

Environmental Life Cycle Assessment

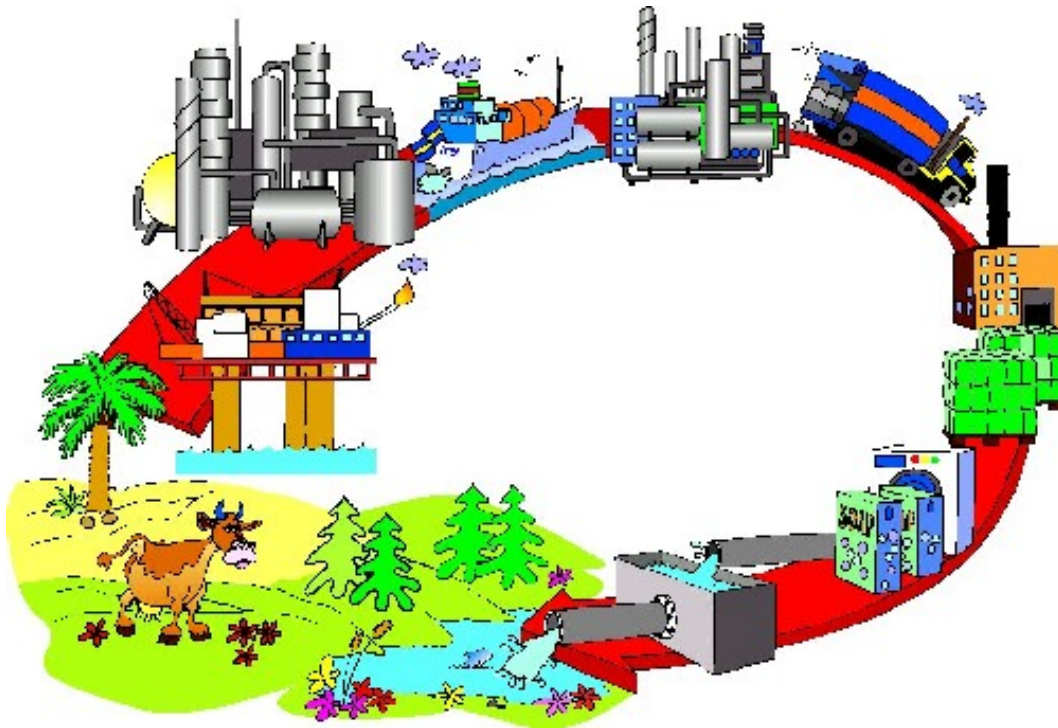
PSE 476/FB 576

Lecture 3: Basic Components of an LCA

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What is a Life Cycle Assessment ?

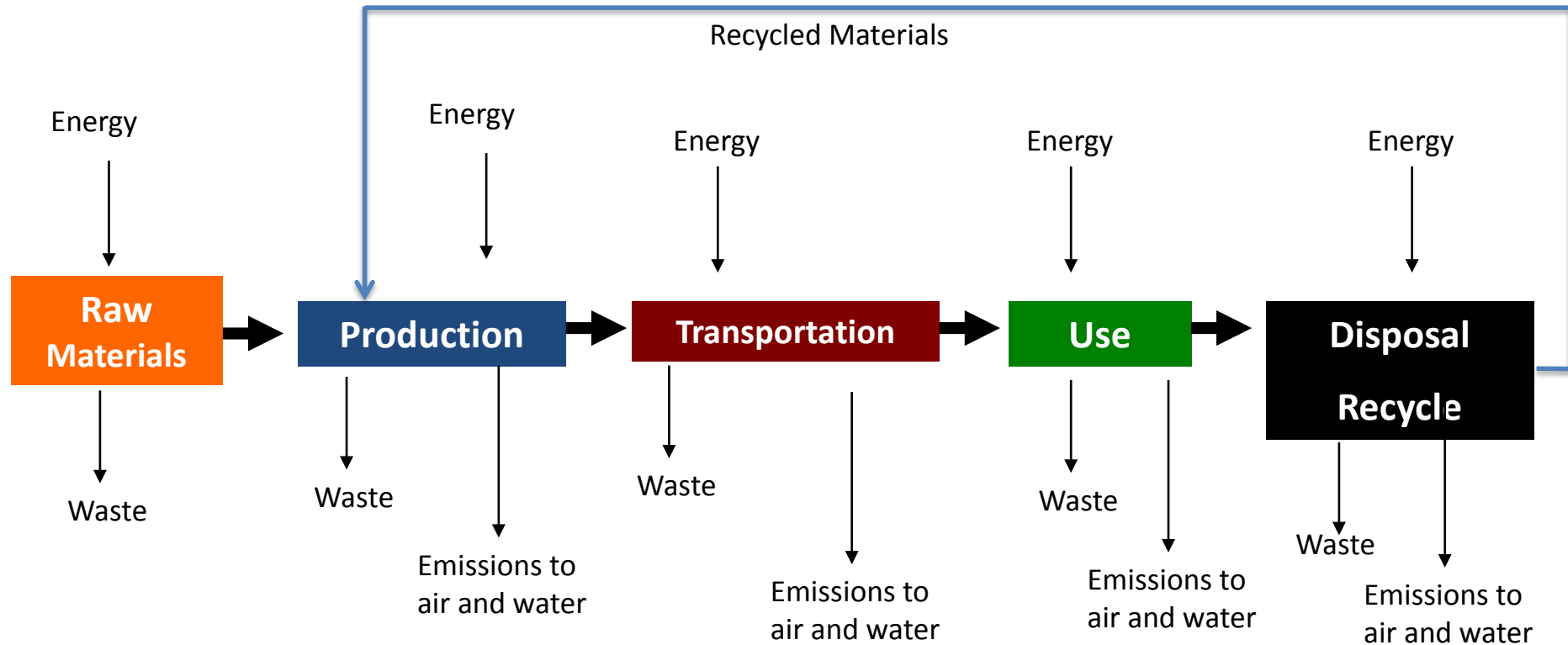
Life Cycle consecutive and interlinked stages of a product system, from the raw material acquisition or generation from natural resources to final disposal [ISO 14044:2006E].

Life Cycle Assessment (LCA) compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14044:2006E].

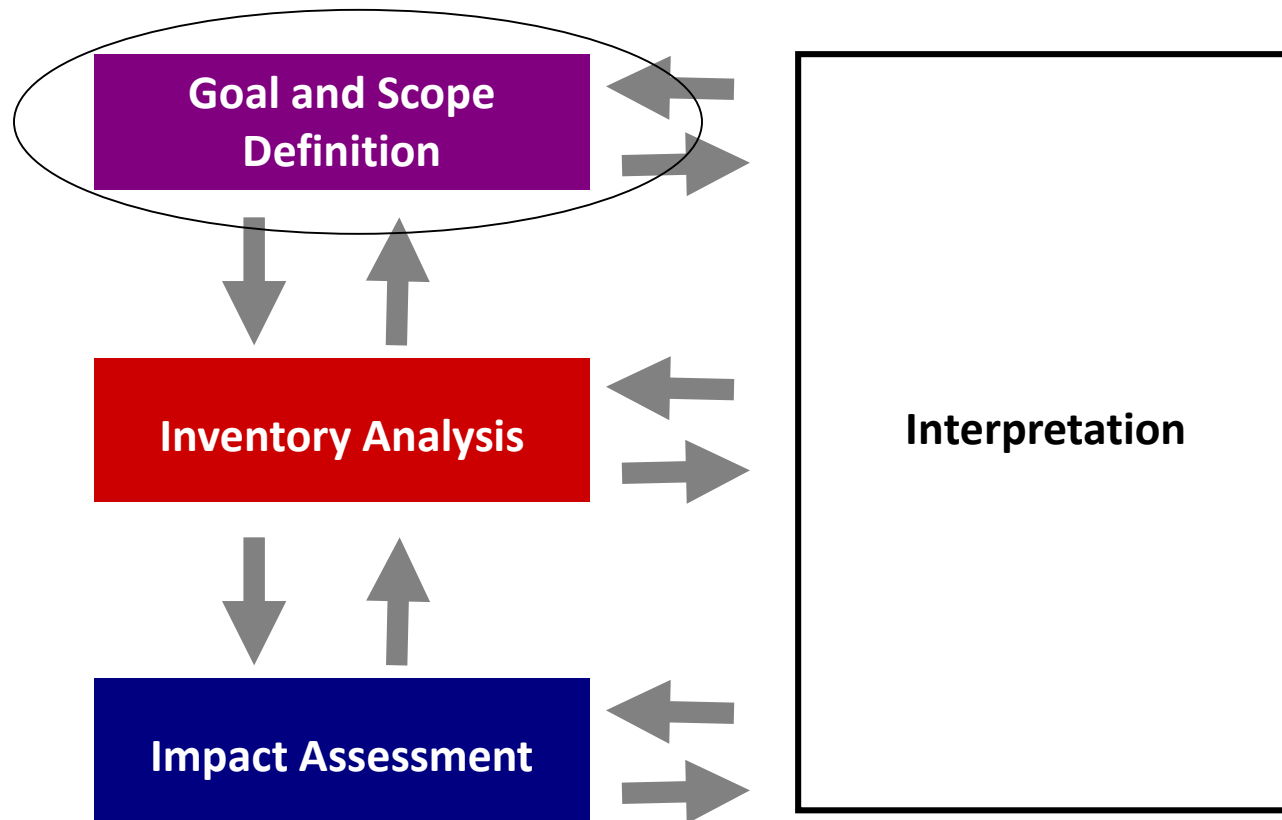
Types of LCA

- **Cradle to Grave:** Considers everything from harvesting materials to the disposal of the finished goods
- **Cradle to Gate:** raw materials to finished good (no use or end life considerations)
- **Gate to gate:** taking products and raw materials from the entrance gate of a manufacturing plant to the finished product leaving the shipping gate (only onsite emissions)
- **Other...**

