Consequential LCA system model: implementation in ecoinvent version 3 and illustration of consequences on selected supply chains

Gregor Wernet
Executive Director, ecoinvent
A **system model** is a collection of modeling choices made for the database

- Solving the allocation problem
- Recycling and waste streams
- Handling constraints in suppliers

In version 3, **multiple system models** are possible

- Different perspectives at the same database
System models in version 3

- LCIA Results
  - Aggregated LCI data
  - Single-output Unit processes
    - Physical process descriptions (multi-output)
  - System model Y
  - Model Y

- Calculation
  - Application of LCIA factors
  - System model X
  - Model X

Trust in Transparency!
System models in ecoinvent v3

- Allocation at the point of substitution
- Allocation, Recycled Content cut-off
- Consequential (long-term, small-scale)
- Other models possible
  - Waste/Recycling system models
  - Other allocation choices
  - Integration with specific standards
  - Complete mass- or carbon-based allocation (Mass Flow Analysis)
The Consequential SM in ecoinvent v3

- Offering a consequential system model was an ambition in version 3 as the use of attributional background data introduced errors of unknown impact in consequential studies.

- Implementation in version 3 is a basic version of the consequential approach:
  - Foreground systems can and should show more specificity.
  - Important parts of the background supply chain can be checked and adapted if necessary.

- A basic consequential ecoinvent version allows research and work on consequential database development.
The Consequential SM in ecoinvent v3

- Use of **Substitution** for by-products to avoid allocation

- Use of **marginal suppliers** only
  - Constraints of by-product production
  - Constraints due to technology

- **Consumption of by-products** creates demand for primary production
  - Alternative production routes
  - **Constrained markets** identify the marginal consumer of constrained products
Substitution in the ecoinvent v3

---

gold mine

→ gold

→ silver
Substitution in the ecoinvent v3

- Silver

supplied by primary production, e.g. silver mine

---

gold mine

gold
Marginal suppliers in ecoinvent v3

- **By-products** are generally constrained and therefore not available to supply activities
  - Many datasets that exist in the allocation-based models do not exist in the consequential model

- Products are also constrained based on the technology level of the producing activity
Marginal suppliers in ecoinvent v3

- **Outdated**
  - Technology no longer in use
  - Technology that is currently taken out of use (least competitive technology)

- **Old**
  - Between modern and old
  - Technology currently used when installing new capacity (most competitive technology)

- **Current**
  - On some aspects technically superior to modern, but not yet the most commonly installed

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>81.4%</td>
</tr>
<tr>
<td>Modern</td>
<td>17.2%</td>
</tr>
<tr>
<td>Outdated</td>
<td>0.6%</td>
</tr>
<tr>
<td>Old</td>
<td>0.5%</td>
</tr>
<tr>
<td>New</td>
<td>0.4%</td>
</tr>
</tbody>
</table>
Marginal suppliers in ecoinvent v3

Attributional model

- Old 50%
- Current 30%
- Modern 20%

Market dataset

Process receives input of 100%
Marginal suppliers in ecoinvent v3

Consequential model

Old 0% → Market dataset → Process receives input of 100%
Current 0%
Modern 100%
Marginal suppliers in ecoinvent v3

- 1 kg Used refrigerant R134a (GLO)
- 0.899 kg Refrigerant R134a (GLO) market for | Conseq, U
- 0.225 kg Refrigerant R134a (REN) production | Conseq, U
- 0.674 kg Refrigerant R134a (REN) production | Conseq, U
- 22.9 kg CO2 eq
- 65.1 kg CO2 eq

- 0.822 kg CO2 eq
- 0.52 kg CO2 eq
- 715 kg CO2 eq

- 716 kg CO2 eq

- final disposal
- reclamation
- venting
Marginal suppliers in ecoinvent v3

- Determination of constraints via technology levels is a basic approach
  - Application to many thousands of datasets requires an efficient solution

- Data providers are looking to improve on these models
  - Integration of advanced forecasting data in the works
Marginal suppliers in ecoinvent v3

impacts of electricity low voltage - consequential versus cut-off SM

cut-off LCIA results = 1, conseq. scale

- cut-off system model
- consequential system model
Constrained markets

- Constrained markets occur when by-product cannot be substituted by primary production
- Chlorine production is an example of a constrained by-product
  - Sodium hydroxide is a by-product of chlorine production
  - Constrained market for NaOH
- Use of NaOH leads not to excess Chlorine production but to reduced use of NaOH elsewhere, requiring a substitute defined by the **marginal consumption activity**
Constrained markets

Special flow: - 1 kg NaOH →

- ignored by linking algorithm in other system models
- direct link to marginal consumption
- property tag which defines the level of constraint and which system models use this special flow

→ Output of 1 kg NaOH
Constrained markets

- Link to marginal consumption activity: NaOH as a neutralising agent
- Market for neutralising agents defines substitution
  - In this case: Sodium Carbonate
- In the consequential model, using NaOH results in adding the burden of the equivalent amount of Sodium Carbonate due to the displacement of the marginal consumption
- Stored in the same database, but does not affect other system models
Constrained markets

Trust in Transparency!
Conclusions

- The consequential model follows the core tenets of consequential modelling
  - Limited to small-scale, long-term
- Implementation rather basic to address poor data situation
- Adaptations possible in the unit process structure
- Improvements on important markets such as electricity foreseen