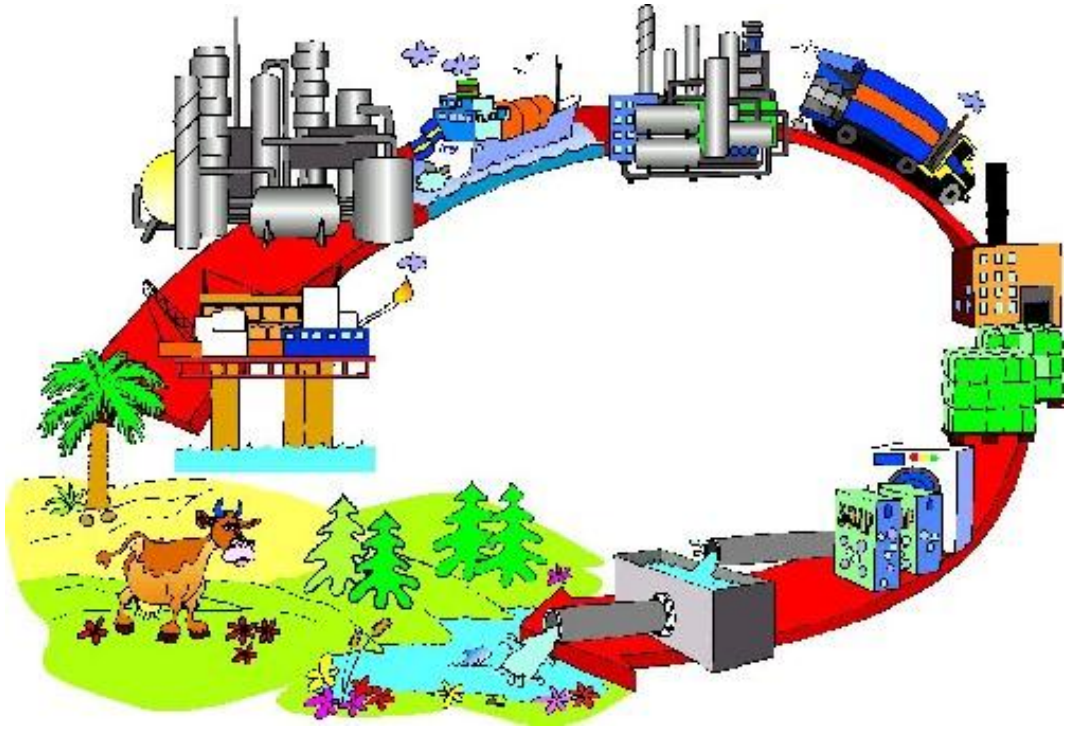
Environmental Life Cycle Assessment
PSE 476/WPS 576/WPS 595-005
Lecture 2 Introd LCA (revised)



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What is a Life Cycle Assessment ?

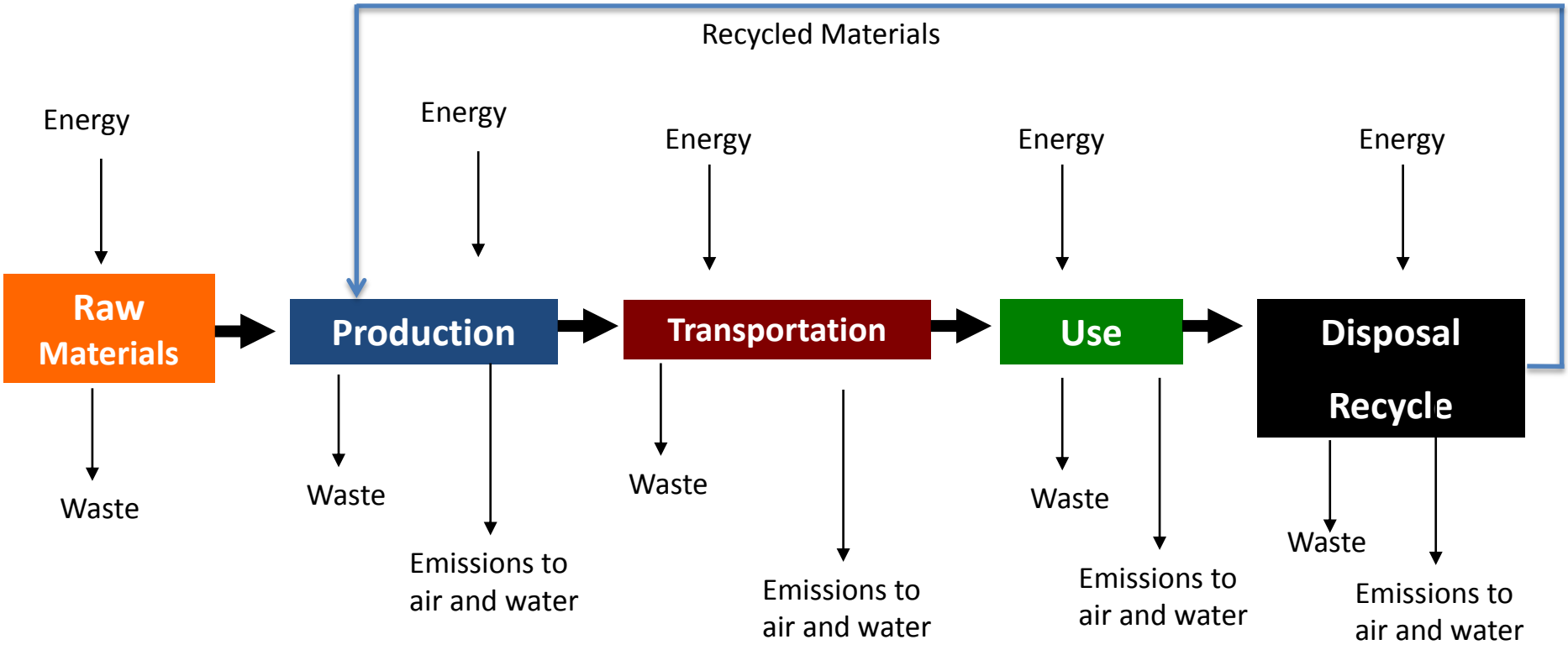
Life Cycle consecutive and interlinked stages of a product system, from the raw material acquisition or generation from natural resources to final disposal [ISO 14044:2006E].

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].