Life Cycle Stages



Major Parts of a Life Cycle Assessment





Defining Goals

- Should state the intent of the study
 - Intended application
 - Intended use
 - Intended audience
- Should also include reason for the study





Defining Scope

- Define functional unit of a product
- Establish system boundaries for the LCA
 - What stages and operations are included?
- Determine data collection methods
 - Literature
 - Measurements
 - Interviews
 - Other...





Functional Unit

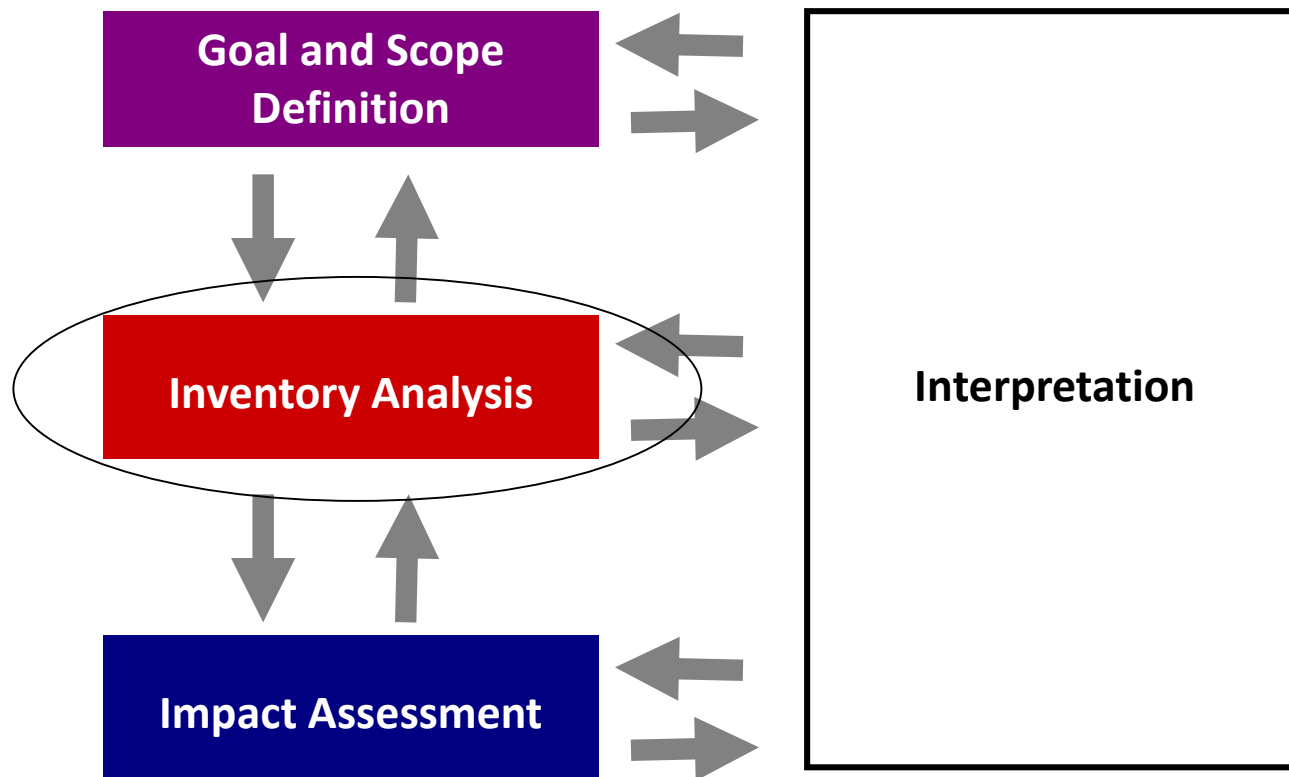
- **Definition:** Quantified performance of a product system for use as a reference unit (ISO 14044: 2006E)
- The *service* delivered that serves as a reference quantity for the study
- Define a functional unit of product
 - Example: 100 disposable paper cups vs 1 glass container washed 99 times
 - The functional unit is _____
- The basis for comparison



Functional Unit

- Brainstorm: functional unit for lipstick?

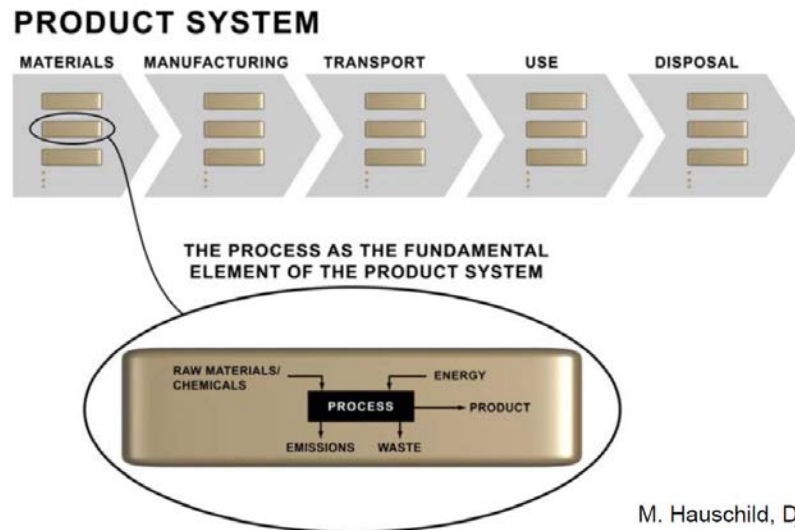
Major Parts of a Life Cycle Assessment



Life Cycle Inventory Analysis(LCI):

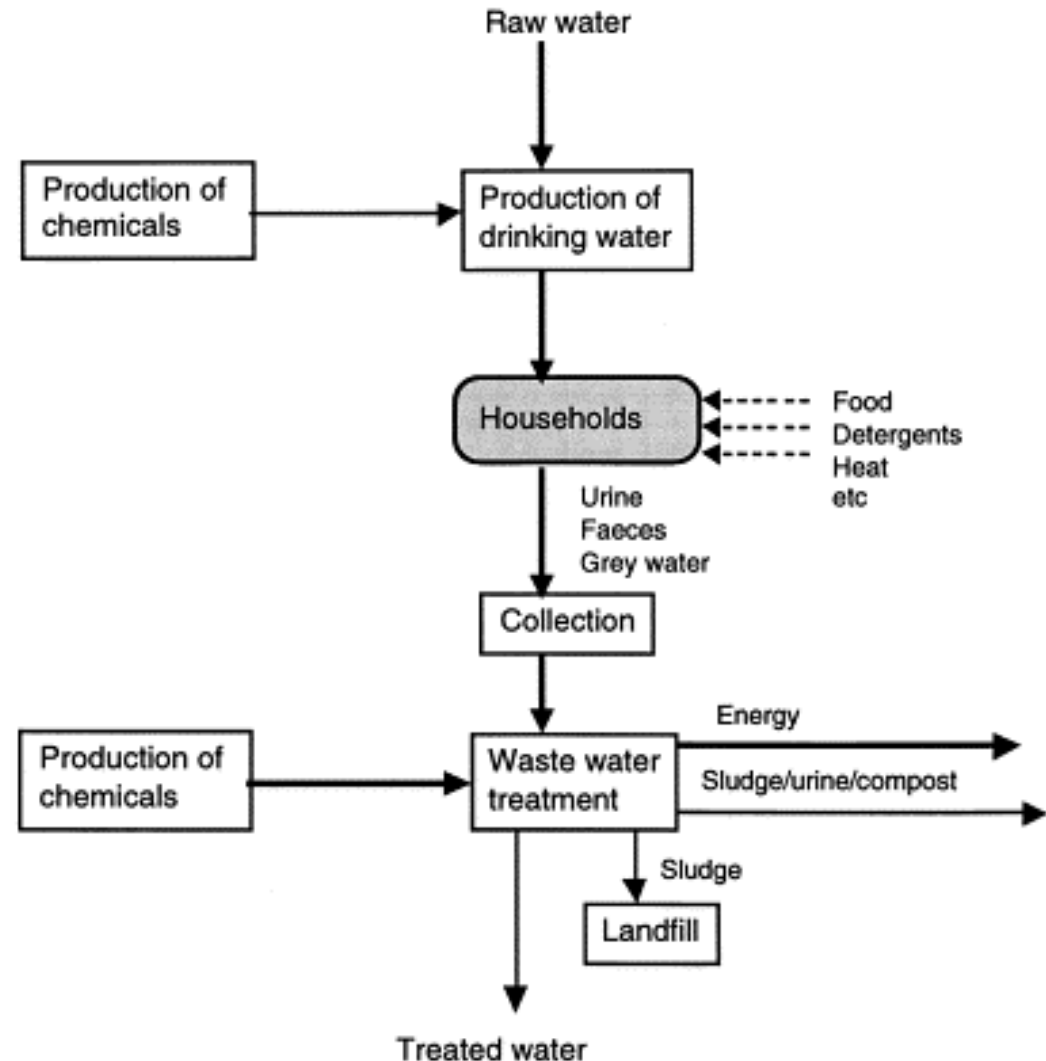
- Definition: Phase of the life cycle assessment involving the compilation and the quantification of inputs and outputs for a product throughout its life cycle [ISO 14044:2006(E)]
- Definition of the process
- Definition of all mass and energy inputs to the process
- Defining all flows from the “technosphere” into and out of the surrounding environment, called **elementary flows**

