Lecture: Advanced Environmental Assessment

Allocation in multi-output processes and recycling

28 September, 2017
Overview

- Introduction to the allocation issue
- Allocation in multi-output processes
- Allocation in recycling: four approaches
- Environmental Product Declarations of cladding products
- Exercises
What we will learn today

- Know the allocation problem of multi-output processes and recycling in life cycle assessments
- Know and apply the four main recycling allocation approaches
- Know the major positions and arguments related to recycling allocation
Allocation deals with ...

Attribution of requirements and emissions to two or more products and/or services that together are causing those requirements and emissions.
Allocation problems occur at ...

1 Processes delivering more than one product, e.g.
   - refinery
   - chemical plants
   - airplane transport
   - dairy farms

2 Recycling of materials or energy
   - materials recycling
   - waste incineration / energy recovery
Allocation in multi-output processes and recycling

Allocation in multioutput processes according to ISO 14040/44

Three steps procedure:

1. Avoid allocation by
   - increase level of detail
   - expand the system

2. Allocation according to physical relationships

3. Allocation according to other relationships
   (e.g. economic)
Allocation in multi-output processes and recycling

Decision tree on allocation

- **Multifunctional process**
  - **Would dividing the process in several subprocesses solve the multifunctionality issue?**
    - **No**
      - **Can the relative amount of co-products be independently varied?**
        - **Yes**
          - Combined production
        - **No**
          - Joint production
    - **Yes**
      - **Not truly a multifunctional process**
      - **Is subdivision practicable?**
        - **Yes**
          - Subdivide (ISO 14044 ‘Step 1’)
        - **No**
          - Treat as multifunctional process
  - **Yes**
    - **Choose your approach (allocation, system expansion, etc)**

**UNEP SETAC Shonan guidance Principles 2012**

**Figure 3.3: Steps to identify the most appropriate allocation approach**
Allocation in multi-output processes and recycling

The cow model working group of the EU PEF

Cow Model Working Group (CMWG)

Angelegt von Imola BEDO, zuletzt geändert am Okt 23, 2014

This working group was started to ensure consistency in modelling the cow as a common element between several EF pilots: dairy, meat, leather, feed and pet food. The CMWG is chaired by DG Environment. Besides the 5 pilots, further members include the Joint Research Centre (JRC) and other European Commission services, the Food SCP Roundtable and the Food and Agriculture Organisation of the United Nations (FAO).

The time frame of the CMWG is six months (until 31st December 2014). In case no consensus is reached until that date on the common cow model, a model proposed by the Joint Research Centre will be used for the pilot work based on the discussions up to that date. In parallel, the working group will continue discussions to reach an agreement on the cow model.

This page contains public information about the work of the CMWG. The members of the working group may access the CMWG Member Working Space.

Members

- JRC (Chair of the CMWG): Erwan Saouter, Rana Pant, Hanna Tuomisto
- DG Environment: Michele Galatola, Imola Bedo
- Food SCP Roundtable: Urs Schenker
- FAO: Pierre Gerber, Camillo De Camillis
- Dairy pilot: Xavier Bengoa, Jean-Baptiste Dollé
- Feed pilot: Nicolas Martin, Philippe Becquet
- Leather pilot: Gustavo Gonzalez-Quijano, Elisabetta Scaglia
- Meat pilot: Cristophe Lapasin, Hans Blonk
- Pet food pilot: Pascale Bensman, Sebastien Humbert

Contacts

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Allocation in multi-output processes and recycling

Product system milk and meat production

Thomassen et al. (2008)
Allocation in multi-output processes and recycling

Product system milk and meat production

Plant cultivation
- Grass/ensilage
- Grain crops
- Other crops

Crops

Grass/ensilage

Feed crops

Milk system
- Dairy cow
- Raising heifers
- Raising bulls

Milk

Food industry
- Veg. oil industry
- Sugar industry
- Flour industry

Protein meals/by-products

Food products

Beef system
- Suckler cow
- Raising heifers
- Raising bulls

Meat

Dalgaard et al. (2014)
Allocation factor depending on allocation approach and beef meat ration (BMR)

\[ AR_S = 1 - 1.51(BMR) \]
\[ R^2 = 0.83 \]

\[ AR_P = 1 - 2.67(BMR) \]
\[ R^2 = 0.98 \]

\[ AR_E = 1 - 3.069(BMR) \]
\[ R^2 = 0.92 \]

\[ AR_B = 1 - 6.04(BMR) \]
\[ R^2 = 0.95 \]