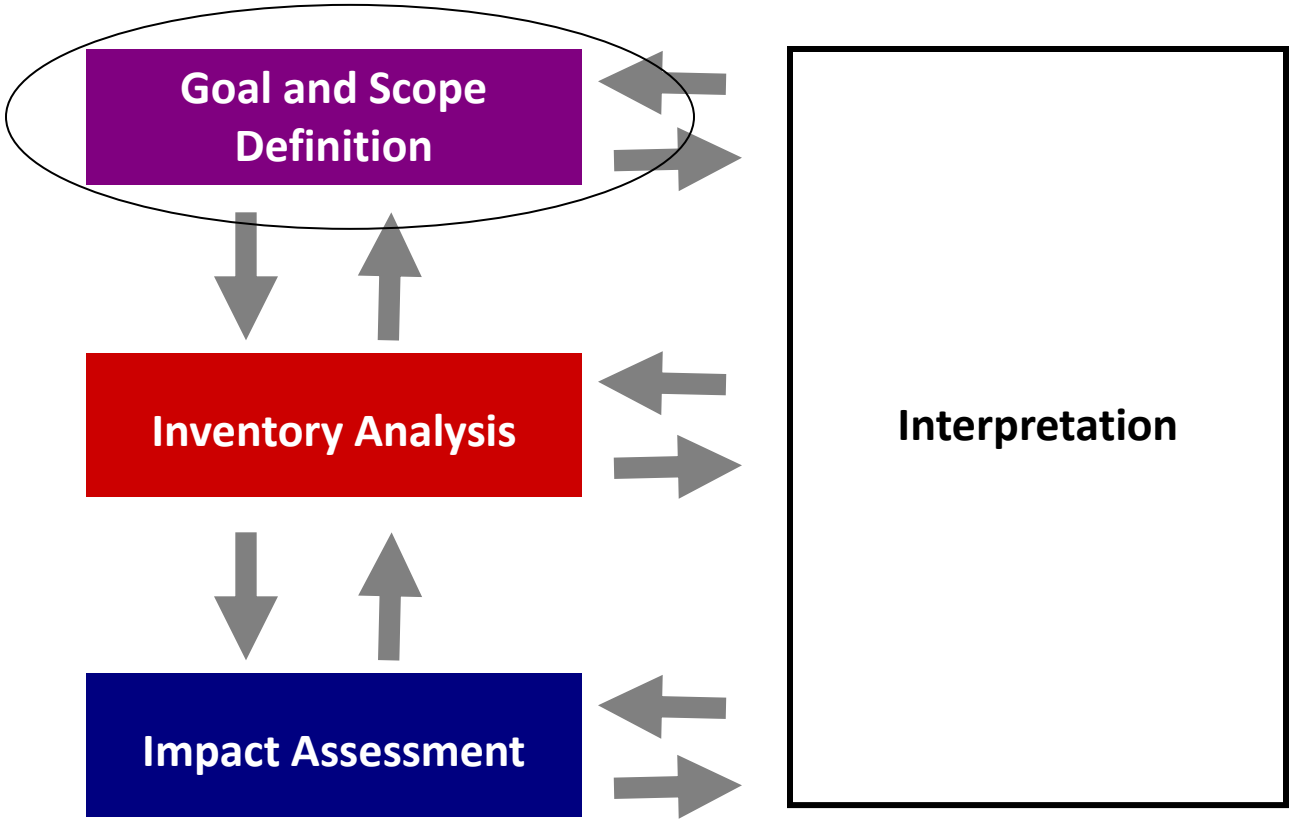
Types of LCA

- **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**
- **Other…**

Life Cycle Stages



Major Parts of a Life Cycle Assessment

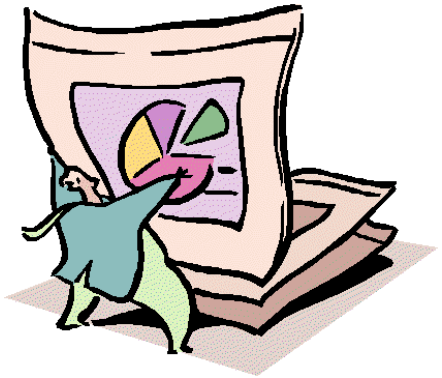


Defining Goals

- 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
- Determine data collection methods
  - Literature
  - Measurements
  - Interviews
  - Other…

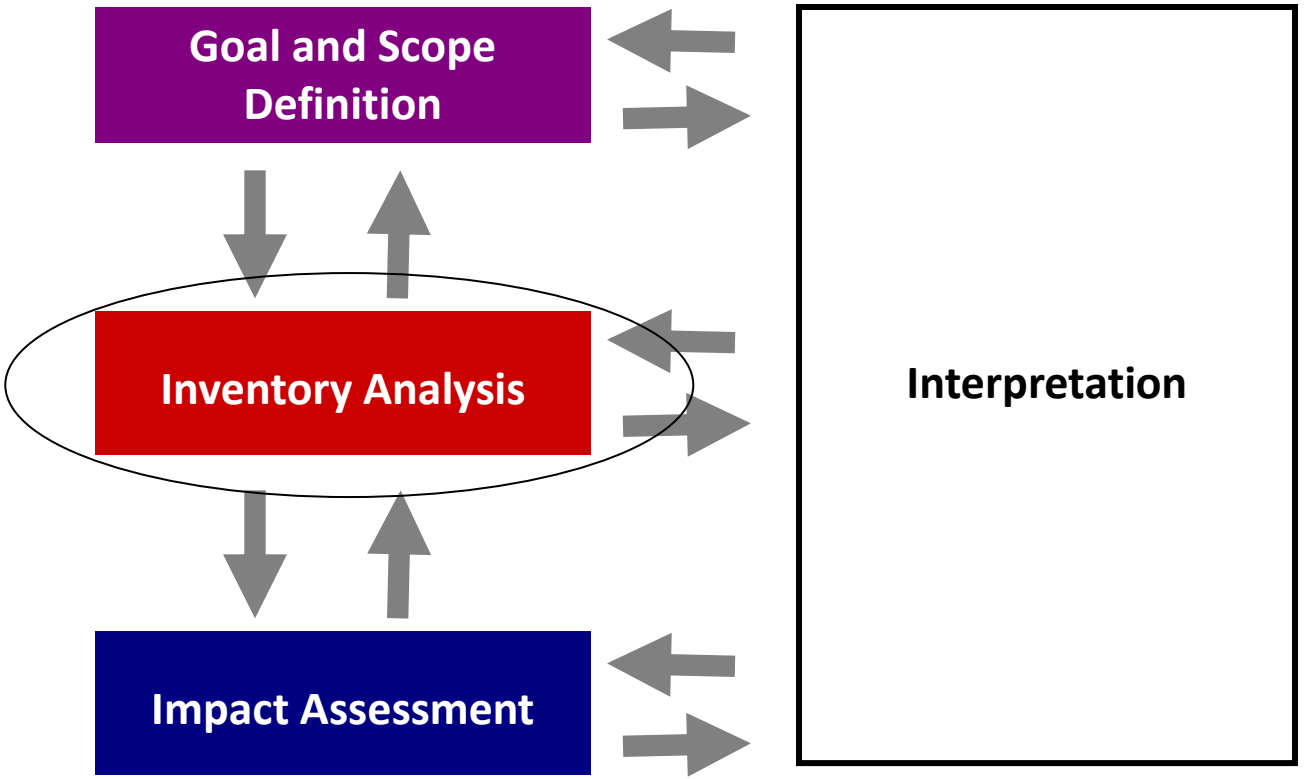


Functional Unit

- **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 a beverage container that delivers 100 individual drinks
- The basis for comparison
- Brainstorm: functional unit for lipstick?