Building an LCI



Life Cycle Inventory (LCI):

- **Elementary flows:** material or energy entering the system being studied that has been drawn from the environment *without previous human transformation*, or material or energy leaving the system being studied that is released into the environment *without subsequent human transformation*. [ISO 14044:2006E].





- **Elementary flows:** which of the following are elementary flows?
- A tree in a natural forest to be harvested
- A log that has been de-limbed and bucked
- Cotton boll in a farmer's field ready to be harvested
- A bale of cotton on a truck
- Oil being put into a car
- Wastewater to the city treatment plant
- Treated waste water from a textiles factory discharged to the river
- Heat radiating off a large chemical reactor
- Gasses coming out of a stack from a wood drying kiln
- Steam from a power boiler stack
- Gasses like CO₂ from a power boiler stack
- Garbage thrown on the roadside
- Garbage sent to a landfill
- Fugitive gasses like methane leaving the landfill
- Gas being delivered to a gas station
- Crude oil from the ground

U.S. Life Cycle Inventory Database

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NREL's Buildings research supports the U.S. Department of Energy's [Building Technologies Program](#).



U.S. Life Cycle Inventory Database

NREL and its partners created the U.S. Life Cycle Inventory (LCI) Database to help life cycle assessment (LCA) practitioners answer questions about environmental impact. This [database](#) provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly in the U.S.

The goals of the U.S. LCI Database project are:

- Maintain data quality and transparency
- Cover commonly used materials, products, and processes in the United States with up-to-date, critically reviewed LCI data
- Support the expanded use of LCA as an environmental decision-making tool
- Maintain compatibility with international LCI databases
- Provide exceptional data accessibility
- Be fully and sustainably supported
- Support U.S. industry competitiveness.

Read the plan to achieve the goals of the LCI Database Project in the [U.S. Life Cycle Inventory Database Roadmap](#) .

EVENTS

NREL Visitors Center Saturday Open House

October 6, 2012, 9:00 - 4:00

MST

Golden, CO

SEAC Sponsors Energy Analysis Seminars

Second Thursday of the month
Golden, Colorado, and
Washington, D.C.

[More Events](#)

U.S. Life Cycle Inventory Database Roadmap



U.S. Life Cycle Inventory Database Dataset Additions





Outputs

BOD5, Biochemical Oxygen Demand	water/unspecified	ElementaryFlow kg	1.19e-03
Carbon dioxide, biogenic	air/unspecified	ElementaryFlow kg	1.41e+00
Carbon dioxide, fossil	air/unspecified	ElementaryFlow kg	4.74e-01
Carbon monoxide	air/unspecified	ElementaryFlow kg	1.15e-03
Containerboard, average production, at mill	Paper Manufacturing/Pulp, Paper, and Paperboard Mills	ProductFlow kg	1.11e+00
Cooling water, non-contact	water/unspecified	ElementaryFlow kg	8.49e+00
Dinitrogen monoxide	air/unspecified	ElementaryFlow kg	4.41e-06
Hydrogen sulfide	air/unspecified	ElementaryFlow kg	9.18e-05
Methane	air/unspecified	ElementaryFlow kg	8.76e-06
Nitrogen oxides	air/unspecified	ElementaryFlow kg	2.16e-03
NMVOC, non-methane volatile organic compounds, unspecified origin	air/unspecified	ElementaryFlow kg	8.58e-05
Particulates, unspecified	air/unspecified	ElementaryFlow kg	5.12e-04
Process effluent	water/unspecified	ElementaryFlow kg	3.18e+01
Sulfur dioxide	air/unspecified	ElementaryFlow kg	2.77e-03
Suspended solids, unspecified	water/unspecified	ElementaryFlow kg	1.89e-03
Water, evaporated	air/unspecified	ElementaryFlow kg	3.66e+00



Details for Containerboard, average production, at mill



[Return to Results List](#)

Activity

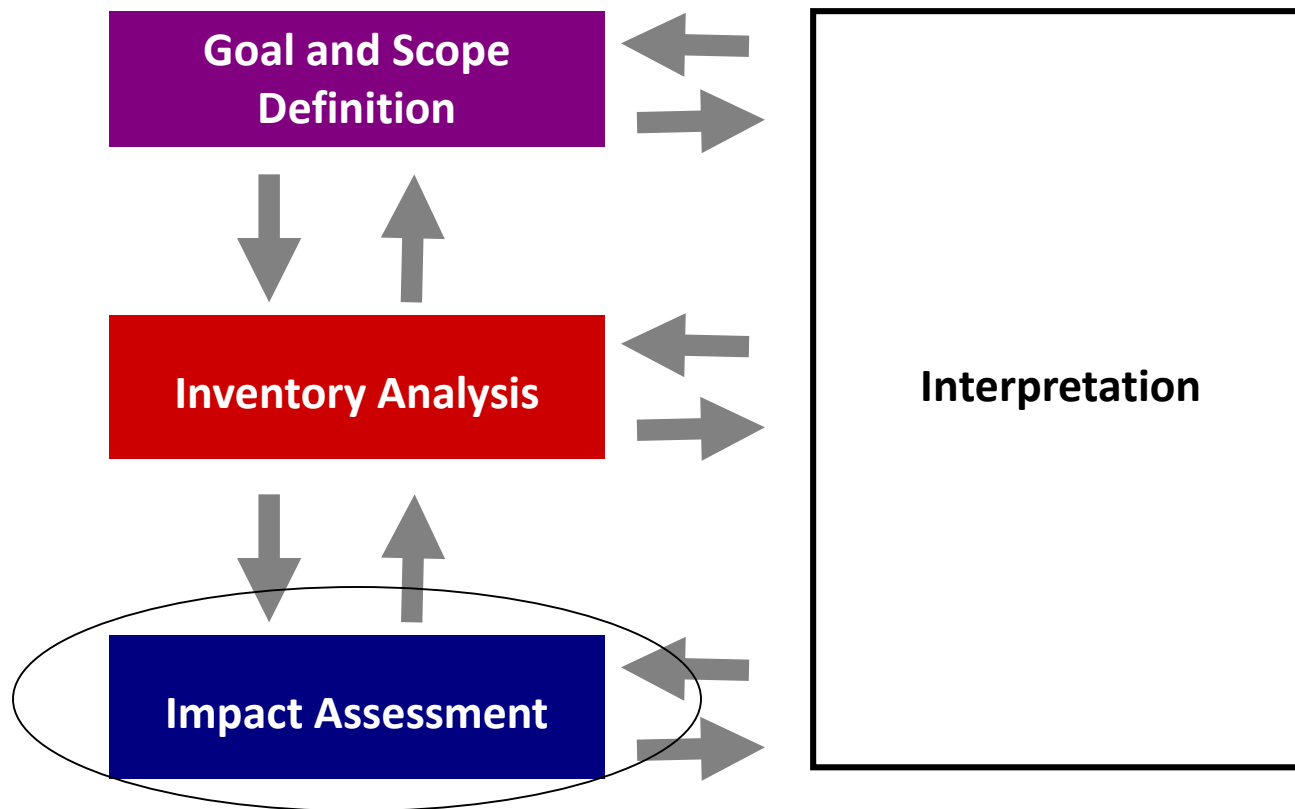
Modeling

Administrative

Exchanges

Flow	Type	Amount	Comment
Inputs			
Anthracite coal, at mine	root/Flows	ProductFlow MJ	2.14e+00
Cooling water, non-contact	water/unspecified	ElementaryFlow kg	8.83e+00
Diesel, at refinery	root/Flows	ProductFlow MJ	1.61e-01
Diesel, at refinery	root/Flows	ProductFlow MJ	1.12e-01
Dummy, BOD5, to municipal wastewater treatment	root/Flows	ProductFlow kg	9.18e-04
Dummy, disposal, solid waste, unspecified, to unspecified incinerator	root/Flows	ProductFlow kg	1.17e-02
Dummy, disposal, solid waste, unspecified, to unspecified land application	root/Flows	ProductFlow kg	1.50e-02
Dummy, disposal, solid waste, unspecified, to unspecified landfill	root/Flows	ProductFlow kg	6.10e-02