International Dairy Federation (2010)
Allocation in multi-output processes and recycling

Greenhouse gas emissions of milk and meat depending on allocation parameter

<table>
<thead>
<tr>
<th>kg CO₂-eq/kg</th>
<th>Separation</th>
<th>Protein content</th>
<th>Economic</th>
<th>Causal (Physical relationship)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allocation factor milk</td>
<td>97%</td>
<td>94%</td>
<td>93%</td>
<td>86%</td>
</tr>
<tr>
<td>1 kg milk</td>
<td>1.36</td>
<td>1.31</td>
<td>1.30</td>
<td>1.20</td>
</tr>
<tr>
<td>1 kg meat</td>
<td>1.61</td>
<td>3.74</td>
<td>4.30</td>
<td>8.46</td>
</tr>
</tbody>
</table>

Production at farm: 1000 kg milk, 24 kg meat
Total GHG emissions: 1’400 kg CO₂-eq
BMR: 0.024 kg meat / kg milk
Allocation factors determined with formula shown in former slide
### Allocation in multi-output processes and recycling

#### Allocation approaches in the dairy sector

<table>
<thead>
<tr>
<th>Preferred approach</th>
<th>Allocation situations</th>
<th>Choice</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO hierarchy</td>
<td>Feed (pre-farm)</td>
<td>Economic</td>
<td>Depends on kind of feed</td>
</tr>
<tr>
<td></td>
<td>Milk/meat and calves</td>
<td>Physical causality</td>
<td>Based on energy feed inputs to the system and associated milk and meat production</td>
</tr>
<tr>
<td></td>
<td>(farm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manure export (farm)</td>
<td>Residual: system separation by cut-off</td>
<td>Based on the classification of manure as a residual, co-product or waste⁹</td>
</tr>
<tr>
<td></td>
<td>Processing (dairy site)</td>
<td>Physical, Mix</td>
<td>Based on milk solids for raw milk, specific values if available</td>
</tr>
<tr>
<td></td>
<td>CHP (farm, dairy site)</td>
<td>System expansion</td>
<td>Replaces electricity from the national grid or heat</td>
</tr>
</tbody>
</table>

International Dairy Federation (2010)
Modelling of recycling in life cycle assessment

• Basic outline
• Motivation: Potential effects of recycling
• ISO 14044 and recycling allocation
• 4 different approaches
Situation: Products 1 and 2 made from primary material

Product 1

Primary material supply

manufacture

use

waste management (e.g. incineration)

Product 2

Primary material supply

manufacture

use

waste management (e.g. incineration)
Environmental impacts along time

- **Product 1**
  - Primary material supply
  - Manufacture
  - Use
  - End of life

- **Product 2**
  - Primary material supply
  - Manufacture
  - Use
  - End of life
Allocation in multi-output processes and recycling

Material Recycling: basic outline

Product 1

Primary material supply

manufacture

use

waste management (e.g. incineration)

Product 2

Primary material supply

manufacture

use

waste management (e.g. incineration)

Recycling
Effect of Recycling

Allocation in multi-output processes and recycling

- Primary material supply
- Manufacture
- Use
- End of life
- Recycling
- Manuf.
- Use

Decision 1
Decision 2

Product 1
Product 2
Modelling of recycling according to ISO 14040/44

Distinction between

- **closed-loop allocation procedure**
  Use of recycled materials in identical products or open-loop but no change in inherent properties
  First use of virgin material in applicable open-loop product systems may be treated according to open-loop recycling procedure

- **open-loop allocation procedure**
  Use of recycled materials in other products
Modelling of recycling according to ISO 14040/44 (cont.)

