Life Cycle Assessment
A product-oriented method for sustainability analysis

UNEP LCA Training Kit
Module e – Impact assessment
ISO 14040 framework

Life cycle assessment framework

Goal and scope definition

Inventory analysis

Impact assessment

Interpretation

Direct applications:
- Product development and improvement
- Strategic planning
- Public policy making
- Marketing
- Other

Source: ISO 14040
Life cycle impact assessment

- ISO: This LCA phase is aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system.
  - International Standard ISO 14044
  - Technical Report ISO/TR 14047

- This is the third phase of an LCA
  - LCIA
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<tr>
<td>Modules B, C and D provide necessary background information for this module.</td>
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The principle of characterisation

- CO\textsubscript{2} and CH\textsubscript{4} both contribute to climate change.
- Global Warming Potential (GWP) is a measure for climate change in terms of radiative forcing of a mass-unit of greenhouse gas.
- Example calculation:
  - 5 kg CO\textsubscript{2} \hspace{1cm} \text{GWP = 1}
  - 3 kg CH\textsubscript{4} \hspace{1cm} \text{GWP = 21}
  - 1 \times 5 + 21 \times 3 = 65
  - 68 kg CO\textsubscript{2}-eq
The principle of characterisation

Simple conversion and aggregation:

$$\text{IndicatorResult}_{cat} = \sum_{subs} \text{CharFact}_{cat,subs} \times \text{InventoryResult}_{subs}$$

- **CO\textsubscript{2} and CH\textsubscript{4}**
- **GWP (1 and 21)**
- **5 and 3 kg**
- **68 kg CO\textsubscript{2}-eq**
- **Infrared radiative forcing**
- **IPCC climate model**

**Climate change**
Two main groups of choice for indicator

- **Midpoint-oriented** place indicators relatively close to the interventions.
  - These have the advantage of relying primarily on scientific information and well-proven facts
  - The amount of subjectivity and uncertainty involved is limited.

- **Endpoint-oriented** place indicators relatively close to the endpoints.
  - These have the advantage of presenting information in an appealing and understandable way: human health is easier to interpret and communicate than ozone layer depletion.
The principle of characterisation

- **Midpoint characterisation**
  examples: CML-IA, EDIP, TRACI, …

- **Endpoint characterisation**
  examples: Eco-indicator 99, Eco-scarcity, EPS, …

- **Efforts to combine/harmonize midpoint and endpoint**
  examples: Impact 2002+, Recipe, …
The principle of characterisation

Life cycle inventory results

LCI results assigned to impact category

Impact category

Characterisation model

Category indicator

Environmental relevance

Category endpoint(s)

Example

Cd, CO₂, NOₓ, SO₂, etc. (kg/functional unit)

Acidification

Acidifying emissions (NOₓ, SO₂, etc. assigned to acidification)

Proton release (H⁺ aq)

- forest
- vegetation
- etc.
• **Structure of endpoint-oriented model** (Eco-indicator 99)

The principle of characterisation
Impact categories, category indicators, characterisation models

- **Impact category**
  - ISO 14040 definition: class representing environmental issues of concern to which LCI results may be assigned

- **Examples:**
  - climate change
  - acidification
Impact categories, category indicators, characterisation models

• **Category indicator:**
  – ISO 14040 definition: quantifiable representation of an impact category

• **Examples:**
  – infrared radiative forcing
  – proton release
Characterisation model:
  - non-ISO definition: mathematical model of the impact of elementary flows with respect to a particular category indicator

Examples:
  - IPCC model for climate change
  - RAINS model for acidifying substances

Provides the basis for a characterisation factor
Impact categories, category indicators, characterisation models

• **Characterisation factor:**
  – ISO 14040 definition: a factor derived from a characterisation model which is applied to convert the assigned LCI results to the common unit of the category indicator.