Important Aspects of Life Cycle Assessment

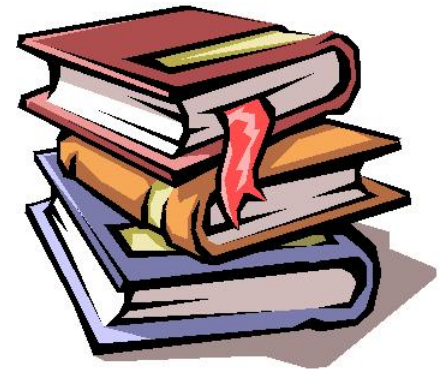




Impact Assessment

Definition:

Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout its life cycle of the product [ISO 14044:2006E].





Impact Assessment: ISO Standard

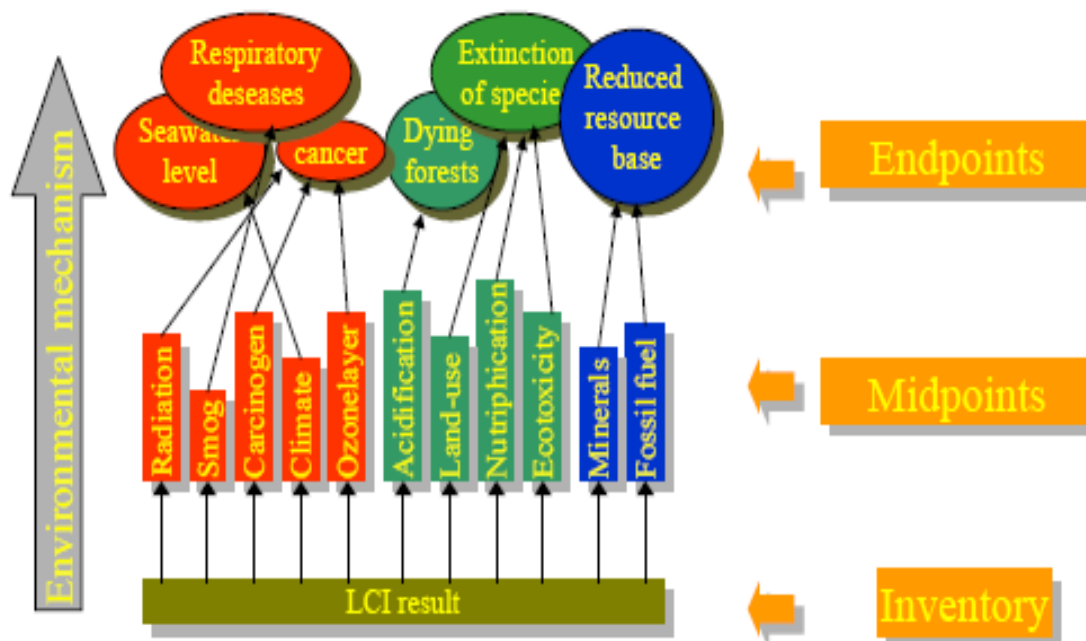
- Overall steps for LCA are defined in ISO 14044
- Defined as: a compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system through its life cycle.
- Protocol for an impact assessment is explained in ISO 14042
- Mandatory elements for an impact assessment
 - Selection of **impact categories**
 - Assignment of inventory analysis results to impact categories (**classification**)
 - Calculation of impact category indicator results (**characterization**)
- Optional elements
 - Calculation of the magnitude of category indicators (**normalization**), to show the significance of the calculated impact category result to the overall environmental problem
 - Grouping and ranking of the impact categories
 - **Weighting** of the impact categories (may not be used if competing products are compared and presented to public)



Impact Assessment: ISO Standard

- Some assessments use midpoints, other use endpoints.
 - LCI Results: flows of mass or energy
 - Midpoints: examples: radiation, smog, ozone layer....
 - Endpoints: **Human health, ecosystems, resources**
 - Interpretation
- Most certain
Less certain
Even less certain

Least certain



Impact Assessment: Choice of Impact Categories

- TRACI, The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts

- Global Warming
- Acidification
- Human health: Carcinogenics
- Human Health: Non carcinogenics
- Respiratory Effects
- Eutrophication
- Ozone Depletion
- Ecotoxicity
- Smog

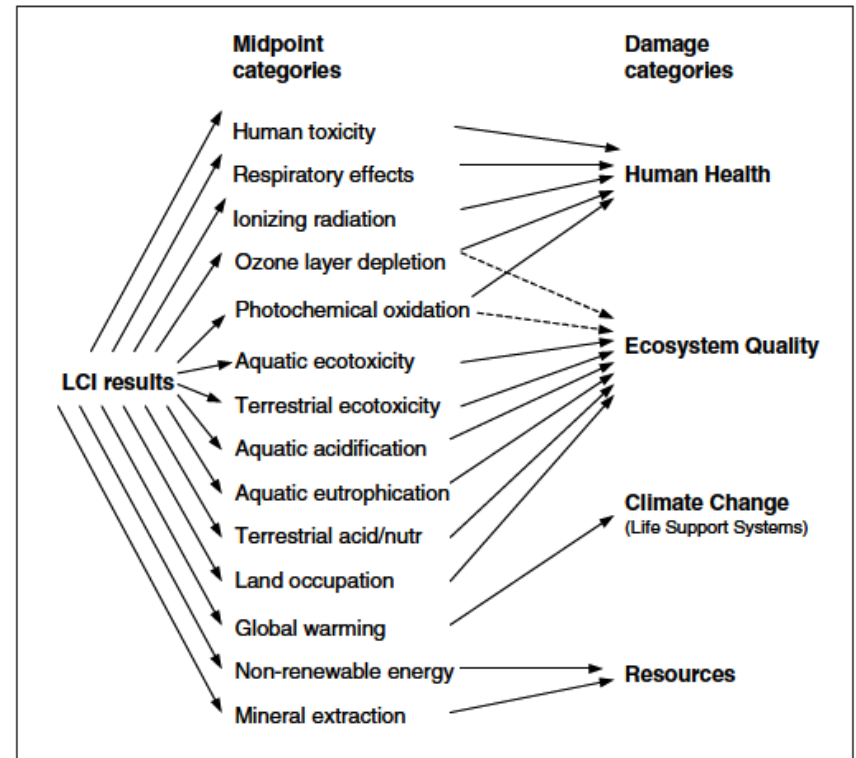
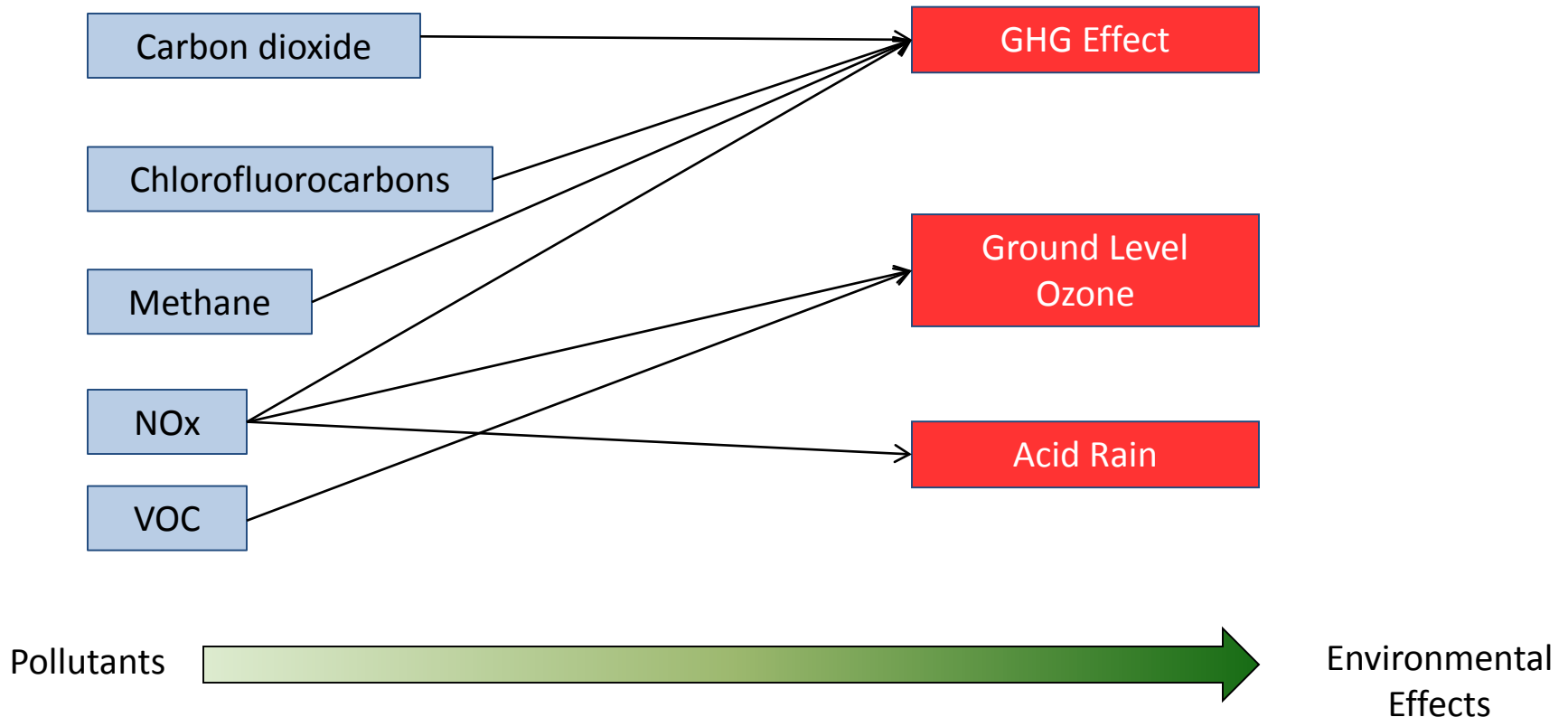