- closed-loop: allocation is avoided, because secondary material replaces primary material
- open-loop: basis for allocation:
  - physical properties (e.g., mass)
  - economic value (market value of scrap compared to price of primary material)
  - number of subsequent uses of the recycled material
Sustainability definitions

- **Weak sustainability:** Manufactured capital of equal value can take the place of natural capital

- **Strong sustainability:** The existing stock of natural capital must be maintained and enhanced because the functions it performs cannot be duplicated by manufactured capital
Decision situations

• Information for decision support includes everything that can be influenced by the decision

• In economics: Costs, that cannot be influenced by a decision, should not be considered

=> sunk costs

• In LCA: principle applicable and applied on environmental impacts
Recycling example

• Yogurt packaging:
  – Polystyrene (PS) body: 6g,
  – Aluminium sleeve: 0.5g

• End of life treatment:
  – PS body:
    municipal waste incineration with energy recovery
    heat: 2.7 Wh/g
    electricity: 1.4 Wh/g
  – Aluminium sleeve:
    recycling
Allocation in multi-output processes and recycling

Recycling example, Carbon footprints

- **manufacture:**
  - Polystyrene (PS): 3.6 g CO$_2$-eq/g,
  - primary Aluminium: 9.3 g CO$_2$-eq/g
  - secondary Aluminium: 0.85 g CO$_2$-eq/g

- **End of life treatment:**
  - PS incineration: 3.0 g CO$_2$-eq/g
  - Aluminium recycling: 0.85 g CO$_2$-eq/g

- **Alternative energy production:**
  - electricity (with gas combined cycle): 0.47 g CO$_2$-eq/Wh
  - heat supply (with natural gas): 0.25 g CO$_2$-eq/Wh
Several approaches for recycling allocation

- recycled content (RC) or cut-off
- end of life recycling (EoL) or avoided burden
- Environmental Product Declaration Standard EN 15804
- European Commission’s Product Environmental Footprint recommendation
Effect of Recycling

Product 1

Product 2

Primary material supply

Primary material supply

Manufacture

Use

End of life

Recycling

Manuf.

Use

decision 1

decision 2
Recycled content or cut-off approach (RC)

Product 1

Primary material supply

manufacture

use

waste management (e.g. incineration)

Product 2

Primary material supply

manufacture

Recycling

use

waste management (e.g. incineration)
Recycled content or cut off (RC)

- First use of (primary) material bears environmental impacts of extraction and refinement
- Secondary materials are considered according to the recycled content in the product at issue
- Secondary material leaves system without burdens
- No credits are granted
Recycled content (or “cut off”) approach

- Product 1
- Product 2

Primary material supply

Manufacture

End of life

Use

Recycling

Manuf.

Use

decision 1

time

decision 2

Env. impacts
Interpretation of recycled content approach (RC)

- Prompt accounting of actually occurring environmental impacts
- No compensation of increased amount of concentrated material with reduced natural capital
  => in line with **strong sustainability** concept
- Secondary materials are considered according to the recycled content in the product at issue
Cut-off (sunk costs) approach to support strong sustainability

- **Choice of materials with a perspective of strong sustainability:**
  all emissions caused today are booked today

=> **Precautionary principle**
  it is unsure, whether our descendants need / wish our “preinvestment” (buildup of a material stock)
Avoided burden (or “end of life recycling”) EOR

Product 1

Primary material supply

manufacture

use

waste management (e.g. incineration)

Recycling

Product 2

manufacture

use

waste management (e.g. incineration)
Avoided burden approach (EOR)

- Recycling of a material from product system 1 avoids extraction and manufacturing of primary material in product system 2
- All avoided future expenses and emissions are completely attributed to the present product 1, which delivers the secondary material after its service life
Avoided burden (or “end of life recycling”) EOR

Allocation in multi-output processes and recycling

- Env. impacts
  - Primary material supply
  - Manufacture
  - Use
  - Recycling

+ time

decision 1

decision 2

Product 1

Product 2

Primary material supply

Manuf.

