the co-producing activity.

The products that are defined as reference products in the ecoinvent database *before* any market modelling (market model *undefined*) are also the reference products of the “consequential, small-scale, long-term” model implementation. Only for other consequential market models (not currently implemented, see Chapter 14.6.2) it may be relevant to define additional *conditional* reference products.

The market model “Consequential, small-scale, long-term decisions” is the one recommended by the ecoinvent Centre for consequential LCA modelling.

14.6.2 Outlook: Other consequential models

The ecoinvent database does not currently provide other consequential models than the above described. However, the flexibility of the database structure allows the creation of other consequential models if desired. Some reflections on other possible models are provided here.

Large-scale decisions affect the overall market situation, and therefore may bring into play new suppliers, new markets, or even new products and technologies. Different large-scale decisions may affect different markets, and it is therefore impossible to provide a generally applicable background database for large-scale decisions. However, the datasets in the ecoinvent database may be modified by the users to model specific large-scale changes, involving changes in market trends etc.

A market model for pure short-term effects of small, short-term changes could be constructed. As the short term per definition does not involve capacity changes, many more production factors would be constrained in such as market model. Only effects within the existing production capacity, including reduction in current capacity would be included, and “old” technology would be the rule for the technology level of unconstrained suppliers, without any relation to the market trend. However, the results of such a model would only be of interest in markets where no capital investment is planned (for example, industries in decline), or where the market situation has little influence on capacity adjustments (monopolised or highly regulated markets, which may also be characterised by surplus capacity). An example of a substitution with a short-term effect only would be an isolated decision to remove heavy metals from the components of a product, which – all other things equal – would not involve capital investment in the metal industry, since heavy metals are already being phased out.

It would also be possible to construct a market model that introduced additional market elasticities via the conditional exchanges, see Chapter 11.4. Thus, the inclusion of more elements from equilibrium modelling would be possible. Research is ongoing at the ecoinvent Centre to investigate these options. Both for such market models and for the modelling of large-scale changes the option to add more conditional reference products is of interest.

14.7 Attributional models in the ecoinvent database

14.7.1 Revenue allocation

In the revenue allocated market model, the property “price” is used as allocation property. When multiplied by the amount of the outputs, the resulting values represent the revenues to the activity from each output. When expressed relative to the total revenue, these values are the allocation factors, representing the share of the other exchanges of the activity to be allocated to each output. Figure 14.7

provides an example of an allocation by revenue, with the allocation factors 9 and 1, based on the amounts 1 kg and 0.5 unit, and the prices 9 EUR/kg and 2 EUR/unit, respectively.

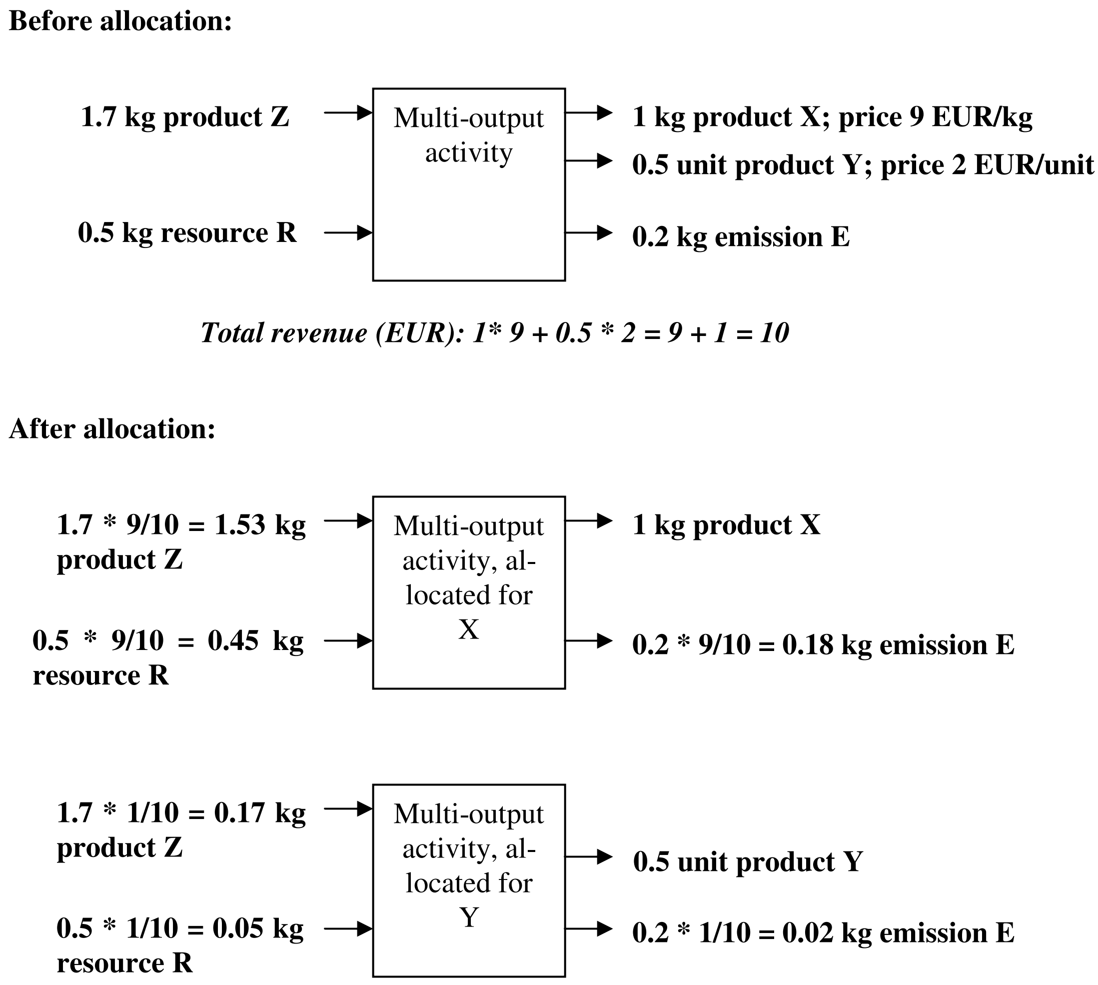

Figure 14.7. Numerical example of an allocation by revenue.

14.7.2 Dry mass allocation (for mass flow analysis; not for LCA)

In the dry mass allocated market model, the property “dry mass” (DM) is used as allocation property. When multiplied by the amount of the outputs, the resulting values represent the dry mass of each output. When expressed relative to the total dry mass balance of the activity, these values are the allocation factors, representing the share of the other exchanges of the activity to be allocated to each output.

Note that this allocation is performed to all outputs with mass, including exchanges to the environment, in order to achieve a complete allocation that can be applied for mass flow analysis. It is *not* a mass allocation to the co-products alone, as described in older LCA literature. The model is relevant for investigating the origin of the mass included in a specific product. It is not appropriate for investigating the total mass required to produce a specific product. For such an investigation, we recommend the consequential model (Chapter 14.6.1) or the true value allocated model (14.7.4).

Figure 14.8 provides an example of the dry mass allocation, using the same example as for revenue allocation.