Fig. 1: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories, based on Jolliet et al. (2003a)

Impact Assessment: Classification

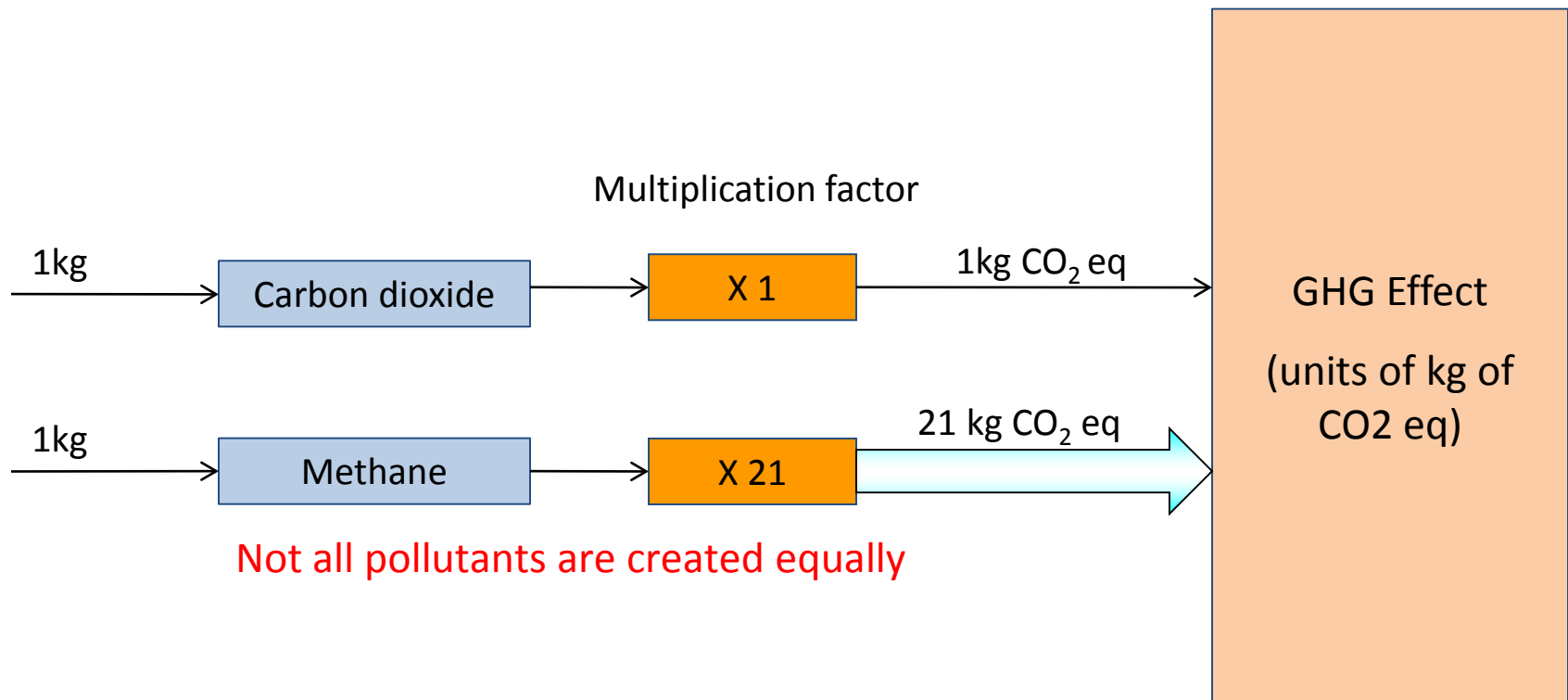
From LCI:



- Classification sorts pollutants according to the effects they have on the environment

Impact Assessment: Characterization

Characterization factor: factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to category indicators and to category endpoints [ISO 14044:2006E]





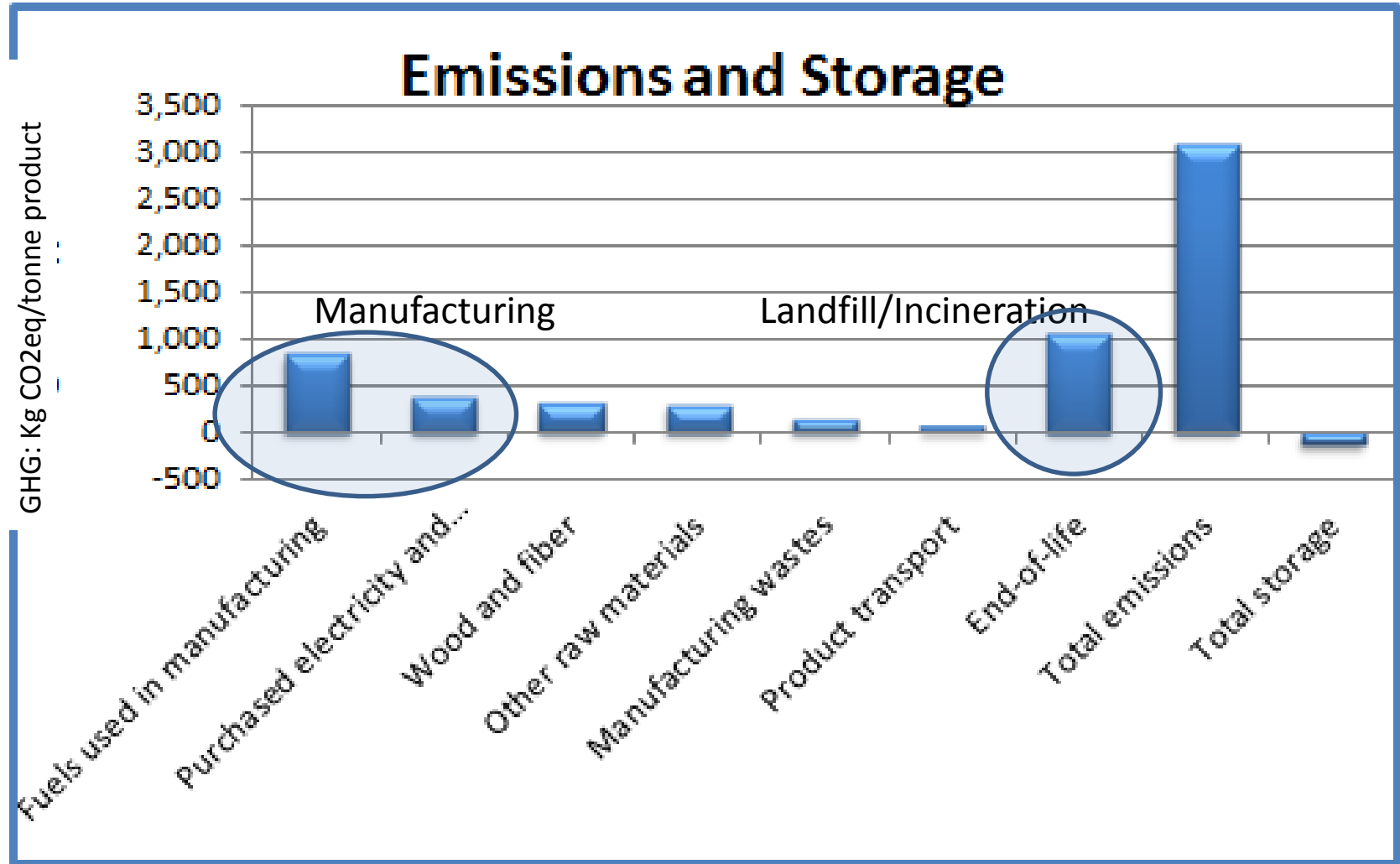
Impact Assessment: ISO Standard

Example

- **Impact Categories:** smog formation, global warming, forest depletion
- Inventory results: particulates, SO₂., trees consumed
- **Classification:**
 - Particulates to smog
 - SO₂ to smog and global warming
 - Trees consumed to forest depletion and to global warming
- **Characterization:** Calculations of category results, eg, 10 mg of particulates causes 20 units of smog and 10 mg of SO₂ causes 5 units of smog, so a LCI with 5 mg of particulate and 10 mg of SO₂ produces 15 units of smog as the impact category result

