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Recent developments in LCA
- attributional and consequential LCA

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Recent developments in LCA - Introduction

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At the computational level, LCA is:

- a number of unit process datasets
- some algorithms for combining these datasets into product systems

In this session:

- "Attributional and consequential LCA": about the algorithms
- "Input-Output": about data sources
- "Footprinting": about the application of the results

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Attributional and consequential - origin and definition of the terms

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Background

International Workshop on Electricity Data for Life Cycle Inventories, Cincinnati, 2001.10.23-25.

- UNEP/SETAC (2011). Shonan LCA database guidance principles:
  - **Attributional approach**: System modelling approach in which **inputs and outputs are attributed** to the functional unit of a product system by linking and/or partitioning the unit processes of the system **according to a normative rule**.
  - **Consequential approach:** System modelling approach in which activities in a product system are linked 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 functional unit.

Recent

Prospective

Change-

Consequential

Accountancy

Retrospective

Effect-

oriented

Status-quo

Comparative

Descriptive

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The algorithms

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The three core aspects of LCI algorithms:

- What is comparable? Within or between product systems
- Which datasets to link? Average or marginal suppliers
- How to handle co-products?
  Partitioning (allocation) or substitution (system expansion)

An algorithm must be expressed clearly enough to be unambiguously interpreted by experts and/or software

1. The comparability algorithm: Defining the functional unit

Background

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- Attributional: No substitutions → No specific requirements to the functional unit.

Recent

Attempts to base functional units on commodity classifications

- Consequential (ISO 14044/49): Functional unit reflects the conditions for substitution → The obligatory product properties on the market where the product is traded (Weidema et al. 2004), considering the size of the decision to be supported.

Recent

Adopted by ecoinvent v3: The obligatory product properties is the basis for the product naming and market segmentation: Same product name and geography → same market

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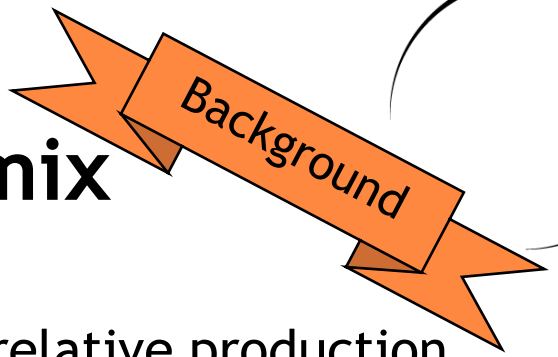
2. The linking algorithm: Composing a consumption mix



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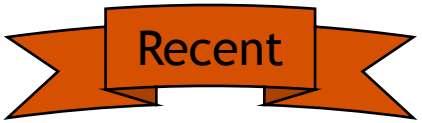
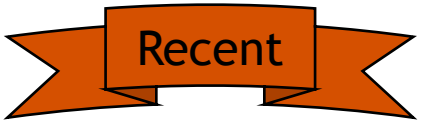
- Attributional: Market averages → Current relative production volumes of suppliers.



ILCD situation A/C1: Market averages without by-products, in order to apply substitution as co-product algorithm

- Consequential (ISO 14044/49): Marginal, unconstrained suppliers → Modern, competitive suppliers, when the product demand is generally increasing; Old, uncompetitive suppliers, when the product demand is generally decreasing (ISO 14049 - Clause 6.4) relative to the replacement rate of capital (Weidema 1993).



Implemented in ecoinvent v3 (consequential system model)

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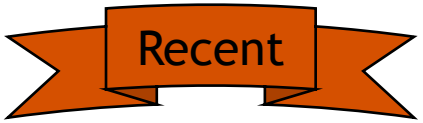
2. The linking algorithm: Composing a consumption mix



Implemented in ecoinvent v3 (consequential system model):

- Only reference products (determining products) can be unconstrained.
- Constraints expressed via relative technology level classification (outdated, old, current, modern, new) of the individual datasets, thus making the determination subject to peer review and scientific dialogue.
- Increasing or decreasing demand identified by trend in market volume (default: increasing demand).
- Constrained markets supplied by reduction in marginal demand/consumption.

3. The co-product algorithms

Background

- Attributional: Partitioning (allocation)
- Consequential: Follows consistently the first priority of the ISO 14044 hierarchy: Substitution (system expansion), which has been proven to be always possible (Weidema 2001).

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3. The co-product algorithms

Recent developments in consequential modelling

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System expansion shown to be the only system model that consistently maintains mass, elementary, energy and monetary balances of the resulting single-product systems (Weidema & Schmidt 2010).

System expansion shown by Suh et al. (2010) to be mathematically identical to the by-product technology model of Stone (1960), clarifying the simplicity of the algorithm: By-product outputs are modeled as negative inputs.

What is substituted is the inputs to the market that the negative input is linking to → Justification of what is substituted is already given by the comparability and linking algorithms.

Implemented in ecoinvent v3 (consequential system model)

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3. The co-product algorithms

Recent developments in attributional modelling

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Shown that the distinction between open-loop and closed-loop recycling is an artifact of incomplete databases (Weidema 2011).

Shown that the point of allocation is an important variable for the allocation result and that allocation at the point of substitution provides more consistent results (Weidema et al. 2012).

Shown that allocation practices have until now been justified by two incompatible paradigms: economic causality and physical tracability (Weidema et al. 2012).

Ecoinvent v3 implements system models with consistent use of a single allocation key and allocation correction for single physical elements, attempting to mimic in a consistent way the main historical practice in attributional modelling.