Use

= avoided burden, (credit)
Credits require offsetting position

- Avoided burdens (credits) accounted for in Product system 1 call for off-setting position in (future) product system 2, which uses the recycled material.
Interpretation of the avoided burden approach

• Future Generations grant an “environmental loan”, environm. credits on primary material used today
• In return, future generations receive concentrated material in infrastructures and consumer durables
• Approach in line with weak sustainability concept
• Aluminium example
  “Environmental loan”: ca. 300 Mio. tons of CO\textsubscript{2}-eq per year
  “inheritance”: ca. 19 Mio. tons concentrated aluminium per year
Critique on the avoided burden approach

- Actual environmental impacts occurring today are not perceived, because impacts are substantially reduced by credits granted.
- Environmental impacts postponed into the future but already occurred in the past (or present) will not be considered in future decisions (sunk impacts!)
Environmental Product Declaration (EPD)

- Type III eco-label
- based on life cycle assessment
- Product Category Rules specify
  - methodology (inventory, impact assessment)
  - reporting
  - certification (third party verification)
European Standard EN 15804 on Environmental Product Declarations

• Load and benefits beyond the system boundary
• not mandatory
• to be reported separately
• based on net output flows of secondary materials
European Standard EN 15804 Information module D
EN 15804 EPD allocation

- Product 1
  - Primary material supply
  - Manufacturing
  - Use
  - Waste management (e.g. incineration)
  - Recycling
  - E_D

- Recycling
  - E_{recycled}

- Product 1
  - Primary material supply
  - Manufacturing
  - Use
  - Waste management (e.g. incineration)
  - Recycling
  - E^* V

- Allocation in multi-output processes and recycling
EN 15804 EPD approach

• Net output flow of secondary material
  – input flow: $R_1$
  – output flow: $R_2$
  – net output flow = $R_2 - R_1$

• Benefits and loads beyond the product system
  – loads: $(R_2 - R_1) \times E_{\text{recycling} \text{EoL}}$
  – benefits: $-(R_2 - R_1) \times E^{*}_V$
Product Environmental Footprint (PEF)

- End of Life Recycling
- 50:50 allocation of primary production and recycling efforts
- 100% credits for electricity and heat recovered
Allocation in multi-output processes and recycling

Product Environmental Footprint (PEF)

The RUaEP per unit of analysis \(^{(104)}\) is calculated with the following formula:

\[
(1 - \frac{R_1}{2}) \times E_V + \frac{R_1}{2} \times E_{\text{recycled}} + \frac{R_2}{2} \times \left(E_{\text{recycling EoL}} - E^*_V \times \frac{Q_S}{Q_P}\right) + R_3 \times \\
(E_{ER} - \text{LHV} \times X_{ER,heat} \times E_{SE,heat} - \text{LHV} \times X_{ER,elec} \times E_{SE,elec}) + \\
\left(1 - \frac{R_2}{2} - R_3\right) E_D - \frac{R_1}{2} \times E_D
\]

The abovementioned formula can be divided into 5 blocks:

\[
\text{VIRG}_{\text{IN}} + \text{REC}_{\text{IN}} + \text{REC}_{\text{OUT}} + \text{ER}_{\text{OUT}} + \text{DISP}_{\text{OUT}}
\]
Allocation in multi-output processes and recycling

**PEF approach**

Product 1

1. **Primary material supply**
   - $E_V$
   - $1-R_1$

2. **manufacture**

3. **use**
   - $1-R_2$

4. **waste management (e.g. incineration)**
   - $E_D$
   - $R_2$

5. **Recycling**
   - $E_{recycling}EoL$
   - $R_1$

6. **waste management (e.g. incineration)**
   - $E^{*}_D$
   - $E^{*}_V$

Product 1

1. **Primary material supply**

2. **manufacture**

3. **use**

4. **Recycling**

5. **waste management (e.g. incineration)**
   - $E^{*}_D$
   - $E^{*}_V$
PEF approach

- 50% of recycled content in product ($R_1$)
  - is assessed with impacts from pre-product recycling
  - gives rise for credits due to avoiding waste management