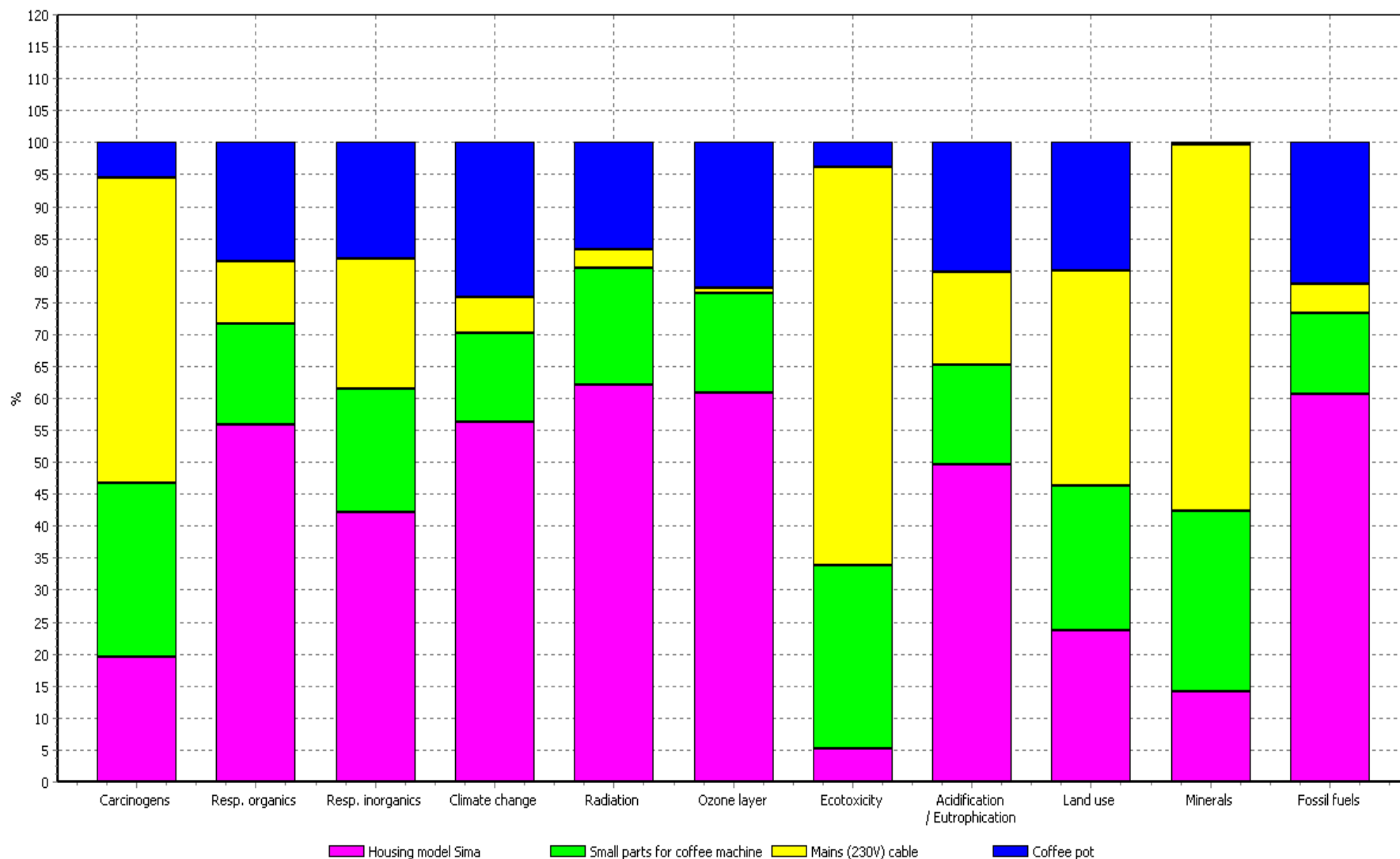


Impact Assessment: Climate Change as an Example: Hot Spot Identification



Impact Assessment

Impact categories: Hot Spot Identification





Normalization

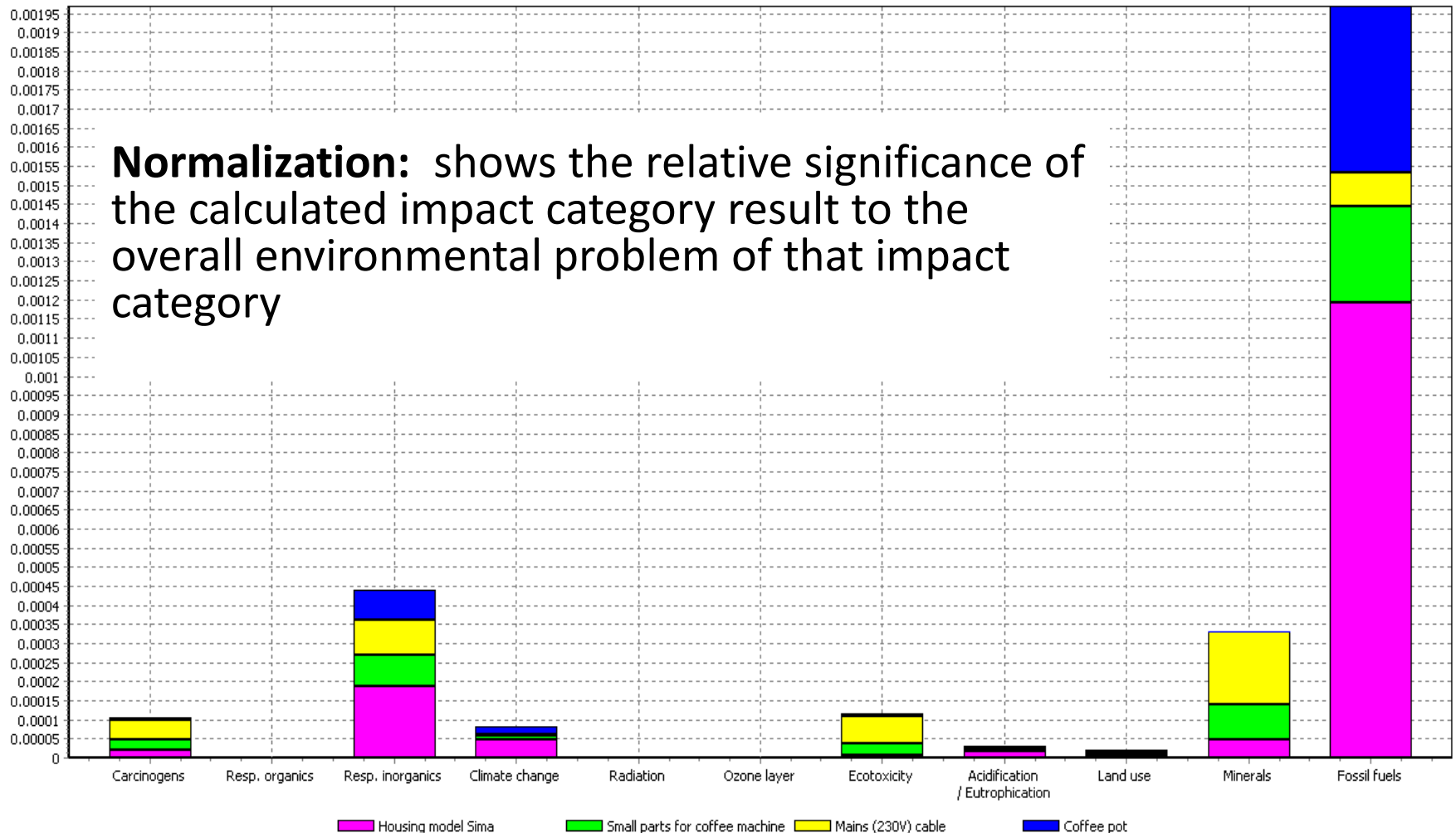
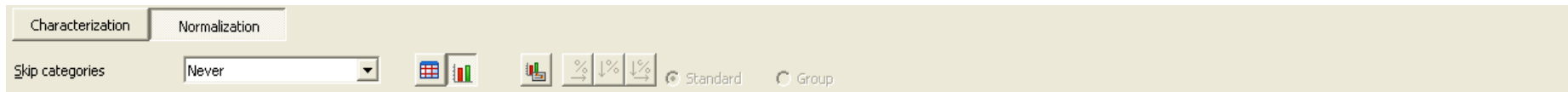
Normalization: shows the relative significance of the calculated impact category result to the overall environmental problem of that impact category

Helps answer the question: What percentage of GHG emissions does this product contribute relative to all the GHG emissions from a certain country/state/person/globe?