• **Examples:**
  – Global warming potential (GWP)
  – Acidification potential (AP)
### Example Impact categories, characterisation models, factors & units

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Indicator</th>
<th>Characterisation model</th>
<th>Characterisation factor</th>
<th>Equivalency unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abiotic depletion</td>
<td>Ultimate reserve/annual use</td>
<td>Guinee &amp; Heijungs 95</td>
<td>Abiotic depletion potential</td>
<td>kg Sb eq.</td>
</tr>
<tr>
<td>Climate change</td>
<td>Infrared radiative forcing</td>
<td>Intergovernmental Panel on Climate Change</td>
<td>Global warming potential</td>
<td>kg CO₂ eq.</td>
</tr>
<tr>
<td>Stratospheric ozone depletion</td>
<td>Stratospheric ozone breakdown</td>
<td>World Meteorological Organization model</td>
<td>Stratospheric ozone layer depletion potential</td>
<td>kg CFC-11 eq.</td>
</tr>
<tr>
<td>Human toxicity</td>
<td>Predicted daily intake, Accepted daily intake</td>
<td>EUSES, California Toxicology Model</td>
<td>Human toxicity potential</td>
<td>kg 1,4-DCB eq.</td>
</tr>
<tr>
<td>Ecological toxicity</td>
<td>PEC, PNEC</td>
<td>EUSES, California Toxicology Model</td>
<td>AETP, TETP, etc.</td>
<td>kg 1,4-DCB eq.</td>
</tr>
<tr>
<td>Photo-oxidant smog formation</td>
<td>Tropospheric ozone production</td>
<td>UN-ECE trajectory model</td>
<td>Photo-oxidant chemical potential</td>
<td>kg C₂H₆ eq.</td>
</tr>
<tr>
<td>Acidification</td>
<td>Deposition/critical load</td>
<td>Regional Acidification Information &amp; Simulation</td>
<td>Acidification potential</td>
<td>kg SO₂ eq.</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Impact categories, category indicators, characterisation models

• **LCA has essentially a flow character:**
  – emissions/ resource extractions in kg per functional unit

• **Impacts have therefore a similar character:**
  – climate change/toxicity/depletion/etc. per functional unit

• **Some impacts do not fit well:**
  – loss of biodiversity/introduction of GMOs/etc.
Classification

• ISO 14040 definition: Classification is the assignment of LCI results to impact categories

• Example: CO$_2$ and CH$_4$ are assigned to climate change
## Classification

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Incandescent lamp</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate change</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{CO}_2$ to air</td>
<td>800000 kg</td>
<td>50000 kg</td>
</tr>
<tr>
<td>$\text{CH}_4$ to air</td>
<td>230 kg</td>
<td>24 kg</td>
</tr>
<tr>
<td><strong>Ecotoxicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper to water</td>
<td>3 g</td>
<td>20 g</td>
</tr>
</tbody>
</table>
• **ISO 14040 definition**: Characterisation is the calculation of category indicator results

• **Example**: 5 kg CO$_2$ and 3 kg CH$_4$ yield 68 kg CO$_2$-eq
• **Formula:**

\[
\text{IndicatorResult}_{\text{cat}} = \sum_{\text{subs}} \text{CharFact}_{\text{cat,subs}} \times \text{InventoryResult}_{\text{subs}}
\]

• **Unit of characterisation result:**
  - kg CO$_2$-eq (climate change)
  - kg SO$_2$-eq (acidification)
  - ...

Characterisation
### Example of a characterisation table

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Incandescent lamp</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>120000 kg CO2-eq.</td>
<td>40000 kg CO2-eq.</td>
</tr>
<tr>
<td>Ecotoxicity</td>
<td>320 kg DCB-eq.</td>
<td>440 kg DCB-eq.</td>
</tr>
<tr>
<td>Acidification</td>
<td>45 kg SO2-eq.</td>
<td>21 kg SO2-eq.</td>
</tr>
<tr>
<td>Depletion of resources</td>
<td>0.8 kg antimony-eq.</td>
<td>0.3 kg antimony-eq.</td>
</tr>
<tr>
<td>etc</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>
• **ISO 14040 definition**: calculation of the magnitude of category indicator results to reference information