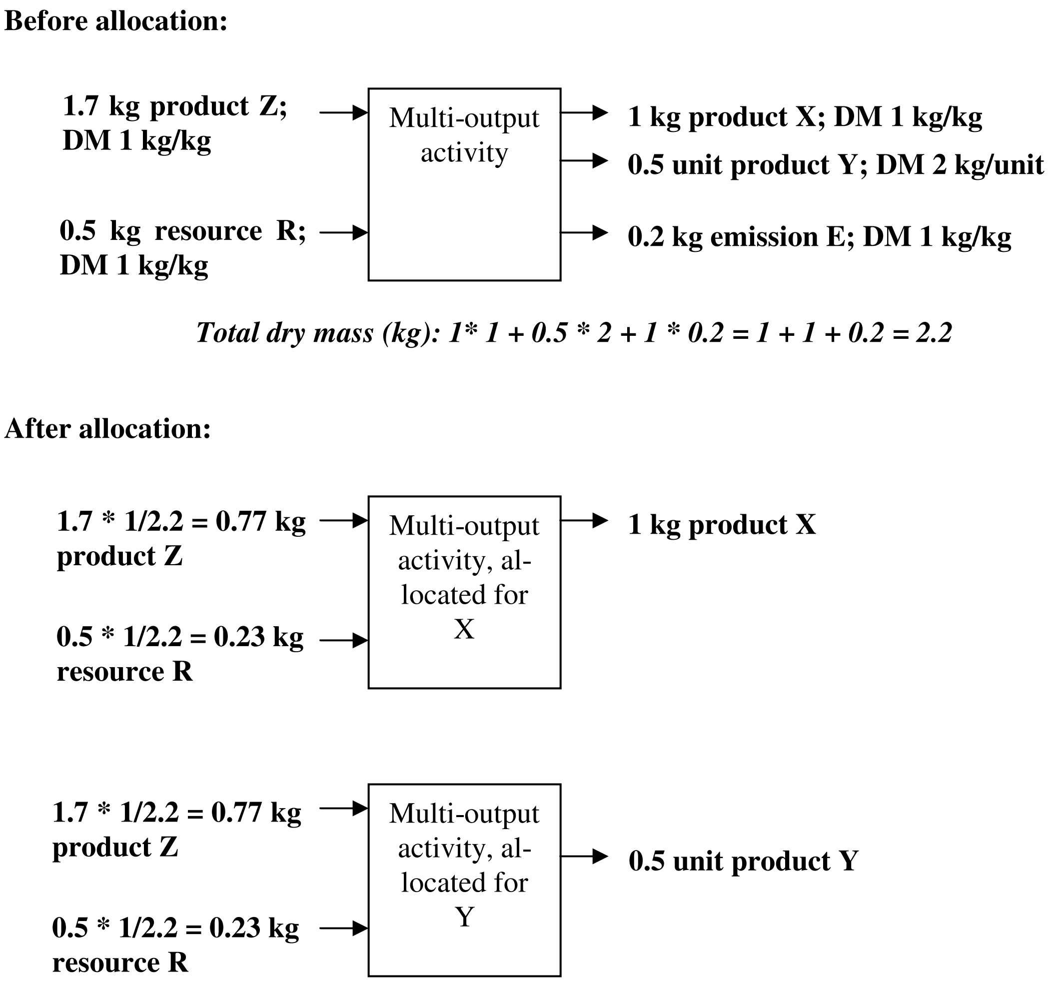

Figure 14.8. Numerical example of an allocation by dry mass. Note that in order to achieve a complete allocation that can be applied for mass flow analysis, allocation is made to all outputs with dry mass. The mass balance is maintained for each activity, also after allocation. Allocation to emission E is not shown in the Figure. This is *not* a mass allocation to be applied for LCA.

It should be noted that in a mass allocated system, no exchanges will be allocated to products without mass, such as electricity and services. In the ecoinvent database, this also affects infrastructure products, since these are modelled as services providing production capacity.

14.7.3 Carbon allocation (not for LCA)

In the carbon allocated market model, the property “carbon allocation” (C_allocation) is used as allocation property. This property is derived by multiplying the property “dry mass” by the property “carbon content” (C_content), which is carbon per dry mass (itself the sum of the properties “carbon content, biogene” and “carbon content, fossil”). When the property “carbon allocation” is multiplied by the amount of the outputs, the resulting values represent the carbon in each output. When expressed relative to the total carbon balance of the activity, these values are the allocation factors representing the share of the other exchanges of the activity to be allocated to each output.

Note that in order to achieve a complete allocation that can be applied for carbon flow analysis, this allocation is performed to all outputs with carbon content, including exchanges to the environment. It is *not* an allocation to be applied for LCA. The model is relevant for investigating the origin of the carbon included in a specific product. It is not appropriate for investigating the total carbon required to produce a specific product. For such an investigation, we recommend the consequential model (Chapter 14.6.1) or the true value allocated model (14.7.4).

Figure 14.9 provides an example of this allocation, using the same example as for revenue and dry mass allocation.

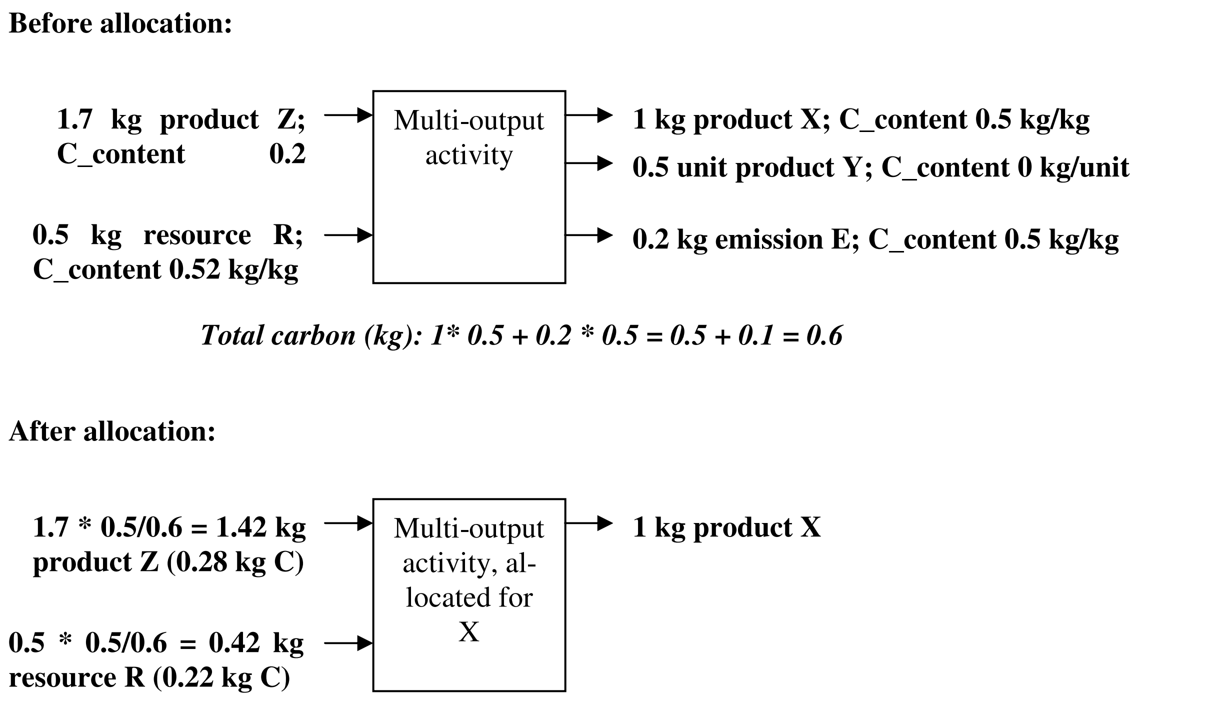

Figure 14.9. Numerical example of an allocation by carbon. Note that in order to achieve a complete allocation that can be applied for carbon flow analysis, allocation is made to all outputs with carbon content, including the emissions. Since only one co-product had carbon content, there is only one allocated product. The carbon balance is maintained for each activity, also after allocation. Allocation to emission E is not shown in the Figure. This is *not* an allocation to be applied for LCA.

No exchanges will be allocated to products without carbon content, such as electricity and services, including infrastructure products, see also under mass allocation. Special care must be taken when using these results.

14.7.4 "True value" allocation

The "true value" allocated market model is a variant of the revenue allocated market model, introduced to correct for some problems identified in the latter approach.

One problem in revenue allocation is that prices may be influenced by market imperfections or perverse regulation, resulting in relative prices that have very little to do with the true, functional value of the co-products. An example of this is the price of heat as a co-product from electricity production. Here, it is possible to argue that exergy, i.e. the ability of the products to perform work, is a shared property of the two products that reflects the true, functional value of the co-products, and that in a perfect market, this would be reflected in the price of the products.

Another problem in revenue allocation is that applying average prices for one single year may result in a very high annual variation in the allocation factors for some multi-product datasets. To correct for this, the true value allocated market model instead applies three-year, historical average prices in such situations.

In the "true value" allocated market model, the property "true value" (true_value) is used as allocation property. This property is identical to the price, unless otherwise specifically provided in the original dataset (the dataset with market model *undefined*). See Chapter 5.6.6 for examples of situations where the true value has been applied. One important example is the use of exergy to allocate between electricity and useful heat. When the property "true value" is multiplied by the amount of the outputs, the resulting values represent the true value of each output. When expressed relative to the total true value of the activity, these values are the allocation factors, representing the share of the other exchanges of the activity to be allocated to each output.

The total true value of the activity (i.e. true value * amount, summed over all co-products) is always identical to its total revenue (price * amount, summed over all co-products). Thus, the true value allocation only re-distributes the overall revenue, but does not change it.

The market model "Attributional, average current suppliers, true value allocation, with corrections for carbon" (for these corrections, see next sub-Chapter) is the market model recommended by the ecoinvent Centre for attributional LCA modelling. It is a consistent implementation of the approach used for ecoinvent versions 1 and 2.

14.7.5 Allocation corrections

An allocation correction is two datasets that counterbalances each other, re-allocating one or more environmental exchanges, so that the resulting allocated product systems have correct mass balances for the re-allocated exchanges.

In the current versions of the ecoinvent database, allocation corrections are applied only to the "true value" allocated implementation, and corrections are made for one exchange only, namely "carbon dioxide, from air". The rationale for applying the corrections to carbon only is that for carbon, in contrast to most other elements, the same substance as both input (capture of carbon dioxide from air) and output (carbon dioxide to air) has the same significant environmental impact pathway (change in the atmospheric concentration). Figure 14.10 illustrates how the allocation correction for carbon works on the example from Figure 14.7 and 14.9.

All allocation corrections are added automatically by the database service layer.