The category impact results for a certain product or service is divided by a normalization reference.

Needs more fleshing out. See page 105 Environmental Assessment of Products, Wenzel et. al.

Impact Assessment: Normalization





Class Activity

Your Aunt Mabel has been living in the same house for the last 40 years in an older neighborhood backed up to a large undeveloped wooded land mass with several significant creeks and a river, about 20 square miles. For each of the items, respond with a 1-10 rating, 1 representing the mildest dislike of the scenario and 10 representing the strongest dislike of a scenario.

_____ A company wants to establish a golf course on the property on about 1/5th of the land. Pesticides, herbicides and fertilizers applied to the golf course are expected to somewhat effect birds, squirrels and fish. Also effected will be many of the plants surrounding the course as well as the water in the creeks and rivers

_____ A company wants to harvest unique, uncommon, stray rocks that lie on the ground that are valuable for interior home decoration. These rocks were formed over long periods of time and will not be replaced.

_____ A very small part of the land mass is sold to a company that will put a factory very close to the neighborhood and emit low, below permissible levels of lead in a smoke stack

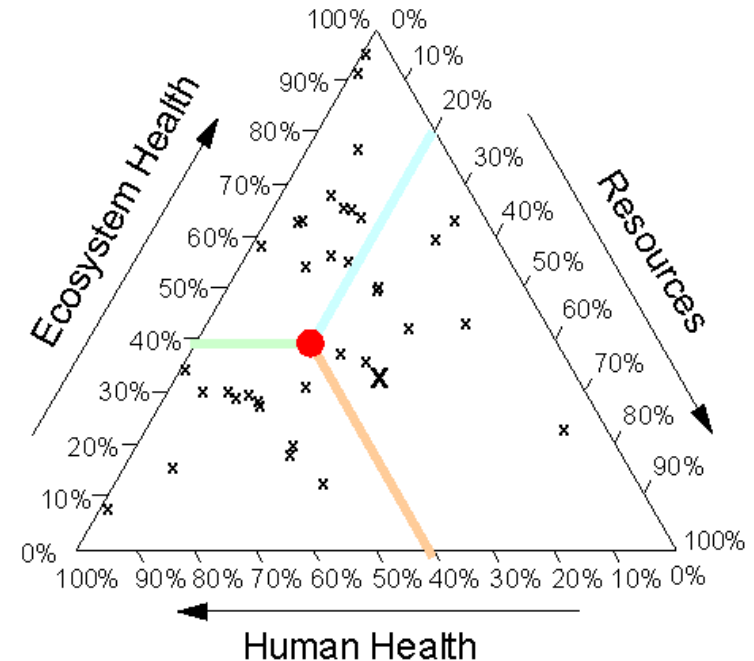
Impact Assessment: Weighting

- Weighting relates the relative importance of impact categories
- Eco-Indicator 99
 - Questionnaire sent to 365 Swiss LCA interest groups
 - Panel members ranked and weighted three damage categories
- SUBJECTIVE

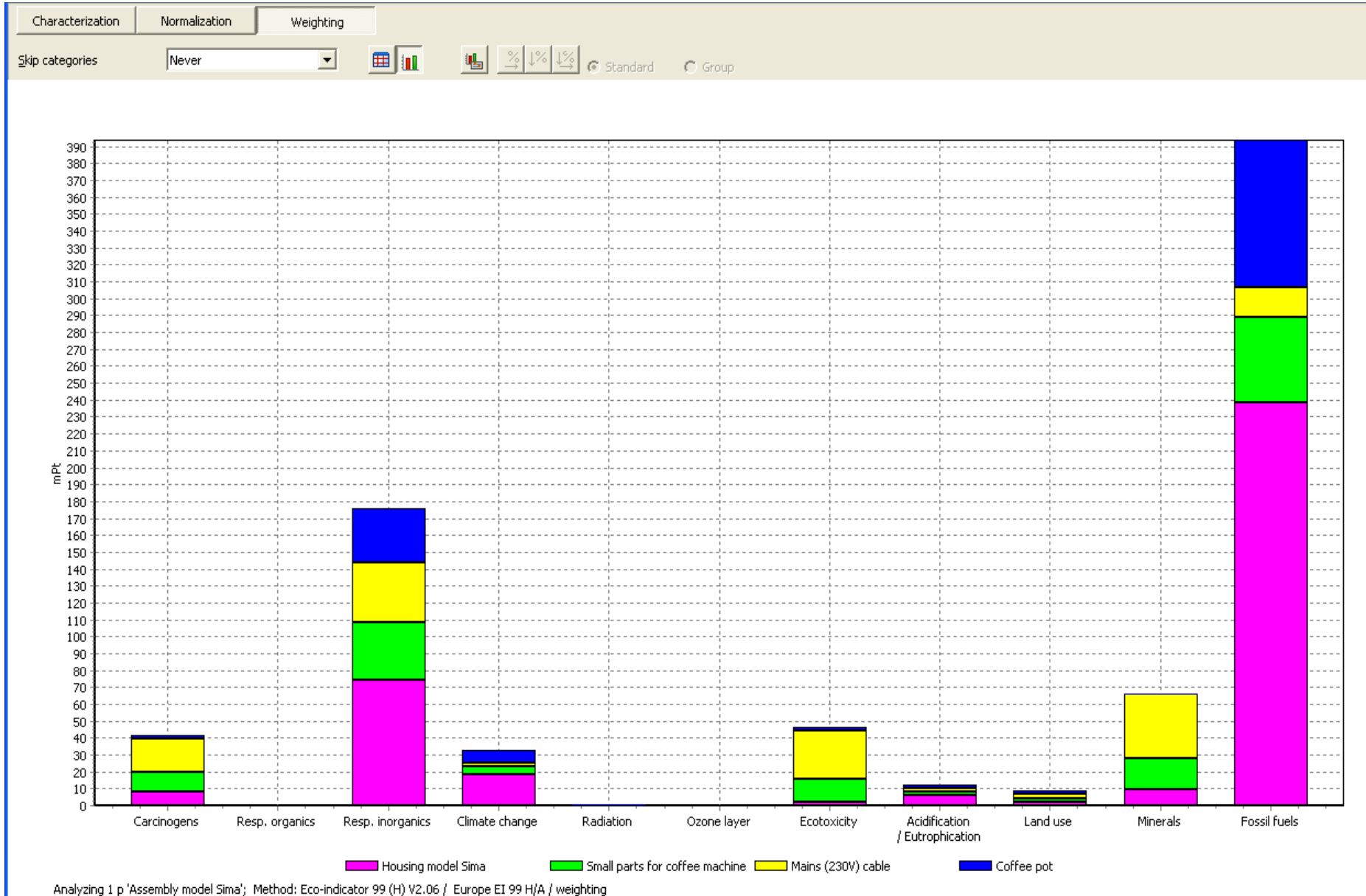
Impact Category	Mean	Rounded	St. Deviation	Median
Human Health	36%	40%	19%	33%
Ecosystem Quality	43%	40%	20%	33%
Resources	21%	20%	14%	23%

[Mettier 1999] Mettier T.: Der Vergleich von Schutzguetern - Ausgewaehlte Resultate einer Panel-Befragung. In: Hofstetter P., Mettier T., Tietje O. (eds.), *Ansaeetze zum Vergleich von Umweltschaeden, Nachbearbeitung des 9. Diskussionsforums Oekobilanzen vom 4. Dezember 1998*, ETH Zürich, Switzerland, 1999