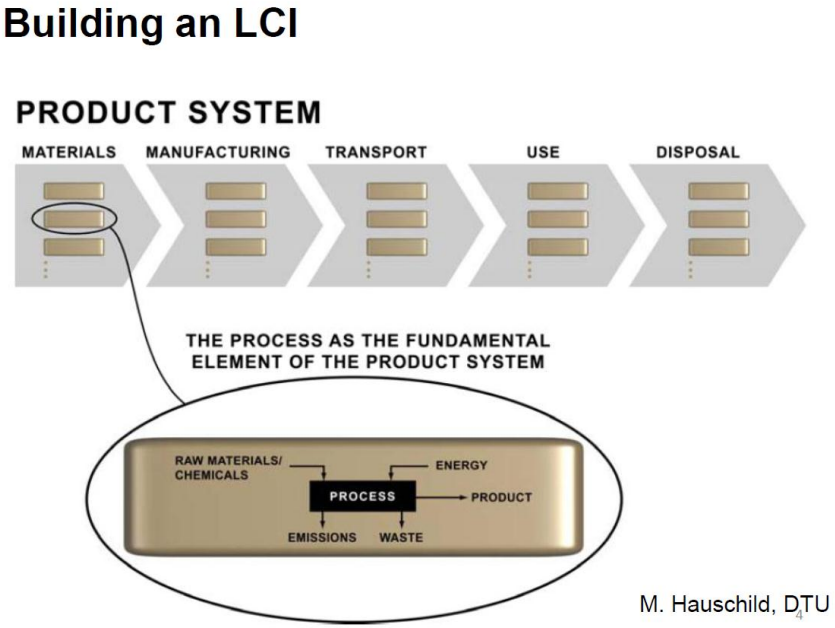
Time, gloss, color, opacity,

Major Parts of a Life Cycle Assessment



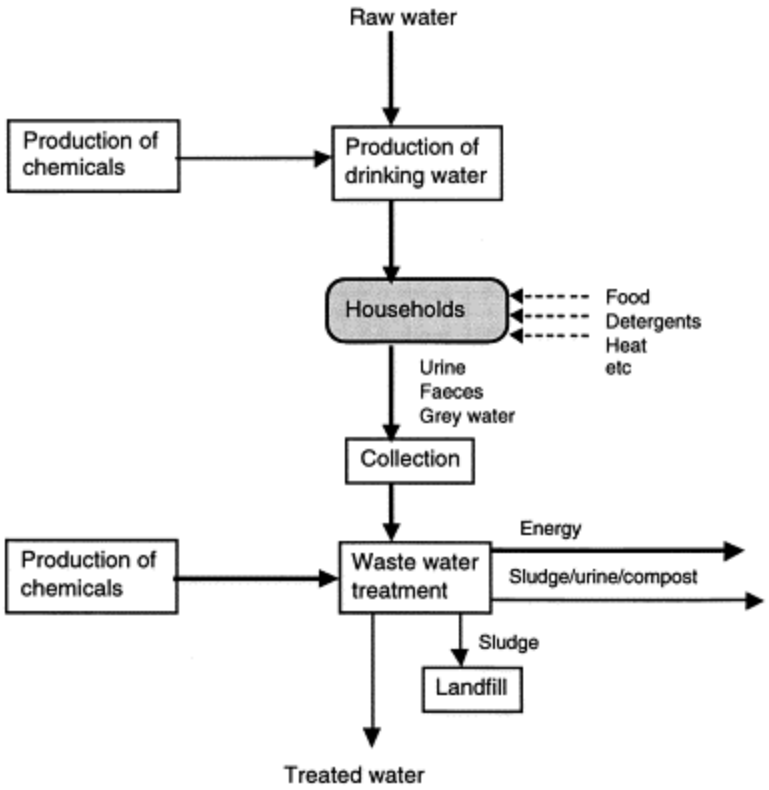
Life Cycle Inventory Analysis(LCI):

- 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**



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].



Tillman, Environmental Impact Assessment Review 20 (2000) 113–123

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U.S. Life Cycle Inventory Database

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SEARCH

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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.

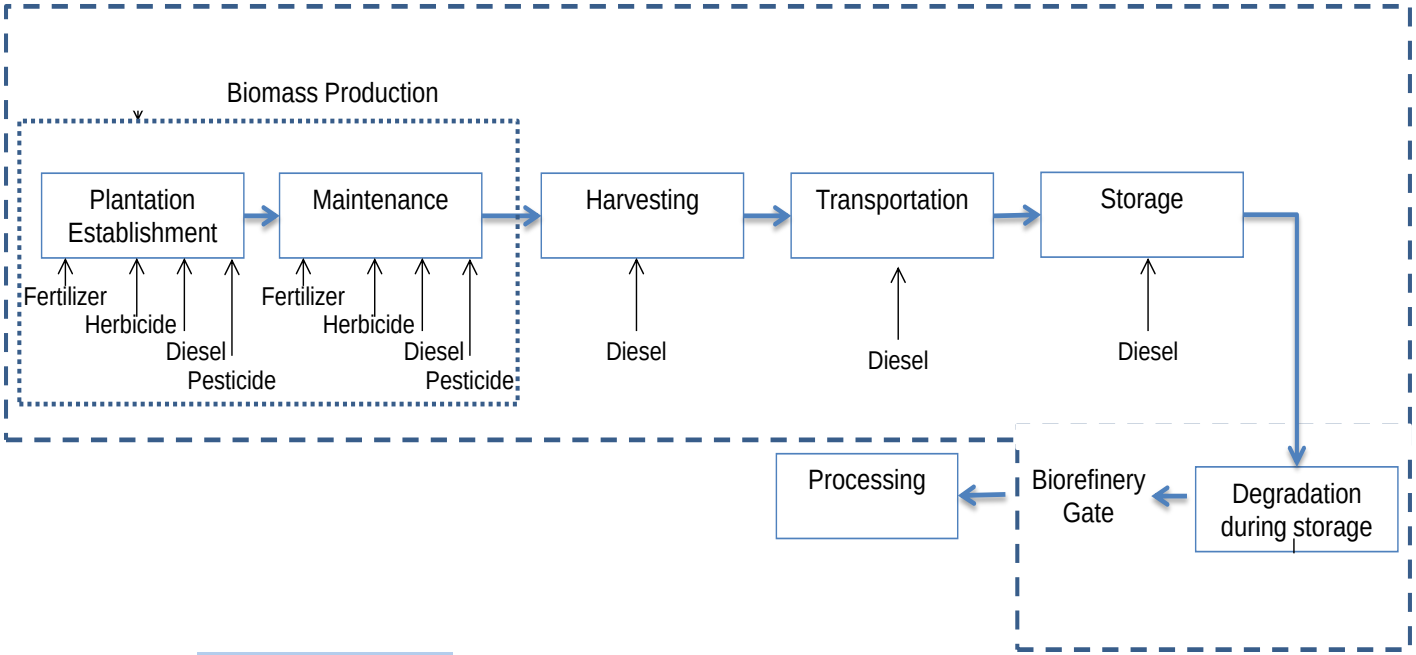
More Events

U.S. Life Cycle Inventory Database Roadmap

U.S. Life Cycle Inventory Database Dataset Additions

Life Cycle Inventory (LCI):