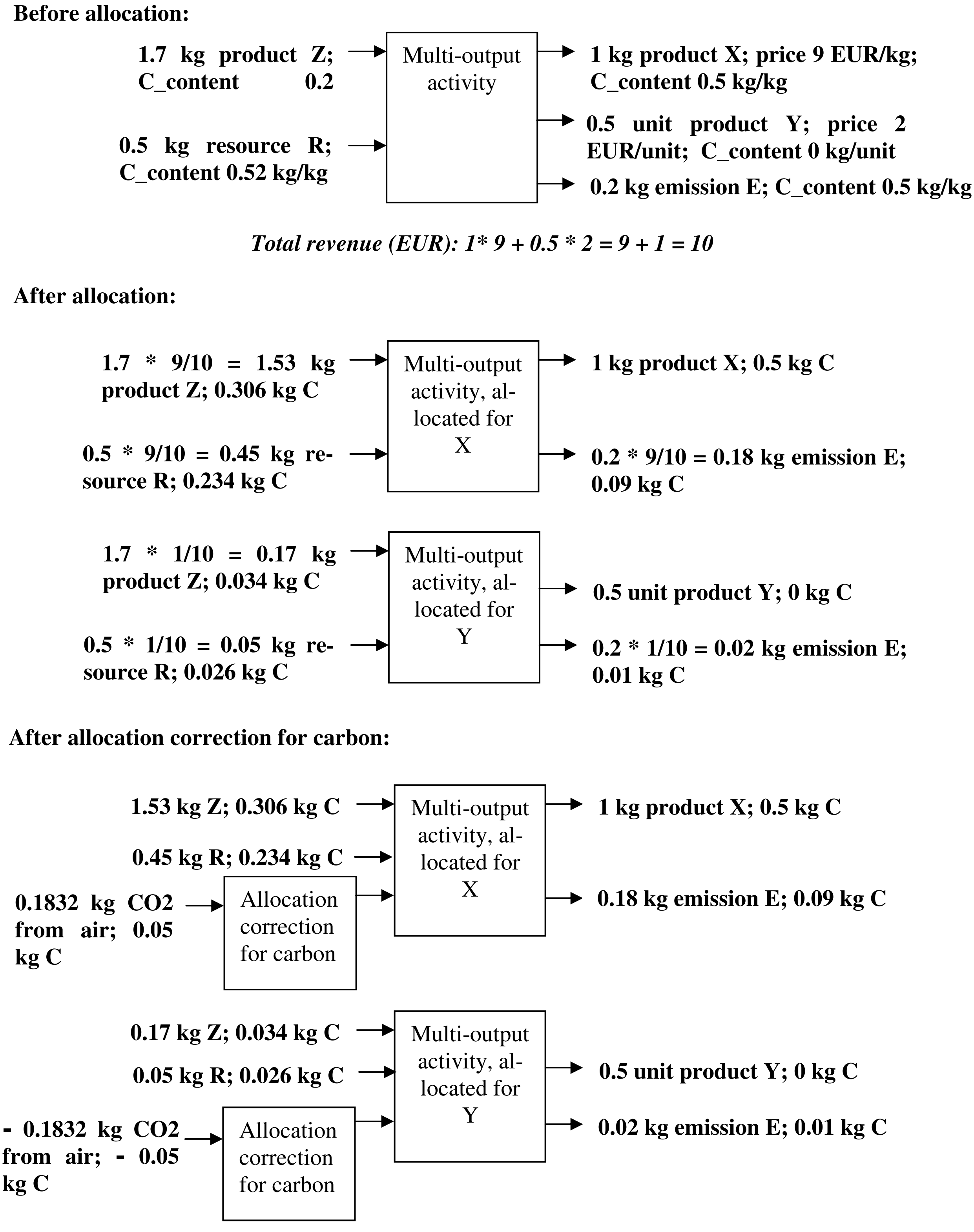

Figure 14.10. The numerical example of an allocation by revenue from Figure 14.7, with the carbon contents from Figure 14.9. After allocation, the activity allocated for X misses an input of 0.05 kg of C, while the activity allocated for Y has a surplus input of 0.05 kg of C. The allocation correction datasets remove the surplus input from the activity allocated for Y and add it to the activity allocated for X, so that both allocated activities balance for both revenue and carbon.

14.7.6 Outlook: Other attributional models

The ecoinvent database currently only provides attributional models with "average current suppliers". It is possible to generate attributional models with e.g. "average modern suppliers" or using similar rules for excluding constrained suppliers as used in consequential modelling, while still maintaining allocation as the procedure for dealing with joint production.

Since allocation is by definition a normative exercise, the number of thinkable allocation properties and allocation corrections is unlimited. The ecoinvent Centre can provide specific attributional implementations on demand.

14.8 Computing of LCI results

[The content of this sub-chapter and the routines described have not been changed from ecoinvent version 2. Nevertheless, the text is in need of updating to ensure that the nomenclature used is consistent with that used in the rest of this document.]

The ecoinvent database system uses matrix inversion to calculate accumulated system datasets (LCI results), separately for each combination of time period, macro-economic scenario and market model for which datasets are present in the database. Calculations are not made for time periods prior to the reference year and only for full calendar years or a number of calendar years. Calculations are made for the reference year and any full calendar year thereafter for which both start date (01-01) and end date (12-31) are present in any dataset. Beyond the years for which individual calculations are made, calculations are also made for longer time periods of calendar years for which the start date (01-01) and end date (12-31) are present in a dataset.

The calculation of the cumulative LCI results uses only the linked, single-product datasets derived from the unlinked, multi-product datasets, as described above.

The exchanges of each linked, single-product activity dataset can be described by a column vector that is divided into an intermediate exchanges part **a** and an environmental exchanges part **b**, respectively. The vector includes *m* intermediate exchanges a_i and *n* environmental exchanges b_j. Intermediate inputs are entered with a negative value, while the product outputs are entered with positive values.

$$\begin{pmatrix} \mathbf{a} \\ \mathbf{b} \end{pmatrix} = \begin{pmatrix} a_1 \\ \dots \\ a_i \\ \dots \\ a_m \\ b_1 \\ \dots \\ b_j \\ \dots \\ b_n \end{pmatrix}$$

All activity column vectors together form a matrix with an intermediate transaction part A and an environmental part B.

$$\mathbf{P} = \begin{pmatrix} \mathbf{A} \\ \mathbf{B} \end{pmatrix} = \begin{pmatrix} a_{11} & ... & a_{1l} & ... \\ ... & ... & ... & ... \\ a_{i1} & ... & a_{il} & ... \\ ... & ... & ... & ... \\ a_{m1} & ... & a_{ml} & ... \\ b_{11} & ... & b_{1l} & ... \\ ... & ... & ... & ... \\ b_{j1} & ... & b_{jl} & ... \\ ... & ... & ... & ... \\ b_{n1} & ... & b_{nl} & ... \end{pmatrix}$$

Since all the datasets are directly linked, and all datasets have only one product output, the intermediate transaction part A of the matrix P is square and non-singular. The inverse of the matrix can therefore be calculated, by which operation we obtain the cumulative demand of intermediate product required to produce each product.

In our model the vectors of the unit processes contain the relation of a unit process with itself (i.e., the activity 1 kg of steel from blast furnace, for instance, produces 1 kg of steel from blast furnace). Matrix A can be rewritten as

$$A = I - Z$$

where $Z \in R^{mxm}$ and their diagonal is composed of zero values. The inverse can be written as

$$C = A^{-1} = (I - Z)^{-1} = \sum_{k=0}^{\infty} Z^k$$

and the cumulative resource extraction and emission matrix D is computed as follows

$$D = BC = B(I - Z)^{-1}$$

The inventory matrix **P***, composed of *C* and *D*,

$$\mathbf{P}^* = \begin{pmatrix} \mathbf{C} \\ \mathbf{D} \end{pmatrix}$$

contains information about the total (cumulative) requirements of economic entities (intermediate goods and services) and about the total (cumulative) exchanges of ecological entities (elementary exchanges, i.e. resource extractions and emissions) of all unit processes the matrix is composed of.

The cumulative amounts of environmental exchanges (matrix **D**) are calculated by multiplying the ecological part **B** of matrix **P** with the computed cumulative transaction matrix **C**.

For the numerical implementation of the matrix inversion direct methods are usually applied that make use of publicly available source code libraries. These methods base on the Gauss-elimination and use the LU factorisation creating a lower left triangular matrix L and an upper right triangular matrix U.

The factorisation is done with a partial pivot strategy in order to guarantee the numerical stability. Because the size of the real figures in the matrix P varies between 10^{-6} to 10^{6} (and even more), the scaling of rows and columns should be done in a way that all new figures are about in the same order of magnitude.

For fully occupied matrices the calculation requirements are proportional to the third power of the size (m) of the matrix. For sparse matrices as the ecoinvent matrix, the use of renumeration and elimination strategies helps to dramatically reduce the calculation effort. The use of partial pivoting and an eventual rescaling of the matrix guarantee the numerical stability.

Nevertheless, computational capacity may make it necessary to place certain restrictions on the number of datasets included in the matrix calculations. If such restrictions on the matrix size become necessary, the limitations will be applied to the geographical detail. First, transforming activities that supply to the same market will be pre-aggregated before matrix calculation, and secondly markets may be pre-aggregated, starting with products that have many small geographical markets.

15 User advice on the results

15.1 LCI, LCIA and LCA results

The ecoinvent database does not aim at providing full LCA information (i.e., including a complete goal and scope, and interpretation phase) of all investigated products. In general the discussion of results is kept quite short or even missing.