- 50% of share recycled after end of life ($R_2$)
  - is assessed with post consumer recycling
  - gives rise for credits due to avoiding primary production (eventually quality-corrected)
  - is NOT assessed with end of life waste management
Allocation in multi-output processes and recycling

EPD of Titanium Zinc sheets and of Eternit Façade panels
Environmental impacts of Eternit Façade panels (17.2 kg/m²)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit per ton</th>
<th>Eterplan</th>
<th>Textura / Natura</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy, non-renewable</td>
<td>[MJ]</td>
<td>9784</td>
<td>14323</td>
</tr>
<tr>
<td>Primary energy, renewable</td>
<td>[MJ]</td>
<td>3887</td>
<td>3890</td>
</tr>
<tr>
<td>Global warming potential (GWP 100)</td>
<td>[kg CO₂-eq.]</td>
<td>734</td>
<td>929</td>
</tr>
<tr>
<td>Ozone depletion potential (ODP)</td>
<td>[kg R11-eq.]</td>
<td>88.9 · 10⁻⁶</td>
<td>89.8 · 10⁻⁶</td>
</tr>
<tr>
<td>Acidification potential (AP)</td>
<td>[kg SO₂-eq.]</td>
<td>2.63</td>
<td>4.73</td>
</tr>
<tr>
<td>Eutrophication potential (EP)</td>
<td>[kg phosphate-eq.]</td>
<td>0.24</td>
<td>0.34</td>
</tr>
<tr>
<td>Summer smog potential (POCP)</td>
<td>[kg ethane-eq.]</td>
<td>0.32</td>
<td>0.52</td>
</tr>
</tbody>
</table>
Environmental impacts of Titanium Zinc sheets (7.2 kg/m²)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit per kg</th>
<th>Sum of production and recycling potential</th>
<th>Production</th>
<th>Recycling potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy, non-renewable</td>
<td>[MJ]</td>
<td>16.3</td>
<td>45.5</td>
<td>- 29.2</td>
</tr>
<tr>
<td>Primary energy, renewable</td>
<td>[MJ]</td>
<td>0.9</td>
<td>3.8</td>
<td>- 2.9</td>
</tr>
<tr>
<td>Global Warming Potential (GWP)</td>
<td>[kg CO₂ eqv.]</td>
<td>0.96</td>
<td>2.62</td>
<td>- 1.65</td>
</tr>
<tr>
<td>Ozone Depletion Potential (ODP)</td>
<td>[kg R11 eqv.]</td>
<td>0.18 * 10⁻⁶</td>
<td>0.56 * 10⁻⁶</td>
<td>- 0.39 * 10⁻⁶</td>
</tr>
<tr>
<td>Acidification Potential (AP)</td>
<td>[kg SO₂ eqv.]</td>
<td>3.32 * 10⁻³</td>
<td>13.5 * 10⁻³</td>
<td>- 10.2 * 10⁻³</td>
</tr>
<tr>
<td>Eutrophication Potential (EP)</td>
<td>[kg PO₄ eqv.]</td>
<td>0.28 * 10⁻³</td>
<td>1.03 * 10⁻³</td>
<td>- 0.76 * 10⁻³</td>
</tr>
<tr>
<td>Photochemical Ozone Creation Potential (POCP)</td>
<td>[kg ethene eqv.]</td>
<td>0.29 * 10⁻³</td>
<td>1.10 * 10⁻³</td>
<td>- 0.80 * 10⁻³</td>
</tr>
</tbody>
</table>
Environmental impacts per m² cladding

- Primary energy, non-renewable
- Primary energy, renewable
- Global Warming Potential
- Ozone Depletion Potential
- Acidification Potential
- Eutrophication Potential
- Photochemical Ozone Creation Potential

- Titanium zinc
- Titanium zinc, credits
- Eternit
Exercise: application of recycling allocation approaches

• Calculate climate change impact (in kg CO₂-eq) of 10 kg of aluminium beverage cans

• apply the four models
  – recycled content
  – avoided burden
  – EN 15804 (EPD) approach
  – PEF approach