- **Table 6. Life cycle inventory for all feedstock biomass production systems for low (L), medium (M) and high (H) productivity scenarios assuming 500,000 BDT/year delivered to a conversion facility (453,592 metric tonnes) and 10% covered area.**
  - **Functional Unit:**
  - **Elementary flows (not necessarily shown on diagram):**

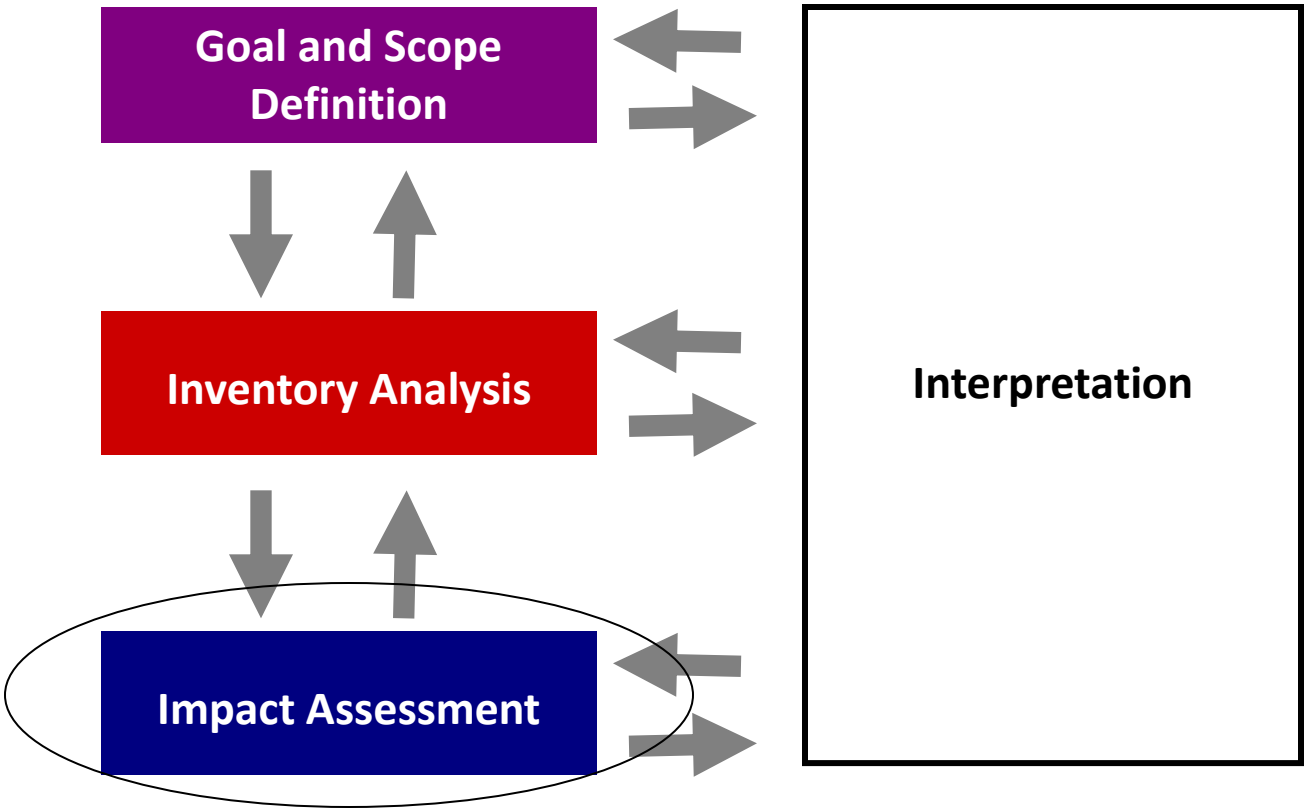


Life Cycle Inventory (LCI):

- **Table 6. Life cycle inventory for all feedstock biomass production systems for low (L), medium (M) and high (H) productivity scenarios assuming 500,000 BDT/year delivered to a conversion facility (453,592 metric tonnes) and 10% covered area.**

	Loblolly Pine			Eucalyptus			Unmanaged Hardwood			Forest Residues			Switchgrass			Sweet Sorghum		
Productivity Level	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
	Liter per Dry Tonne			Liter per Dry Tonne			Liter per Dry Tonne			Liter per Dry Tonne			Liter per Dry Tonne			Liter per Dry Tonne		
Fuel consumption, collection	-	-	-	-	-	-	-	-	-	0.05	0.04	0.03	-	-	-	-	-	-
Establishment and maintenance, diesel	0.86	0.65	0.52	2.47	1.85	1.48	-	-	-	0.61	0.45	0.36	-	-	-	-	-	-
Establishment and maintenance, gasoline	0.04	0.03	0.03	0.12	0.09	0.07	-	-	-	8.0	6.0	4.8	3.93	2.95	2.36	-	-	-
Harvesting, diesel	10.1	7.58	6.06	10.1	7.58	6.06	10.1	7.6	6.1	-	-	-	6.02	4.51	3.61	4.13	3.1	2.48
Storage	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6	0.6	0.84	0.84	0.84
	Dry Tonne-km			Dry Tonne-km			Dry Tonne-km			Dry Tonne-km			Dry Tonne-km			Dry Tonne-km		
Transportation forest-to-facility	79	69	62	78	67	60	204	177	157	327	283	253	-	-	-	-	-	-
Transportation farm-to-storage	-	-	-	-	-	-	-	-	-	-	-	-	51	44	39	175	152	136
Transportation storage-to-facility	-	-	-	-	-	-	-	-	-	-	-	-	9.5	9.5	9.5	31	31	31
Fertilizer	kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne		
UREA	2.1	1.6	1.3	2.9	2.2	1.7	-	-	-	0.13	0.1	0.08	-	-	-	-	-	-
Phosphorus	-	-	-	-	-	-	-	-	-	-	-	-	1.6	1.2	0.96	3.43	2.57	2.06
Potassium	-	-	-	-	-	-	-	-	-	-	-	-	15.83	11.88	9.5	1.7	1.27	1.02
Lime	-	-	-	-	-	-	-	-	-	-	-	-	62.28	46.71	37.37	-	-	-
Nitrogen	-	-	-	-	-	-	-	-	-	-	-	-	8.47	6.36	5.08	-	-	-
Herbicide	kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne			kg per Dry Tonne		
General herbicide, glyphosate	0.03	0.01	0.01	0.08	0.04	0.03	-	-	-	0.002	0.001	0.001	-	-	-	-	-	-
Pursuit	-	-	-	-	-	-	-	-	-	-	-	-	2.36	1.77	1.41	-	-	-
MSO	-	-	-	-	-	-	-	-	-	-	-	-	3.31	2.48	1.99	-	-	-
2,4	-	-	-	-	-	-	-	-	-	-	-	-	1.14	0.85	0.68	-	-	-
Alzarine 90 DF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19	0.14	0.11
Dipel ES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.15	0.12