The ecoinvent database also contains life cycle impact assessment (LCIA) results to facilitate the interpretation of LCI results. Assumptions and interpretations were necessary to match current LCIA methods with the ecoinvent inventory results. They are described in Frischknecht *et al.* (2007a). It is strongly advised to read the respective chapters of the implementation report and the original reports describing the LCIA methods before applying LCIA results. Impact assessment results are reported on the basis of a final indicator (eco-indicator 99, hierarchist/average, total) as well as on the basis of safeguard subjects (e.g., human health) and environmental topics (e.g., ionising radiation).

The data collected and compiled in the ecoinvent database are not primarily suited for direct comparisons. Waste management datasets for instance shall not directly be used for waste management policy assessments (landfilling versus incineration), transport service datasets shall not directly be used for transport systems comparison and farming systems (integrated, extensive or organic production) shall not directly and solely be compared based on ecoinvent data. In all cases the systems for comparison have to be thoroughly defined beforehand. Then it has to be checked which adaptation to the average data investigated would be necessary to appropriately describe these systems according to the goals of the study.

15.2 Legal disclaimer

The ecoinvent Centre shall not be liable for any material defects/damages, including consequential damages, loss of income, business or profit, special, indirect or incidental damages due to the use of ecoinvent database or any ecoinvent dataset. The ecoinvent Centre disclaims all warranties, expressed or implied, including, but without limitation, the warranties of merchantability and of fitness for any purpose of ecoinvent Database or any ecoinvent Dataset. The database user must assume the entire risk of using the ecoinvent database or any ecoinvent dataset.

15.3 Choice of market model

The ecoinvent data are available in different implementations representing different market models. The original stand-alone activity datasets, each representing a specific human activity as it can be observed "in real life", the market model (ecoSpold field 3005 marketModelName) is:

- *Undefined*

These activity datasets are useful for investigating the environmental impacts of a specific activity (gate-to-gate), without regard to its upstream or downstream impacts.

When the activity datasets are linked into product systems, a choice of a market model has to be made, providing the rules for linking the activity datasets into contiguous product systems, each one isolated from the datasets of all other product systems.

Two classes of market models can be distinguished: attributional and consequential. Within each of these two classes, several instances can be defined. The ecoinvent database supports currently only one consequential market model:

- *Consequential, small-scale, long-term decisions*

This is the database implementation recommended by the ecoinvent Centre for use in consequential LCA studies that investigates the long-term consequences (i.e. the consequences including changes in production capacity) of small-scale decisions (i.e. decisions that do not change the overall market conditions).

Consequential market modelling can be defined as a linking of activities in a product system so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the product. Most LCA studies are aimed at decision support involving a choice or substitution between two product systems. Even studies of a single product are typically later used in a comparative context. For example, in LCA studies for hot-spot-identification and product declarations, what appears to be stand-alone assessments of single products have the ultimate goal to improve the studied systems, thus supporting decisions that involve comparisons:

If a hot-spot-identification of a current product identifies a number of improvement options, it is still necessary to assess the environmental impact of implementing the improvements, namely the difference in impact between the improved and the current product, obtained as a result of adding the improved product and removing the current product.

Product declarations are used by the customer to make a choice between several products, and the (intended) effect of this choice is that more of the chosen product will be produced at the expense of the competing products. Thus, the impact of the choice is obtained as a result of adding one unit of the chosen product and removing the corresponding amount of the current average product.

However, there are application areas where consequential modelling is less relevant, and an attributional model may be more appropriate. For these applications, the ecoinvent Centre recommends the market model:

Attributional, average current suppliers, true value allocation, with corrections for carbon

True value allocation is a variant of allocation according to economic revenue, but where some market imperfections and fluctuations are corrected for. Mass balances for carbon are maintained through corrections, while other mass and monetary balances are not corrected for.

Examples of application areas are:

Studies at a societal level, where the entire environmental impact of all human activities is studied, with the aim of identifying areas for improvement, disregarding whether such improvements shall be sought through product-oriented policies or through direct regulation of the individual activities. In such a situation, it would not be reasonable to limit the study to those activities that can be affected by changes in demands, but to include all activities, also those that are not linked to any consequential product system, and for which a policy-driven improvement can only be achieved through direct regulation. One can argue that since the objective of such a study is not product-oriented, LCA is simply not the (only) relevant assessment technique. An attributional model, where all activities in society are included in proportion to a specific attributional rule, such as true value, would better reflect the objective of such a study. Once improvement options are identified by such a model, those improvement options that have upstream or downstream consequences can then afterwards be studied with a consequential model. The IMPRO study on meat and dairy products (Weidema et al. 2008) is an example of such an attributional study at the level of EU-27, where the identified improvement options were analysed with a consequential model.

Studies on environmental taxation, where the focus is less on the consequences of the tax, but rather on who is to carry the burden. Often, studies on taxes or quota systems are performed for a specific administrative area, and any consequences outside this administrative area are discounted. Although the consequences of a tax on a product or an activity can be studied by a consequential model, this model cannot say anything about the attribution of the tax and its fairness. An attributional model, where all activities in society are included in proportion to their perceived contribution to the taxed activity variable, whether or not this changes as a consequence of the tax, would better reflect the objective of such a study.

Studies that seek to avoid blame or to praise or reward for past good behaviour, for example avoiding blame that a specific deplorable activity, such as slavery, occurs in the product system, or rewarding producers that have invested in a praiseworthy technology such as solar power. While a consequential model can answer the question whether the deplorable or praiseworthy activity changes as a consequence of buying the product, it cannot tell how much of the deplorable or praiseworthy activity *exist* in the product system. An attributional model, where activities are included in proportion to a specific attributional rule, for example true value, would better reflect the objectives of such studies.

In addition to the above database implementations recommended respectively for consequential and attributional LCA studies, the ecoinvent database is also available in separate implementations for very specific application areas:

Attributional, average current suppliers, revenue allocation

This implementation uses the annual prices as basis for allocation, and the allocations may therefore fluctuate more than in the true value allocated implementation. However, this implementation is using the same modelling principle as applied in many input-output analyses, and is therefore the most appropriate implementation to compare with national direct requirement tables (“input-output” tables) using the industry-technology model, and for creation of corresponding hybrid models.

Attributional, average current suppliers, dry mass allocation

This implementation is applicable for mass flow analysis, since the dry mass balances are preserved, including the mass leaving the product systems as emissions. It is *not* a mass allocation to the co-products alone, as described in older LCA literature. This model can therefore be used to investigate exactly how much of a specific elementary input is contained in any product.

Attributional, average current suppliers, carbon allocation

This implementation is applicable for carbon flow analysis, since the carbon balances are preserved, including the carbon leaving the product systems as emissions. It is *not* an allocation to be applied for LCA. This model can be used to investigate exactly how much of a specific carbon input is contained in any product.

15.4 Uncertainty information

The ecoinvent inventory result files contain quantitative and qualitative information about the uncertainty of each individual elementary exchange. In many cases a simplified pedigree approach has been used.

Uncertainty information is valuable to judge the overall variability of LCI results. Care must be taken when using the uncertainty values in comparative assertions on the basis of LCI results because most underlying uncertainty values are estimated.

The uncertainty values presented in the cumulative LCI results should not be used directly for LCA case studies, since the uncertainty values of the individual exchanges and datasets are not independent. For a correct uncertainty assessment for the modelled LCA case study, the uncertainty information on a unit process level is required. A simulation (e.g. Monte Carlo) based on the case study’s LCI raw data is required to correctly assess the uncertainty in the LCI results. Some of the commercially available LCA software are able to perform such project-specific simulations.

The minimum and maximum values of elementary exchanges reported in the LCI results of the ecoinvent database shall not be added to total emissions into a compartment because the sum of all minimum and maximum values, respectively, does not correspond to the minimum and maximum values determined with a Monte Carlo simulation.

15.5 How to reproduce and quote ecoinvent data in case studies

The ecoinvent terms of use state that:

"Licensee is not entitled to use the ecoinvent Database or the ecoinvent Dataset by preparing extracts, or for any further commercial purposes.

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It means that ecoinvent LCI raw data and results and LCIA results (either directly downloaded from the ecoinvent database or calculated with ecoinvent LCI results and the factors downloaded from the ecoinvent database) shall not be reproduced in other LCA case studies. Contribution analyses may include graphical representation of the share of ecoinvent activities on the total LCA results (e.g., the contribution of energy supply to the total burdens of manufacturing a mobile phone). Hereby the possibilities to recalculate the exact LCI and LCIA results of an ecoinvent dataset shall be prevented as much as possible.

The ecoinvent data shall generally be quoted by including the exact version number and market model of the database applied. Additional reference may be made to the respective location of the datasets if specific datasets have been used. If the ecoinvent database and its contents are cited as a whole the following format is recommended:

ecoinvent Centre 2011	ecoinvent Centre (2011) ecoinvent data v3.0. Swiss Centre for Life Cycle Inventories, St. Gallen, retrieved from: www.ecoinvent.org.

16 Contributing to the ecoinvent database

16.1 Individual data providers

Anyone can contribute to the ecoinvent database. To supply new data or to make larger changes to existing datasets, prospective data providers should download (from www.ecoinvent.org) the ecoEditor 2 software that supports the editing process.

The dataset(s) that you wish to edit can be downloaded to your harddisk from the working version of the ecoinvent database. From the web-site it can be seen if the dataset has an active author assigned. If you intend to edit an existing dataset with an active author, it may be a good idea to inform the active author of your intentions/suggestions, e.g. by using the dataset talk page, see Chapter 16.4.