Red dot represents the average weights used for Eco-Indicator 99

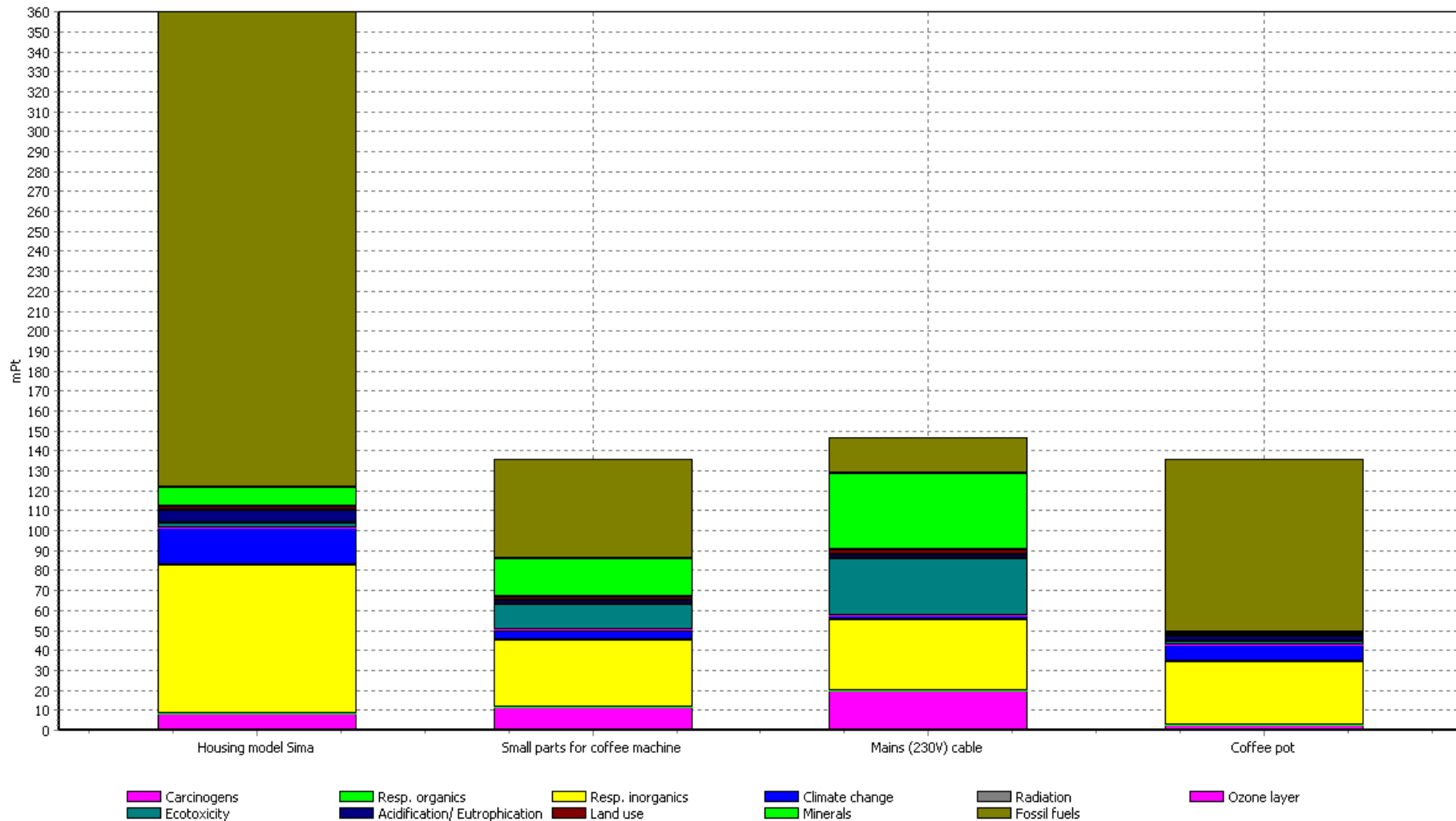
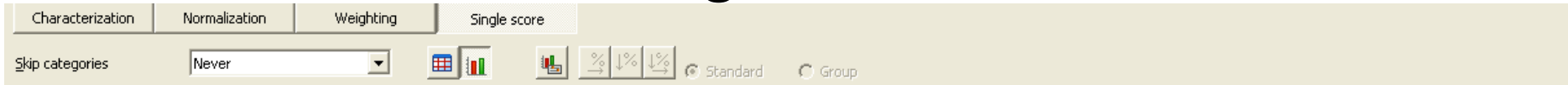


Impact Assessment Weighting

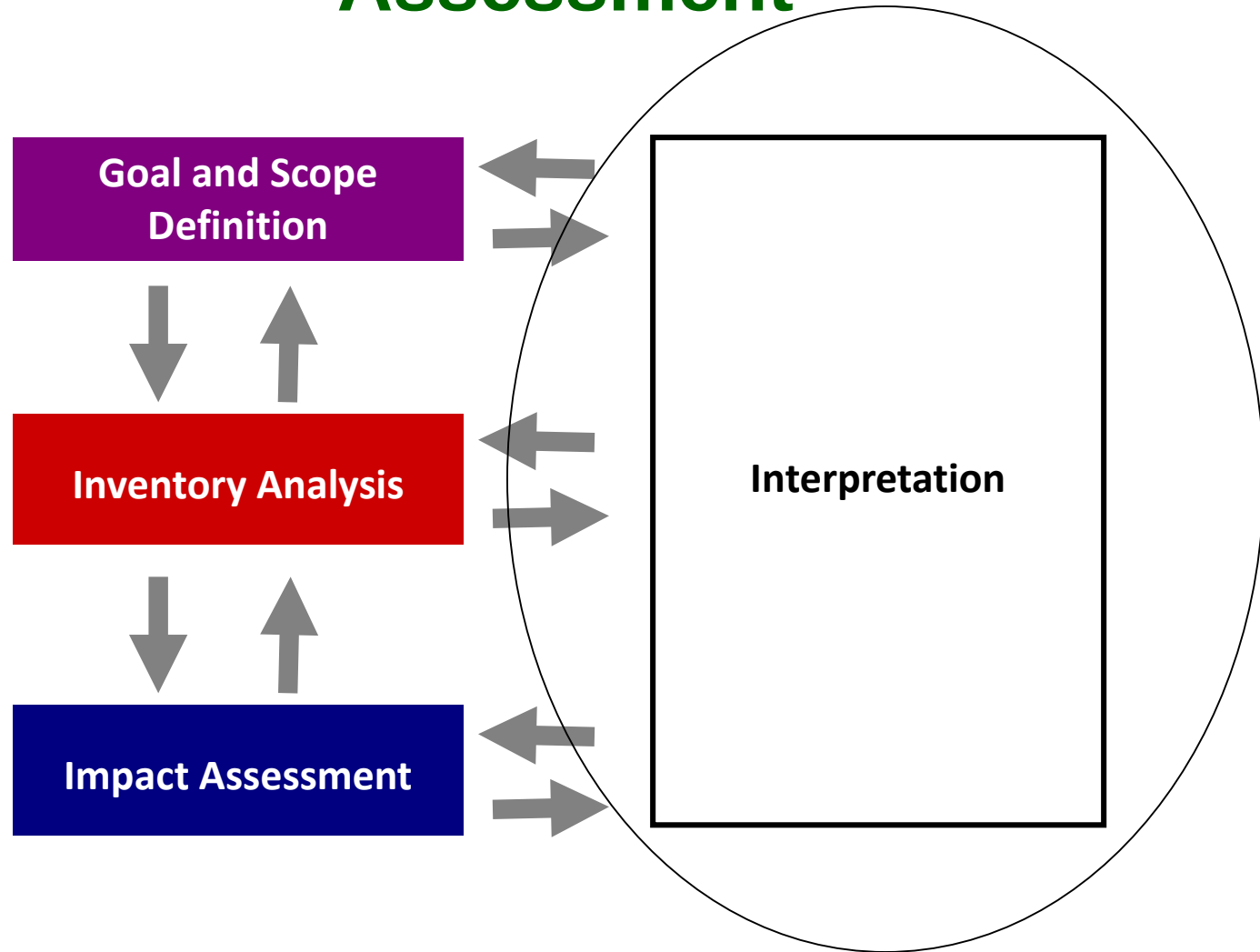


Impact Assessment

Single score



Important Aspects of Life Cycle Assessment





Life cycle interpretation:

- Definition: Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations [ISO 14044:2006E]



Interpretation: ISO Standard

- Overall steps for LCA are defined in ISO 14044
- Proper protocol for interpretation is explained in ISO 14043
- 1. Should identify the significant issues based on the inventory and assessment phases of the LCA
- 2. The interpretation should conduct these checks
 - Completeness check
 - Is relevant data present?
 - Sensitivity check
 - How sensitive are the LCA results to an assumption? To test: make a change to the assumption and recalculate the LCA results.
 - Consistency check
 - Did the LCA abide by the stated goals and scope
- 3. Include conclusions, limitations and recommendations



Summary

- Life cycle
- Life cycle assessment
- Life cycle inventory analysis
- Elementary flows
- US LCI
- Life cycle impact assessment
- Classification
- Characterization factor
- TRACI
- Normalization
- Weighting
- Single Score
- Life cycle interpretation