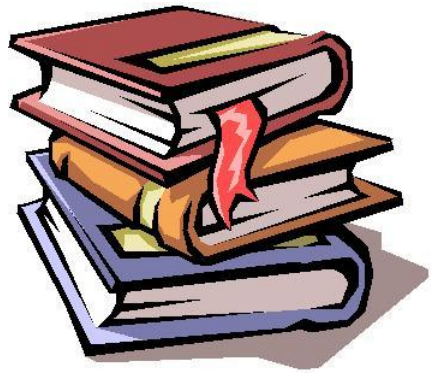
Important Aspects of Life Cycle Assessment



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

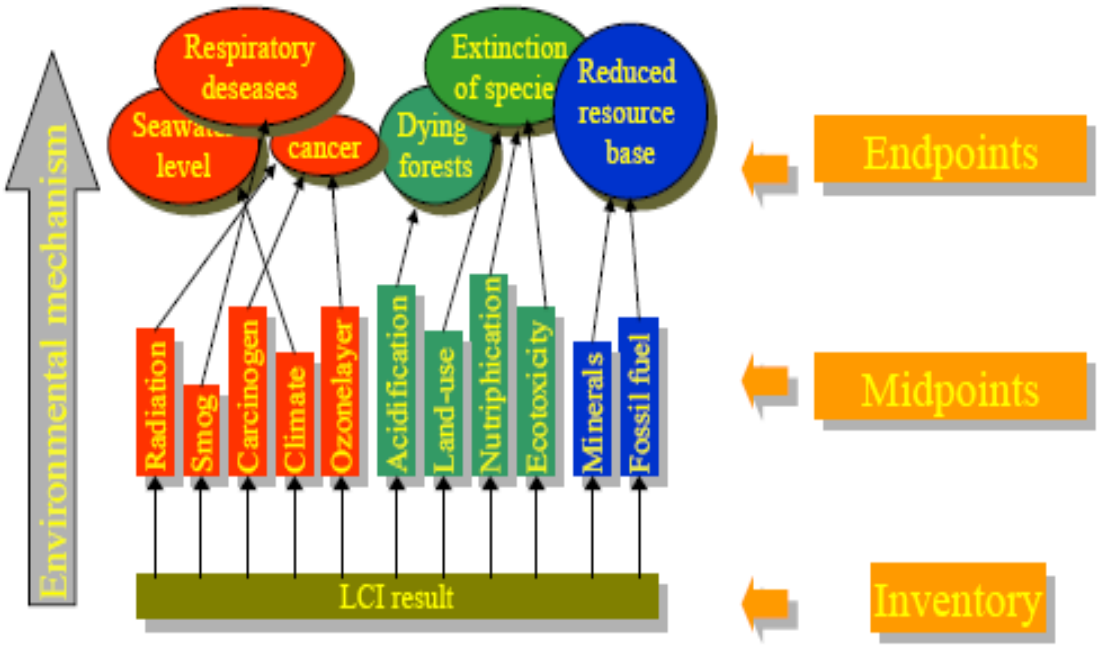
- Overall steps for LCA are defined in ISO 14044
- Defined as: a compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system through its life cycle.
- Protocol for an impact assessment is explained in ISO 14042
- Mandatory elements for an impact assessment
  - 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)

  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: ISO Standard

- Some assessments use midpoints, other use endpoints.

• LCI Results: flows of mass or energy	Most certain
• Midpoints: examples: radiation, smog, ozone layer….	Less certain
• Endpoints: **Human health, ecosystems, resources**	Even less certain
• Interpretation	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