Once you have finished editing your dataset(s), you can upload it/them for pre-validation and/or for review directly from the ecoEditor 2, when on-line. If you have restrictions on allowing the ecoEditor on-line access (e.g. a firewall), you may submit your dataset(s) via the ecoinvent web-site, using your web-browser. When submitting a dataset, the data provider confirms ownership to the data, and transfers the right to use to the ecoinvent Centre.

We particularly encourage LCA practitioners to share their data though the ecoinvent database. The new data collected for a specific LCA could very well be useful for others. An added benefit is that both you and others will be able to reuse the supplied data in other contexts, fully embedded in the richness of the ecoinvent database.

We also encourage industry associations, individual enterprises and public and private organisations to provide data for their own activities. For larger data collection projects, the ecoinvent Centre offers support for planning and fundraising.

16.2 National data collection initiatives

The ecoinvent Centre cooperates with national data collection initiatives (NDIs) to provide national versions of the ecoinvent database, fully integrated with the rest of the World.

The ecoinvent Centre provides free of charge the necessary infrastructure for validation and publishing of the national data as part of the ecoinvent database. The ecoinvent Centre provides an in-kind payment of free ecoinvent licenses to all active in the NDIs, and supports the NDIs with annual financial contributions.

The NDI proposes one or more editors to be responsible for reviewing datasets for geographical consistency before uploading to the ecoinvent database, irrespective of whether the datasets result from the national data collection programme or is provided by a third party. The ecoinvent Centre has the final responsibility for appointing and supervising editors. Editors are paid directly by the ecoinvent Centre in accordance with the ecoinvent procedures for such payments.

The NDI retains copyright and the right to license the collected data to third parties, while providing the collected data for publication in the ecoinvent database. Data provided to the ecoinvent Centre are provided with the permission to the ecoinvent Centre to publish these data.

16.3 Active and passive authorship

The ecoinvent Centre regards data providers as authors of the supplied datasets. Thus, editors cannot make corrections to the datasets, but only comment back to the data provider, asking the data provider to make corrections. This is also the case after publication of the dataset, if the editor or a third party discovers an error in a dataset, or suggests improvements.

When submitting a dataset, the data provider (author) chooses to be either an *active author,* i.e. responsible for future modifications of the dataset, or a *passive author*, i.e. recognised as author of the submitted version, but not involved in any further maintenance or modifications of the dataset.

If a dataset has an active author, prospective data providers are recommend to submit comments to the active author via the talk pages before submitting changes as full datasets.

Active authors are automatically informed when there are news on the talk page related to the dataset and if another data provider submits a modified version of the dataset. In the latter situation, the active author is given 14 days to comment on the suggested modifications, and to indicate whether she/he wishes to maintain authorship of the dataset, before the dataset is passed on to the activity editor. Failure to react is interpreted as acceptance that authorship and responsibility for the modified dataset is transferred to the modifying data provider. The original author is informed of this, and has the option to resume responsibility as long as the modified dataset is not yet published. This does of course not affect the authorship of the original, unmodified dataset which remains accessible in the older versions of the database.

An author can always decide to withdraw from this active role, in which case the responsibility for responding to questions and suggestions for modifications of the dataset lies exclusively with the editor. If modifications are to be made in a dataset where the author has withdrawn from active participation, the person who modifies the dataset becomes the author of the new modified dataset. Appropriate credits to the previous author(s) are included in the new dataset.

An author of a dataset cannot at any time be editor for the same dataset. Instead, a co-editor will be the editor for this dataset. This applies to the situation where an editor contributes datasets within his own editorial area, and also when an editor is forced to make corrections to a dataset for which the active author has withdrawn. In the latter situation, the editor may ask another author to make the required changes and remain as editor, or – when this is not possible or appropriate – perform the changes and thus resign as editor for this particular dataset.

In the situation that an active author refuses to make changes that are seen by the editor as essential for the scientific validity of a dataset, the editor may allow a new version of the dataset with another author. As always, the old dataset remains in the old version of the database. Such cases, where an editor suggests dismissing an active author, will automatically be reported to the ecoinvent database management, which will express its view on the matter. Both the editor and the author will also have the possibility to consult the ecoinvent database management before the decision is made to transfer the responsibility to a new author.

16.4 Reporting errors / suggesting improvements

If you discover an error in an ecoinvent dataset, or wish to suggest an improvement, but are not interested in supplying the corrected or improved dataset yourself, you may submit your observations via the ecoinvent talk pages for the dataset in question at www.ecoinvent.org. The ecoinvent talk pages are also open for placing questions, which may be answered by the authors, the editors or any other interested party.

Active authors and the editor of an ecoinvent talk page are responsible for ensuring a response to reported errors, suggestions and questions within a reasonable time (typically 14 days).

Discovered errors will be corrected in a next intermediate version of the database. Until then, known errors are reported on the ecoinvent web-site, both on the relevant talk page and in the aggregated “Known errors” page.

17 History of the ecoinvent database

17.1 The origin

Up to the late nineties, several public Life Cycle Assessment (LCA) databases existed in Switzerland, partly covering the same economic sectors (Frischknecht et al. 1994, 1996; Gaillard et al. 1997; Habersatter et al. 1996, 1998; Künniger & Richter 1995). These databases were developed by different institutes and organisations. Life cycle inventory data for a particular material or activity available from these databases often did not coincide and therefore the outcome of an LCA were (also) dependent on the institute working on it. Furthermore, the efforts required to maintain and update comprehensive and high quality LCA-databases are beyond the capacity of any individual institute.

At the same time, LCA received more and more attention by industry and authorities as one important tool for e.g., Integrated Product Policy, Technology Assessmen, or Design for the Environment. In parallel with this increasing trend in LCA applications, the demand for high quality, reliable, transparent, independent and consistent LCA data increased as well.

17.2 ecoinvent data v1.01 to v1.3

The first steps for the ecoinvent project were taken during the late 1990ties. The individual projects for data harmonisation and compilation have been funded by the Swiss Federal Roads Authority (ASTRA), the Swiss Federal Office for Construction and Logistics (BBL), the Swiss Federal Office for Energy (BFE), the Swiss Federal Office for Agriculture (BLW), and the Swiss Agency for the Environment, Forests and Landscape (BUWAL). The database software development was funded by the Swiss Centre for Life Cycle Inventories and the salary for the project management by Empa and the Swiss Centre for Life Cycle Inventories.

After the successful launch of ecoinvent data v1.01 in 2003, the work concentrated on an extension and revision of the contents resulting in the release of version 2.0 in 2007.

17.3 ecoinvent data v2.0

The LCA-institutes in the ETH domain (Swiss Federal Institutes of Technology (ETH) Zürich and Lausanne, Paul Scherrer Institute (PSI) Villigen, and Swiss Federal Laboratories for Materials Testing and Research (Empa) in St. Gallen and Dübendorf) as well as the LCA-group of the Agroscope Reckenholz-Tänikon Research Station (ART) in Zürich continued their co-operation in the Swiss Centre for Life Cycle Inventories, the ecoinvent Centre.

Besides the institutions mentioned above the following consultants contributed with LCI data compilation: Basler & Hofmann, Zürich, Bau- und Umweltchemie, Zürich, Carbotech AG, Basel, Chudacoff Oekoscience, Zürich, Doka Life Cycle Assessments, Zürich, Dr. Werner Environment & Development, Zürich, Ecointesys - Life Cycle Systems Sarl., Lausanne, ENERS Energy Concept, Lausanne, ESU-services Ltd., Uster, Infras AG, Bern and Umwelt- und Kompostberatung, Grenchen. Rolf Frischknecht lead the ecoinvent management, Annette Köhler was in charge with Marketing and sales and ifu Hamburg GmbH with software development and support.

By 2007, the ecoinvent database had become the most widespread and acknowledged life cycle inventory database worldwide. This success was only possible because of the on-going support by Swiss Federal Offices and European Organisations. In particular we wish to express our thanks to the Swiss Federal Office for the Environment (FOEN - BAFU), the Swiss Federal Office for Energy (BFE) and the Swiss Federal Office for Agriculture (BLW). We received further support from several associations, namely Alcosuisse, Biogas Forum Schweiz, Entsorgung und Recycling Zürich, Amt für Hochbauten Stadt Zürich, Erdöl-Vereinigung, the European Photovoltaics Industry Association (EPIA) and others. We wish to express our thanks for their valuable support.