Concluding observations

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- Since ISO 14040/44: Many additional national, single-issue and industry specific guidelines and PCR documents, all claiming to be in accordance with ISO 14040/44, but often deviating on specific points, i.e. mainly adding confusion.

- Ecoinvent v3 supports both ISO 14040/44 consequential modeling and the many new attributional variants, based on the same unit process data, thus making the differences in algorithms explicit.

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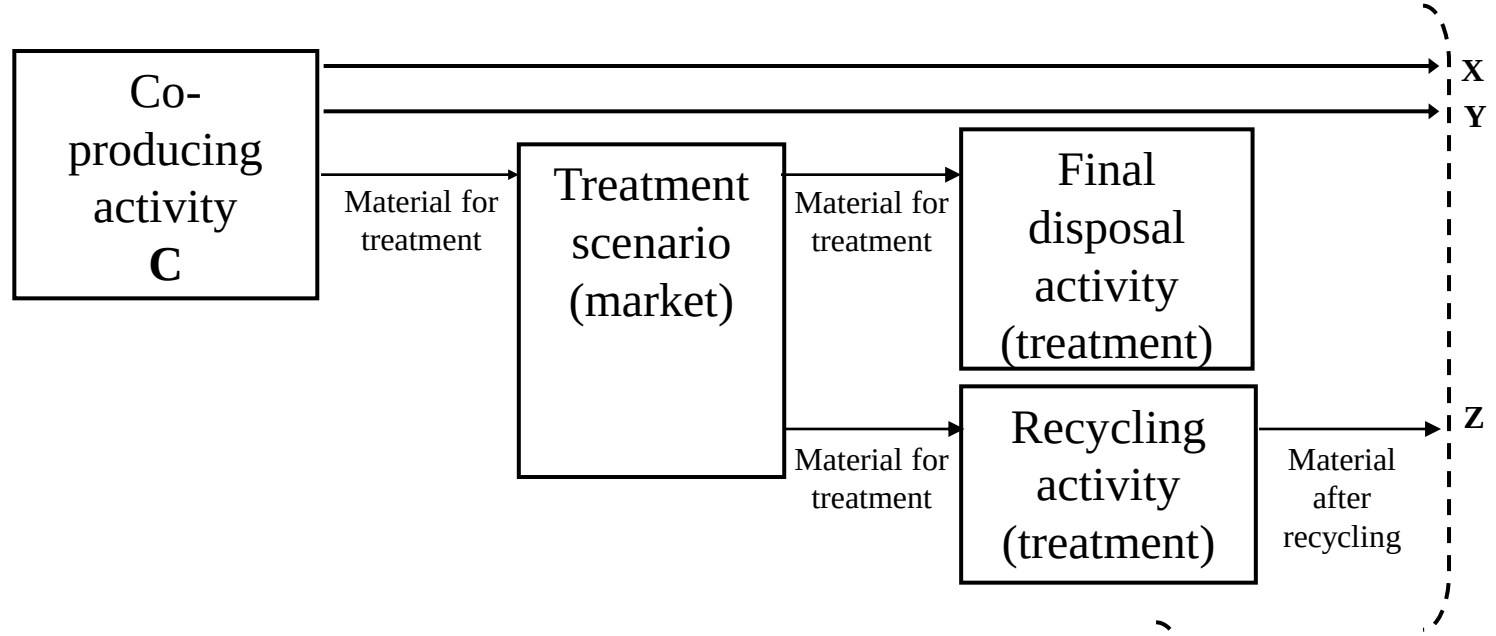
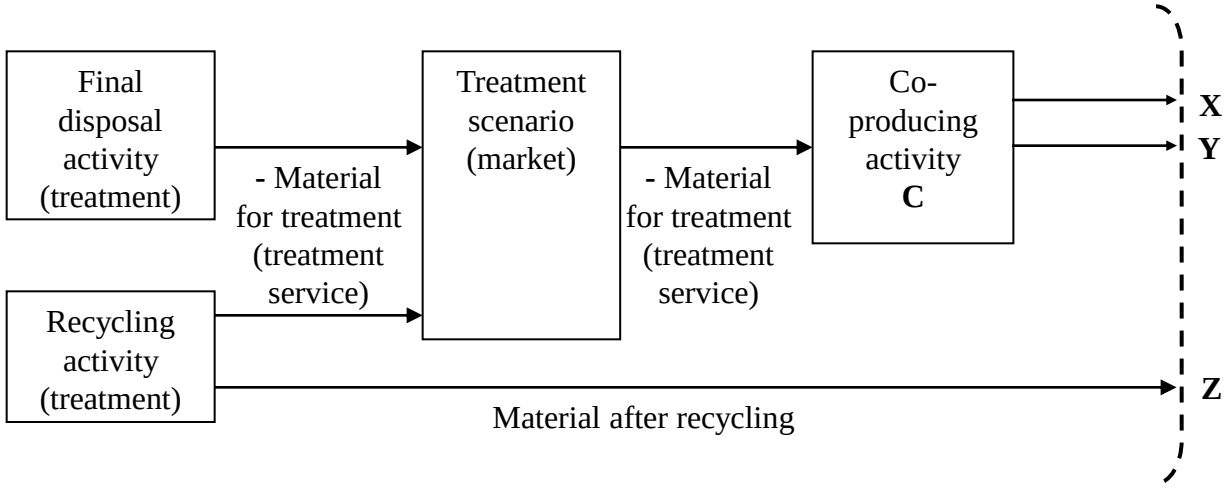
Allocation - at the point of substitution:





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