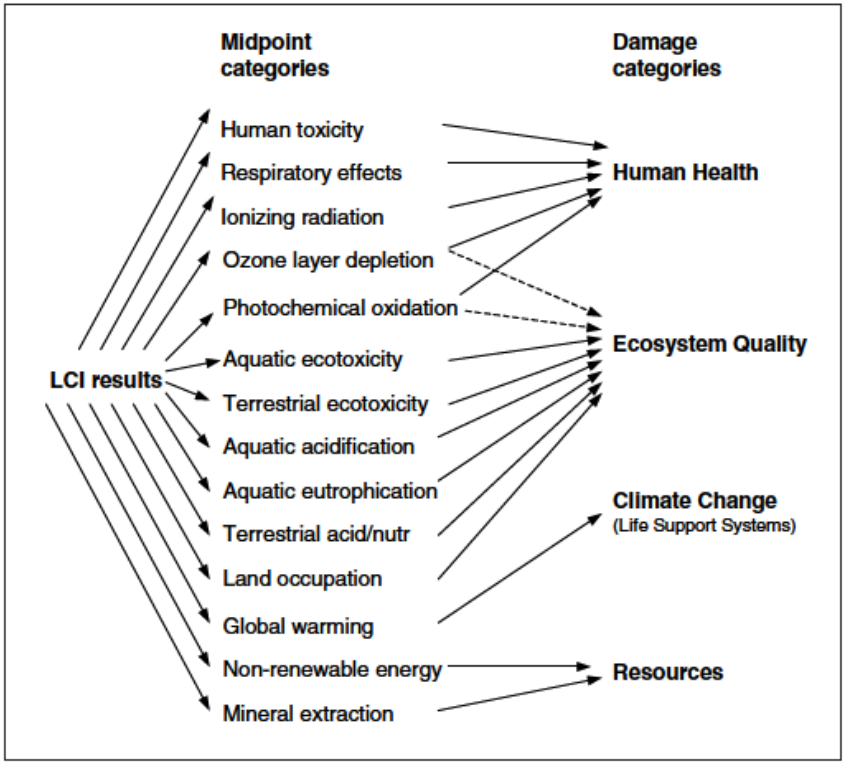
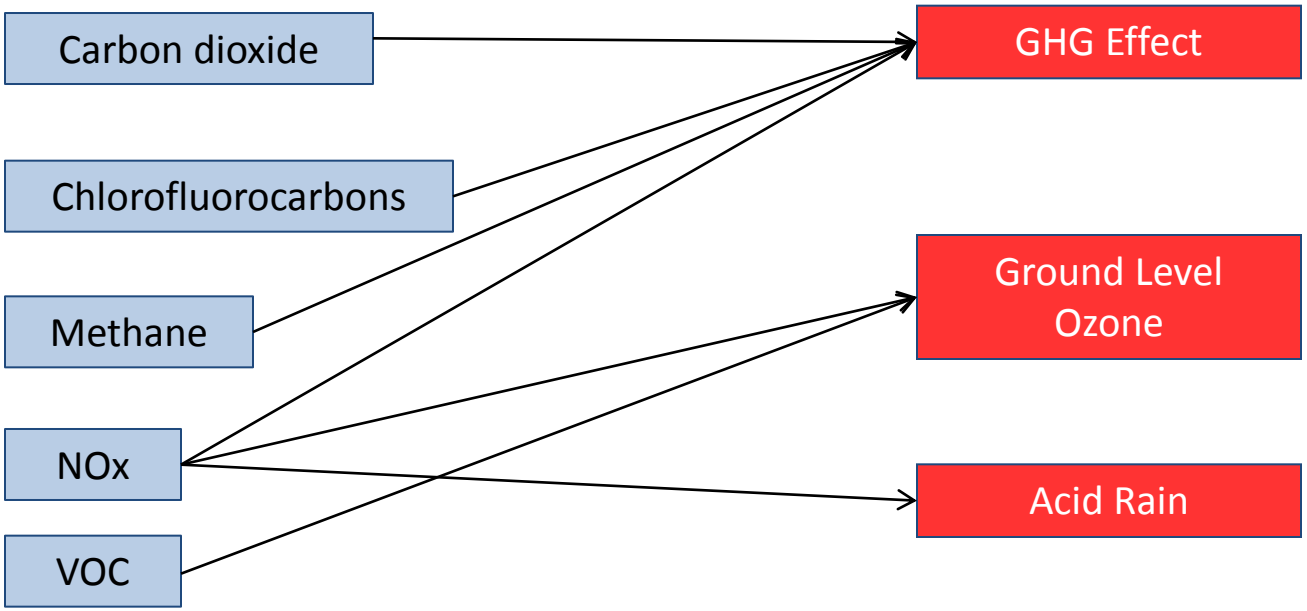


Fig. 1: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories, based on Jolliet et al. (2003a)

Impact Assessment: Classification

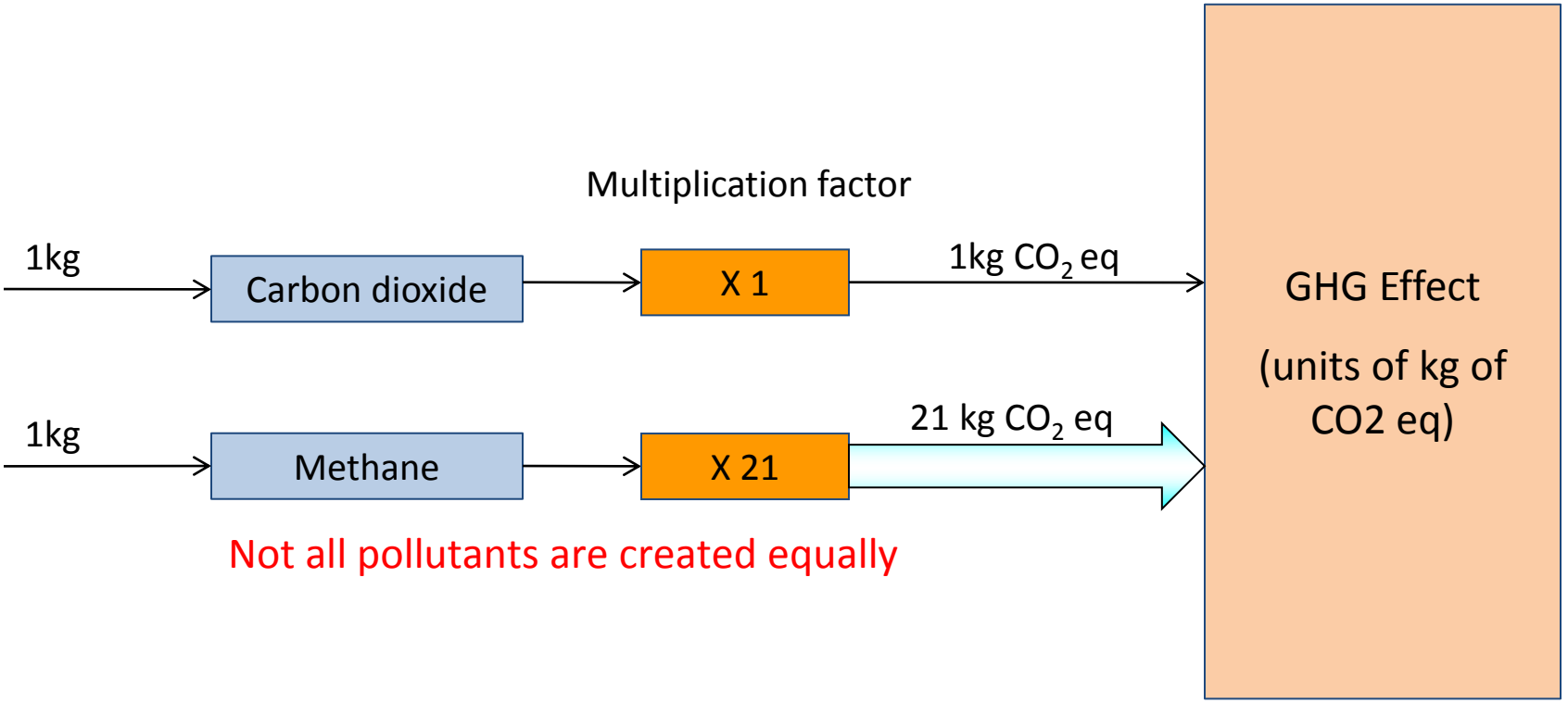
From LCI:



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

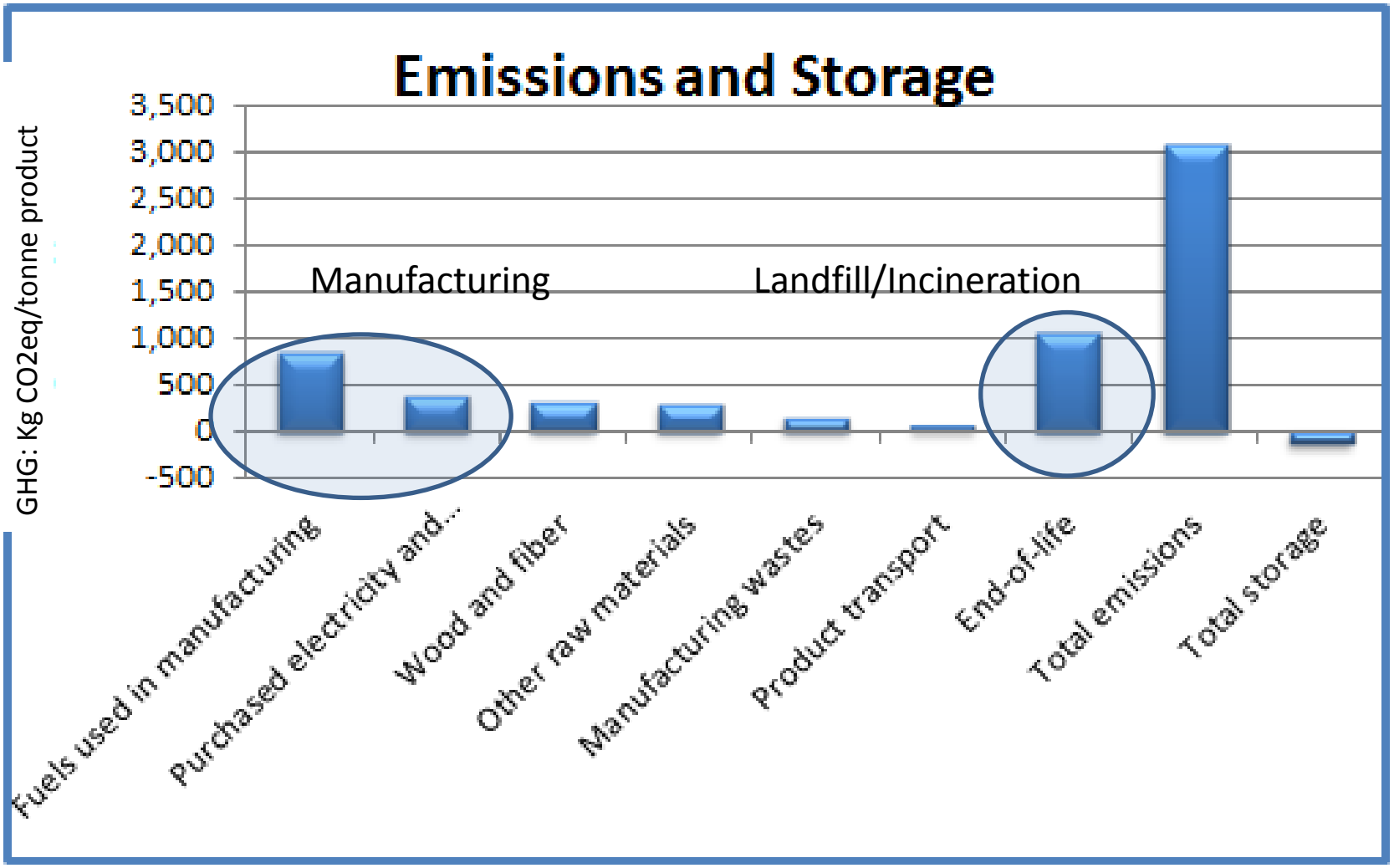
Impact Assessment: Characterization

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]

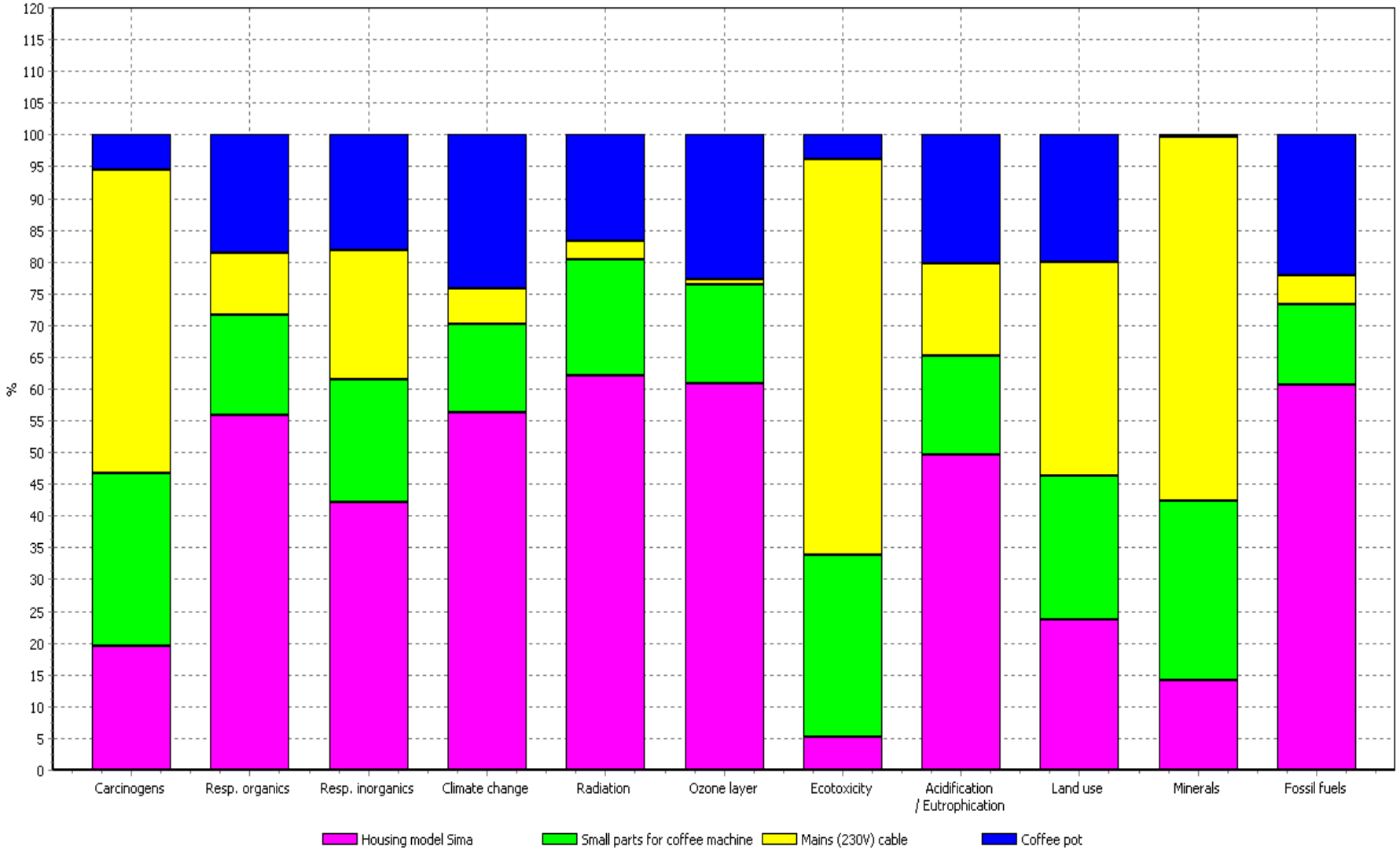


Reference: http://www.epa.gov/RDEE/energy-resources/calculator.html#results

Impact Assessment:
Climate Change as an Example



Impact Assessment
Impact categories



Analyzing 1 p 'Assembly model Sima'; Method: Eco-indicator 99 (H) V2.06 / Europe EI 99 H/A / characterization