17.4 ecoinvent data v3.0

[to be written]

Annex A. The boundary to the environment

To distinguish human activities from their environment, two principles are followed in combination:

1) “The natural background”, i.e. to include everything that would not have occurred without the activity, and to exclude anything that would have occurred even without the activity. The exclusion of the natural background may be done implicitly, by simply ignoring it, but for transparency it may be preferable to include the natural background phenomena in the activity description (or in a separate description) and *explicitly* subtract them. [examples from database to be added]. This principle delimits the subject of LCA from the study of natural phenomena, but does not in itself provide a delimitation between life cycle inventory (LCI) and life cycle impact assessment (LCIA). Examples of application of this principle are:

- Forest residues, such as branches and stubs left after harvesting, are excluded, because they would anyway have decomposed, *in situ*, on the forest floor (although possibly at a different time). This implies that only the wood actually harvested (and the management activities required to achieve this) is seen as included in the forest activity and in the mass and carbon balance for this activity.
- If the forest activity has an effect after the harvest, e.g. CO_2 emissions from the soil after a clear-cut, additional to those that would have occurred without the clear-cut, these are to be included in the LCA.
- The heavy metals and nutrients brought into an agricultural system by the management are to be included, while the deposition from precipitation (whether from natural or human sources) are excluded. Likewise, the natural background leaching that would have occurred from the area, had it been under natural climax vegetation, is excluded.
- Indoor emissions from an activity are to be included, since they would not have occurred without the activity.
- Deposition of waste in a landfill, as well as littering, is included as an activity, since it would not have occurred without human presence.

2) “Human management”, i.e. to include everything that takes place under human management and exclude anything that takes place after human management has terminated. This principle is mainly aimed at delimiting LCI (the human activity) from LCIA (the fate and exposure modelling and assessment of e.g. the emissions from the activity). While this principle may at first appear simple, it does not in practice provide a clear and practicable boundary between LCI and LCIA:

- The CO_2 emissions from the soil after a forest clear-cut do not take place under human management. The human management leaves a disturbed soil (this could be seen as the “exchange to the environment”) which then has these emissions. Nevertheless, it appears more practical to include the CO_2 emissions as emissions from the forestry activity (or a separate after-forestry activity), rather than to introduce disturbed soil as an environmental exchange.
- Many fate models for pesticides take their starting point in the amount of pesticide applied to the agricultural soil, although this clearly is within the sphere of human management and only the amount of pesticide that reaches the surrounding environment (and possibly the soil after human management terminates) are included in the final impact assessment (i.e. excluding the effect on the flora and fauna of the agricultural soil while under human management).
- Landfill emissions are included as elemental emissions also after the human management of the landfill has terminated. If the principle of management was followed strictly, the landfill content at the time of termination of human management should be reported as an exchange to the environment, and the rest treated as part of the LCIA fate modelling. Since the fate models used would not be different from those applied during human management, this would be a very unpractical division.

- Following the principle of management, each individual type of litter (PET bottles, alu cans, etc.) should be treated as an exchange to the environment. Although specific issues of littering (e.g. direct harm to wildlife) may still need special treatment, a more practical solution would be to apply a surface landfill model resulting in the traditional elemental emissions.

As it appears difficult to determine an unambiguous and practicable boundary between LCI and LCIA, the ecoinvent database applies a pragmatic, exemplary approach, where the centrally managed master list of elementary exchanges (available via www.ecoinvent.org and via the ecoEditor software) provides the definition of the borderline between LCI and LCIA. This implies that all activities up to the point where the listed emissions first occur are regarded as included as human activities, while the remaining fate modelling is regarded as belonging to the LCIA. The ecoinvent Editor for Exchanges with the environment is thus responsible for the smooth linking to the available LCIA methods, ensuring that no gaps or overlaps occur between the LCI and the LCIA phases.

Annex B. Parent/child datasets (inheritance)

B.1 Reference datasets

A reference activity dataset is intended as a datset that provides data close to the global average for the activity, for a reference year and reference macro-economic scenario.

The reference settings applied in the ecoinvent database version 3 are:

- Geography: Global
- Time period: 2005-01-01 to 2005-12-31
- Macro-economic scenario: Business-as-Usual

Contrary to the situation for scenarios and geography, where Business-as-Usual and Global are "natural" references, there is no "natural" reference year. While the current reference year of the ecoinvent database is 2005, this is likely to be updated in future versions of the ecoinvent database. Updating the reference year is only possible for the entire database, as it involves changes to all delta/child datasets. [experimenting with this is required on a small sample set before deploying inheritance database-wide]

B.2 Inheritance rules

The ecoSpold 2 data format is in itself not very restrictive in terms of which datasets are allowed to inherit from which. In order to ensure consistency of the ecoinvent database, a number of further restrictions are therefore applied:

A child dataset always refers to a parent dataset with the same activity name as the child, using the "parentActivityId" field of the ecoSpold format. Also the market model, activity type (unit process or aggregated system, see Chapter 4.15) and special activity type (see Chapter 4.3) cannot be changed from parent to child.

A child dataset differs from the parent dataset on one (and only one) of the settings for geography, time period and macro-economic scenario. In the ecoinvent database, the inheritance is furthermore limited to the fixed sequence: Reference activity → Geography child → Temporal child → Macro-economic scenario child.

This means that:

- A geography child (i.e. a dataset with a geographical location setting different from the parent) can only refer to a reference activity as a parent.
- A temporal child (i.e. a dataset with a time period setting different from the parent) can only refer to a reference activity or a geography child as a parent.
- A macro-economic scenario child (i.e. a dataset with a macro-economic scenario setting different from the parent) can only refer to a reference activity, a geography child, or a temporal child as a parent.

This sequence implies that different geographies are allowed to have different temporal resolution and different developments over time, while all macro-economic scenarios using inheritance must have the same geographical and temporal resolution, but can still have different developments over geography and time.

This also means that inheritance is *not* used to model technologically similar datasets (e.g. lorries with different capacities) outside the context of a geography child. Technologically similar datasets are instead modelled with the use of variables, see Chapter 5.7. Ideally, the reference activity dataset is parameterised with the use of variables, before it is applied for inheritance.

In the ecoSpold 2 format, inheritance is implemented through the use of *delta datasets* that contain only data on the inheritance and difference of the child as compared to a parent dataset, so that the actual *child dataset* only occurs when the delta dataset is combined with the inherited content from the parent dataset.

The ecoSpold format distinguishes 5 ways in which data in a delta dataset is interpreted:

1. A blank field: The value from the parent activity dataset applies.
2. Filled-in content: The filled-in value applies, and the value from the parent activity dataset is ignored.
3. In text fields of the string type, content may include the text {{PARENTTEXT}}, in which case the field content from the parent activity dataset is included at this place in the filled-in text in the child dataset.
4. In fields of the type TTextAndImage, content may include both {{PARENTTEXT}} and {{text_variables}}. The latter represents a text variable defined in the parent dataset, which may be redefined by the delta dataset while keeping the rest of the parent text intact. This allows easy changes of text parts in child datasets.
5. In amount fields with corresponding mathematical relation fields, the latter may include the reserved variable PARENTVALUE referring to the value of the parent dataset. For example, the formula PARENTVALUE*0.5 halves the value of the parent amount field.

Additional advice for data providers:
When expressing an amount in a delta dataset, it is important to consider whether it is most relevant to enter the child value as a fixed value (i.e. not relative to the parent), or whether the PARENTVALUE variable should be used. When the PARENTVALUE relationship is used, it is important to consider whether the relationship is additive or multiplicative. For example, a child value of 50 relative to a parent value of 100 can be expressed as PARENTVALUE-50 or PARENTVALUE*0.5. It is important to consider what will happen to the child value if the parent amount is changed. If there is no specific reason to assume an additive relation, the multiplicative relation should always be preferred. If the child value is believed to be more correct than any relative amount, e.g. because it is a measured value, the child value should be entered as a fixed value that will *not* change with the parent value. If the parent field is a mathematical relationship, it is often relevant to re-use this mathematical relationship in the child dataset. It is important to use the comment fields to explain the rationale behind any entered relationships.

Annex C. Input-Output data from national statistics[6]

ecoSpold reference: specialActivityType (field 115)

Input-output (IO) data is a somewhat imprecise term for the data presented by national statistical agencies as supply-use tables (also known as make-use tables) and direct requirements tables.

Supply-use tables are, as the name indicates, divided in two, the supply table and the use table. Both tables have activities on one axis and products on the other. The supply table stores data on the supply of products from each activity, and the use table stores data on the use of products by each activity. Together, the two tables can be interpreted as providing the production function of an activity, i.e. what production factors (inputs) are required to produce the outputs of an activity. Supply-use tables are used by national authorities to accumulate and balance enterprise reported data on supplies and use of products, as basis for deriving national economic indicators such as the GDP. The transpose of the supply table is sometimes referred to as a make table.

If placed with columns representing activities and rows representing products, the columns in a supply-use table are thus equivalent to LCI activity datasets, but usually the activities represented in supply-use tables are more aggregated than what is found in LCI databases. Each column in a so-called "product-by-product" direct requirements table represents a consequential or attributional implementation of the activity dataset from the supply-use table.

An IO activity dataset, i.e. a column in a supply-use or direct requirements table, can be stored in the same data format as a traditional LCI activity dataset, and vice versa. Both data types can therefore be stored in the same database, and both can be used in the same life cycle calculations.

For use together with other sources of LCI data it can generally be recommended to use the original supply-use data, rather than the derived direct requirements tables, because:

- The operations performed by the statistical agencies to calculate the direct requirements table from the supply-use tables are seldom reported in a transparent way, and often the methods deviate more or less from what is described for consequential or attributional market models in Chapter 14, especially in terms of the additional efforts that are often made to eliminate negative values; efforts that may in fact corrupt basically sound data. Some agencies do not publish product-by-product tables, but instead industry-by-industry tables, which are less relevant for LCA.
- Supply-use data are published with less delay and usually more frequently and with more product detail than the corresponding direct requirements table.
- When starting from the supply-use data, other data sources obtained for the same activities as in the supply-use table can be included, for example natural resource and energy inputs, waste statistics, emissions data, and work hours, and these data will thereby be correctly included in the transformation to the consequential and attributional implementations.