• **Reference information** (over a given period of time):
  – area (e.g., France, Europe, the world)
  – person (e.g., a Danish citizen)
  – product (e.g., the most frequently used product)
• **Aim:** to better understand the relative magnitude for each indicator results of the product system under study.
  – checking for inconsistencies
  – providing and communicating information on the relative significance of the indicator results
  – preparing for additional procedures
Normalisation

- **Formula:**

\[
\text{Normalized Indicator Result}_{cat} = \frac{\text{Indicator Result}_{cat}}{\text{Reference Value}_{cat}}
\]

- **Unit of normalisation result: year**
## Normalisation

### Example of a normalisation table

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Incandescent lamp</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>$1.2 \times 10^{-11}$ yr</td>
<td>$4 \times 10^{-12}$ yr</td>
</tr>
<tr>
<td>Ecotoxicity</td>
<td>$1.6 \times 10^{-10}$ yr</td>
<td>$2.2 \times 10^{-10}$ yr</td>
</tr>
<tr>
<td>Acidification</td>
<td>$9 \times 10^{-11}$ yr</td>
<td>$4.2 \times 10^{-11}$ yr</td>
</tr>
<tr>
<td>Depletion of resources</td>
<td>$24 \times 10^{-12}$ yr</td>
<td>$9 \times 10^{-13}$ yr</td>
</tr>
<tr>
<td>etc</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Grouping

• ISO 14040 definition: assigning impact categories into one or more sets

• Sorting: grouping on a nominal basis
  – e.g., global versus regional

• Ranking: grouping on an ordinal basis
  – e.g., high, medium and low priority
  – based on value choices
### Example of the results of grouping

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Incandescent lamp</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change</td>
<td>$1.2 \times 10^{-11}$ yr</td>
<td>$4 \times 10^{-12}$ yr</td>
</tr>
<tr>
<td>Depletion of resources</td>
<td>$24 \times 10^{-12}$ yr</td>
<td>$9 \times 10^{-13}$ yr</td>
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<tr>
<td><strong>Regional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidification</td>
<td>$9 \times 10^{-11}$ yr</td>
<td>$4.2 \times 10^{-11}$ yr</td>
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</table>
Weighting

• ISO 14040 definition: converting and possibly aggregating indicator results across impact categories using numerical factors
  – based on value-choices
  – ISO: “weighting shall not be used for comparative assertions disclosed to the public”
Weighting

• **Basis for weighting factors:**
  – monetary values
    • willingness-to-pay
    • damage costs
    • reduction costs
  – *distance-to-target methods*
  – *panel methods*
    • expert panels
    • non-expert panels
  – ...
Weighting

• **Some methods that include weighting**
  – ecopoints/ ecoscarcity
  – Eco-indicator 99
  – EPS
Weighting

• **Formula:**

\[ \text{Weighted Index} = \sum_{cat} \text{Weighting Factor}_{cat} \times \text{Indicator Result}_{cat} \]

• or

\[ \text{Weighted Index} = \sum_{cat} \text{Weighting Factor}_{cat} \times \text{Normalized Indicator Result}_{cat} \]

• **Unit of weighted index:**
  – year (when based on normalized results)
  – euro, dollar, etc. (when based on monetary valuation)
  – but often renamed: ecopoints, millipoints, ELU, etc.
### Example of the results of weighting

<table>
<thead>
<tr>
<th>Weighed index</th>
<th>Incandescent lamp</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted index</td>
<td>$8.5 \times 10^{-10}$ yr</td>
<td>$1.4 \times 10^{-10}$ yr</td>
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</table>
Do you need to review any of the contents of this module?

<table>
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<td>Life cycle costing</td>
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<td>k</td>
<td>Uncertainty in LCA</td>
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<td>Carbon footprint</td>
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