The ecoinvent database provides an "IO repository", i.e. a repository for supply-use tables, where each column in the supply-use table is stored as an IO activity dataset in the ecoSpold format (as signified in the ecoSpold field 115 specialActivityType). These supply-use tables can be utilised for so-called hybrid analysis.

The ecoinvent database supports integrated or embedded hybrid analysis, in which the more detailed activity datasets are embedded into the IO activity datasets, leaving only the residual of each IO activity after subtraction of the embedded process level data. In this hybrid approach, the detailed activity

[6] This Annex is based in parts on Weidema & Heijungs (2009).

datasets and the residual IO datasets are fully integrated, exchanging data both ways, and the resulting database is as representative of the entire economy as the original IO table, just at a higher level of detail.

[It remains to be decided whether ecoinvent will provide a hybrid database as such, or whether the ecoinvent support will be limited to providing the basis for other suppliers to produce a hybrid version.]

What is accounted for in the core part of a supply-use table is the supply and use of intermediate products within a geographical area. When adding imported products to the supply, and exported products and final consumption activities to the use, the supply-use table is balanced per product, as described for ordinary LCI data in Chapter 11.5.

To balance the supply and use of an activity, non-product inputs and outputs must also be accounted for. The nature of non-product inputs and outputs are quite different between monetary and physical accounting. In a monetary supply-use table, the difference between the value of the outputs (revenue) of an activity, and the value of the inputs of intermediate products (including investments[7]) to this activity, is the expenditures on primary production factors (labour costs, net taxes, net operating surplus, and rent, see Chapter 6.4). In a supply-use table in mass units, the difference between the mass of the intermediate outputs of an activity (products and wastes, including net additions to stock) and the mass of the of intermediate inputs to this activity, is made up by the elementary exchanges: the inputs of natural resources, minus the emissions from the activity.

In the most usual form of supply-use tables, the intermediate exchanges are expressed in monetary units. It is common practice with statistical agencies to express the supply table in basic or producer's prices, while the use table is in purchaser's prices (see Chapter 4.7 and 5.6.5). The trade and transport margins and the product taxes and subsidies per transaction are then typically placed in one or more valuation tables, providing the necessary translation between the values of the supply table and the values of the use table. In publication, these tables may be aggregated into single columns. Before transforming a supply-use table to a product-by-product direct requirements table, it is normal practice to express also the use table in basic prices, by subtracting the valuation tables from the use table, adding the trade and transport margins, aggregated per activity, as inputs from the activities supplying the trade and transport services, and placing the product taxes and subsidies in a separate row below the core table.

An alternative to the use of a valuation table, which is more in accordance with the structure of the ordinary LCI datasets, and which is therefore applied for the ecoinvent IO repository, is to introduce a set of market activities, one for each reference product, as part of the core supply-use table, see Figure C.1. Each market activity uses the corresponding industry product in basic prices and supplies the same product in average purchaser's prices. The difference comes from the inputs from the trade and transport service industries, and the taxes less subsidies, which in this approach are added to the products at the market. If different users pay different prices for the same market product, the difference to the average trade and transport margins must be added directly to the using activity as a (positive or negative) input from the trade and transport service industries. With this approach, the original use table can be maintained in purchaser's prices, thus closer to the original statistical data. The tables can still be balanced per product, because each product is provided in the same valuation in the supply and the use table: Industry products are valued in basic prices and market products are valued in purchaser's prices.

[7] In national accounting practice, investments are not included in the intermediate inputs, but represented by a separate 'use of fixed capital' row outside of the activity table, sometimes only reported together with the net operating surplus as 'gross operating surplus'.

Balanced MSUT	Industries	Markets	Import	Final use	Export
Industry products	**Supply** table in basic prices		Import CIF		
Market products		**Market supply** in purchaser's prices			
Industry products		**Use** table in basic prices			
Market products	**Use table** in purchaser's prices			Final use in purchaser's prices	Export in purchaser's prices (FOB)
Primary inputs	Value added at basic prices	Product taxes less subsidies			

Figure C.1. A balanced monetary supply-use table using market activities instead of valuation tables.

In the physical supply-use table, where price valuation is not of concern, market activities can be used to model product losses during transport and trade, and the market activities for the treatment of wastes are applied to distribute the physical amount of the waste over the different waste treatment services (see Chapter 4.9), integrating waste treatment markets directly in the core supply-use table, thus eliminating the satellite tables for waste that are necessary in traditional physical supply-use tables.

Because the ecoSpold format allows adding different properties to each exchange (see Chapter 5.5), supply-use tables can be stored in parallel monetary and physical units, in the same activity datasets. From these datasets, different supply-use use tables can be extracted, in purely monetary, purely physical, or in hybrid units.

A physical supply-use table is constructed by applying data on physical flows of activities and the relation between monetary and physical flows (prices). Product prices and/or data on physical flows may be obtained from production, imports, and export statistics. The required environmental extensions to the supply-use table are natural resource extraction data from resource statistics (see Chapter 6.2), and emissions (typically be limited to those that can be derived from fuel inputs by an emission factor approach). Such environmental extensions can be stored in each IO activity dataset, using the same nomenclature (see Chapter 9.4) as for the detailed LCI data. When combining these data, the mass balancing principle allows building up a supply-use table that matches the monetary supply-use table.

The supply-use tables published by national statistical agencies do not include the consumption stage as an activity, but as a column outside of the activity table. In the ecoinvent IO repository, the final use column is integrated into the core activity part of the table, and modelled as an activity with product outputs. It may be further sub-divided to reflect the interaction between different products and activities in the households, see Chapter 4.12.

In the supply-use tables published by national statistical agencies, capital formation (investments, infrastructure, capital goods) are not included in the core activity part of the table. Product supplies that go into capital formation are represented by a separate column in final consumption, outside of the activity table, and the depreciation of the investment expenditures is represented by a separate 'use of fixed capital' row outside of the activity table. In the ecoinvent IO repository, the capital goods are seen as part of the production function of each activity, in the same way as other product inputs, thus integrating the 'capital formation' column and 'use of fixed capital' row into the core activity part of the table. This is done by applying an investment table, which has the same format as the use table and provides information on the distribution of the 'capital formation' on activities. If an investment table is not available from the national statistical agency[8], it may be constructed by extrapolation from another country's investment table, normalised to the total output of each activity. Since the incorporation the 'capital formation' into the core activity part of the IO table represents a specification of the 'use of fixed capital' row under a steady-state-assumption, this row is then eliminated to avoid double counting of the use. In national accounting, investments are included in the value added used for calculating the GDP (Gross Domestic Product). To maintain the possibility of calculating the GDP indicator, the products originally supplied to the 'Capital formation' column must be specified as infrastructure goods (see Chapter 4.11). After the incorporation of the 'Capital formation' column, the sum of the infrastructure goods purchased will then be equal to the value in the original 'use of fixed capital' row, and the contribution to the GDP can therefore be recalculated. Because the 'use of fixed capital' row is determined from depreciation allowances, its sum is not necessarily equal to the sum of the 'capital formation' column. The incorporation of the 'capital formation' column and the simultaneous elimination of the 'use of fixed capital' row may therefore give rise to small discrepancies between the total inputs and outputs of each activity. These discrepancies are adjusted in the net operating surplus, see Chapter 6.4. In physical terms, the investment table represents both the input of capital goods, but also the corresponding net additions to the stock of these purchased capital goods, see Chapter 11.10.1, and is therefore also added as physical intermediate outputs, thus maintaining the mass balance of each activity.

Although UN classification systems exist both for activities and products (ISIC and CPC, respectively), different statistical agencies use different activity and product classifications. Especially the North American Industry Classification System (NAICS) is a widely used activity classification. Correspondence tables exist between many of the classifications, but in case of overlapping categories these do not eliminate the need for manual interaction during translation. Furthermore, all classification systems are regularly being revised, which adds to the work required when combining several tables. And even when statistical agencies follow the same classification, there may be subtle exceptions and differences in interpretations that make an error-free translation difficult. For the ecoinvent IO repository, the ISIC and CPC classifications are required, but the original classifications are maintained as well, allowing later revisions.

In physical supply-use tables, complementary products, such as packaging, are typically not included with the product flows, and therefore appear to become waste at the producer rather than at the user. For the ecoinvent IO repository, such complementary products are therefore added to match the modelling of these intermediate exchanges in the detailed process level data, see Chapter 11.8.

The national supply-use tables in the ecoinvent IO repository can be combined with the detailed LCI data in the ecoinvent database, to produce a so-called hybrid LCI database, which combines the completeness of the supply-use tables with the detail of the traditional LCI data. Such a combination requires:

[8] Unfortunately, this may be the rule rather than the exception.

The availability of production volume data for all national production, consumption, import, and export activities (see Chapter 11.5, especially Figure 11.7) for all products that are specified in the ecoinvent database and are produced or consumed within the national area. If national production volumes for some or all of these activities are only known at a more aggregated level, the same composition as at global level can be assumed.

The addition of data for non-monetised internal trade to the IO activities: A process level LCI database will typically have more activity sub-division than in the supply-use tables, for example typically all internal heat production that is not a by-product of the manufacturing is placed in one or a few technically defined activities (and classified under 'Steam and air-conditioning supply'), rather than included in each manufacturing activity, and all agricultural field operations are recorded separately from the crop production (and classified under 'Support activities for plant production'), disregarding whether these operations are performed by the farmer or by a contractor. The more detailed the subdivision, the more non-monetised internal trade will be recorded. In the supply-use tables, such intermediate exchanges, like the agricultural services and the purchase of animal feed, will be included when supplied by a contractor or by another farmer, but not when supplied by the farmer herself. Since the true values, that is, the total amount of these intermediate products, are better known from the process level LCI data, these values are used to adjust the supply-use table before integration. Whenever an internal activity is added, the product supply increases, but so does the use of this added product. As price information is often not available for internal processes, prices must be imputed from the costs of the inputs, adding an average amount of added value for the industry in question. The resulting monetisation of internal activities will increase the total monetary output but the total value added remains the same (because the same money "changes hands" more often, but with a proportionally smaller amount of value added between each exchange).

The supply-use table and the detailed data in the ecoinvent database will now have the same structure, and the integration can be performed. The integration consists of 5 steps:

The process level LCI data are scaled up to the level of the geographical production volume.

The up-scaled LCI data are summed up for each product-activity classification level of the supply-use table, and these aggregated data are subtracted from the corresponding cell content in the supply-use table (except for physical elementary exchanges). The result is a residual for each cell in the supply-use table. These may be represented as 'residual IO activity' datasets, at this time only using inputs from other 'residual IO activity' datasets.

For each of the products in the up-scaled process LCI database, a monetary and a mass balance at the geographical level is performed, thereby identifying the missing use of each product.

The missing use is distributed to the residual IO activity datasets, using the size of the activity residuals for the corresponding product group as distribution key, and subtracting the distributed missing use from the corresponding residual data, thereby obtaining a remaining residual for each cell in the original use table. The residual IO activity datasets now have the relevant inputs from all other activities.

The remaining residual, representing input of unspecified products, is redistributed over all non-market activity datasets, using the monetary value of the production output as distribution key. To maintain the balance per activity, the value added of the activities are adjusted accordingly, by subtracting the distributed remaining residual from the net operating surplus of each activity.

Emissions can be added to the residual IO activities, but since the residual activities per definition cannot have any process-specific emissions, emissions can only be added on the basis of emission factors relating to specific inputs, such as fuels. Since fuels are primarily inputs of the specific heat producing activities, it will in most cases only be for this residual heat producing activity that emissions can be meaningfully added. Even when no emissions are added for the residual IO activities, they play a role in increasing the completeness of the life cycle emissions of all products in the database, since they serve as (previously missing) links to other activities that do have emissions.

Meaningful waste outputs (or materially specified inputs of waste treatment services) can be added to the residual IO activities based on their mass balances.

[**Changes relative to ecoinvent version 2:** The option to store IO activity datasets with a special designation (ecoSpold field 115 specialActivityType) is new.]

Abbreviations

AOX	Adsorbable Organic Halogen Compounds
BOD_5	Biological oxygen demand in five days
CED	Cumulative Energy Demand
CIF	Cost Insurance and Freight
COD	Chemical oxygen demand
CPC	Central Product Classification
CV	Coefficient of Variance
DM	Dry matter
DOC	Dissolved organic carbon
FOB	Free On Board
GDP	Gross Domestic Product
GLO	Global
ID	Identifier
IO	Input Output (economic model)
ISO	International Organization of Standardization
ISIC	International Standard Industrial Classification
KML	Keyhole Markup Language
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NAICS	North American Industry Classification System
NDI	National Data collection Initiative
NMVOC	Non-methane Volatile Organic Compound
PM10	Particulate matter with a diameter of less than 10 µm
PM2.5	Particulate matter with a diameter of less than 2.5 µm
ROW	Rest-Of-World
SD_{g95}	square of the geometric standard deviation (95% interval)
SPOLD	Society for the Promotion of Lifecycle Development (www.spold.org)
TCDD	Tetra-chlor-dibenzo-dioxin
TOC	Total Organic Carbon
TPM	Total Particulate Matter
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UN	United Nations
UUID	Universally Unique Identifier
XML	Extended Markup Language

Standard terminology used in the ecoinvent network (glossary)

Accumulated system dataset: An activity dataset showing the aggregated environmental exchanges and impacts of the product system related to one specific product from the activity.

Activity: The doing or making something. Example: "International Standard Industrial Classification of All Economic Activities". Etymology: Latin: actio ("'doing or making'")

Activity class: Group of activities classified together under a heading in a statistical classification of activities, such as ISIC.

Addition to stock: By-product or waste with a lifetime in excess of one year. See also under Infrastructure.

Branded dataset: Dataset for a specific brand or a specific company, where the company or brand name is specifically mentioned as part of the activity and/or product name.

Child dataset: Dataset that occurs when a parent dataset is combined with a delta dataset.

Conditional exchange: Exchange that is only activated for a specified market model.

Consumption mix: The output from a market activity.

Cost: The expenditure necessary to aquire a product or production factor.

Delta dataset: Dataset that contains information on the inheritance and difference of a child dataset as compared to a parent dataset.

Determining product: See reference product.

Direct requirements table: A transformed supply-use table representing a linear, homogeneous steady-state model of the economy. In a "product-by-product" direct requirements table, each column represents a consequential or attributional implementation of an activity dataset.

Elementary exchange: Exchange with the natural, social or economic environment. Examples: Unprocessed inputs from nature, emissions to air, water and soil, physical impacts, working hours under specified conditions.

Environment: Surroundings. Etymology: French: environ ("around").

Exchange: Relationship between a human activity and another human activity or the natural, social or economic environment. Synonym: Input or output.

Human activity: Activity performed by humans, machines or animals in human care.

Infrastructure: Product not intended for consumption, with a lifetime exceeding one year. In the ecoinvent database typically modelled as a service, and identified by the property "capacity" or "lifetime_capacity". Synonyms: Capital goods, Investments.

Inheritance: Passing on of field contents from a parent dataset to a child dataset.

Intermediate exchange: Product, material or energy flow occurring between unit processes. Synonym: Product or waste.

IO activity dataset: A dataset corresponding to a column in a supply-use or direct requirements table.

Lifetime of a product: The period between the time of production and the time of initiating waste treatment of the product.

Make-use table: See Supply-use table.

Material for treatment: A by-product/waste that no other activity in the same geographical area has as its *positive* reference product, and which therefore cannot substitute a reference product as an input to an activity.

Market activity: An activity representing a market for a specific product, mixing similar intermediate outputs from the supplying transforming activities and providing the resulting consumption mix to the transforming activities that consume this product as an input.

Market model: A model describing how activity datasets are linked to form product systems. Synonym: Technology model (input-output economics).

Parent dataset: A dataset referred to by a delta and child dataset as the dataset from which field values in the child dataset are to be inherited to the extent defined by the delta dataset.

Process: Set of interrelated or interacting activities that transforms inputs into outputs. ISO 9000:2005, definition 3.4.1.

Product: Good or service output of a human activity with a positive either market or non-market value. Example of a product with a non-market value: Household childcare.

Product system: Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product. ISO 14040:2006, definition 3.28.

Production mix: The production-volume-weighted average of the suppliers of a specific product within a geographical area.

Reference activity dataset: A dataset representing a default description of an activity for a reference year and scenario, intended to be close to the global average, to be applied as parent dataset for other datasets for the same activity but with other specific geographical location and/or temporal and/or scenario settings. Products of reference datasets have the production volume = 0 to enable avoiding of their inclusion in automatically generated production or consumption mixes, but may contain the global production volumes as parameter values.

Reference product: Product of an activity for which a change in demand will affect the production volume of the activity (also known as the determining products in consequential modelling).

Residual activity: Resulting activity when subtracting all available unit processes within an activity class from the supply-use data of the same activity class, for the same year and geographical area.

Revenue: The income from the sale of a product.

Supply mix: A production mix with the addition of the import of the specified product to the geographical area.

Supply-use table: A combination of a supply table and a use table, each with activities on one axis and products on the other. The supply table stores data on the supply of products from each activity, and the use table stores data on the use of products by each activity. Together, the two tables can be interpreted as providing the production function of an activity, i.e. what production factors (inputs) are required to produce the outputs of an activity. The transpose of the supply table is sometimes referred to as a make table.

Transforming activity: A human activity that transforms inputs, so that the intermediate output of the activity is different from the intermediate inputs, e.g. a hard coal mine that transforms hard coal in ground to the marketable product hard coal, as opposed to a market activity. Including extraction, production, transport, consumption and waste treatment.

Treatment activity: Transforming activity with a reference product with a negative sign, which means that the activity is supplying the service of treating or disposing of the reference product.

Unit process: Smallest element considered in the life cycle inventory for which input and output data are quantified. ISO 14040:2006, definition 3.34.

Variable: A placeholder for a value for use in mathematical formulas.

Variable property: A property of an exchange which is included as a variable in a mathematical relation of another exchange of the same dataset.

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