Normalization

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

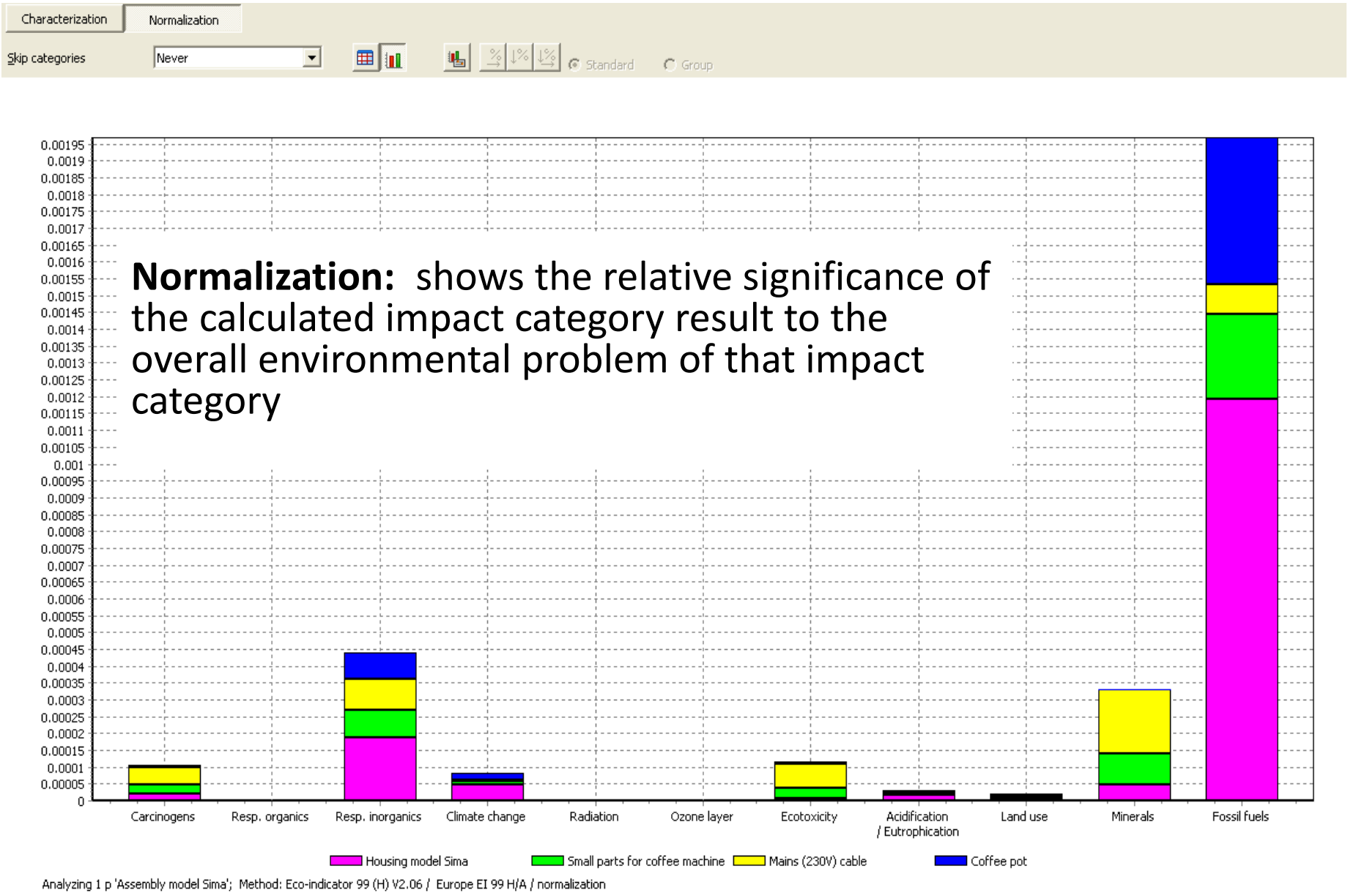
Helps answer the question: What percentage of GHG emissions does this product contribute relative to all the GHG emissions from a certain country/state/person/globe?

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

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

Time, gloss, color, opacity,

Impact Assessment: Normalization

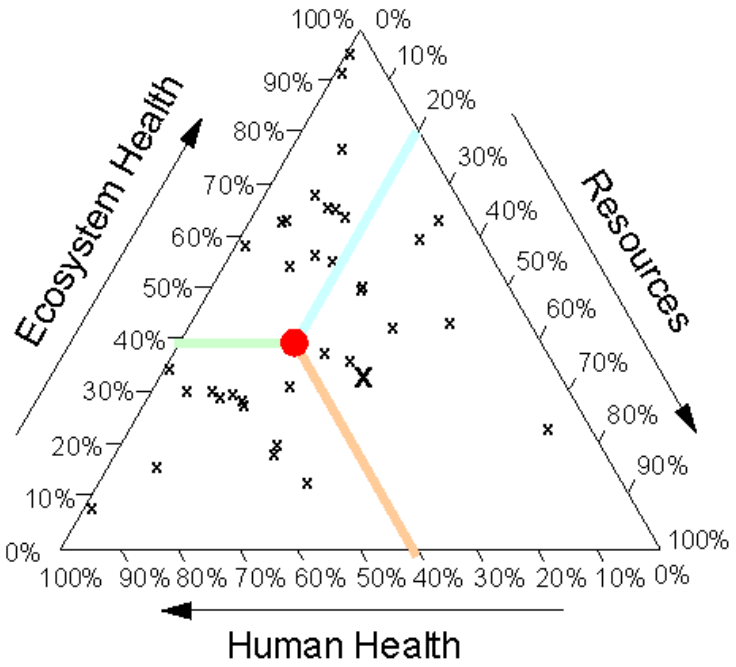


Normalization: shows the relative significance of the calculated impact category result to the overall environmental problem of that impact category

Impact Assessment: Weighting

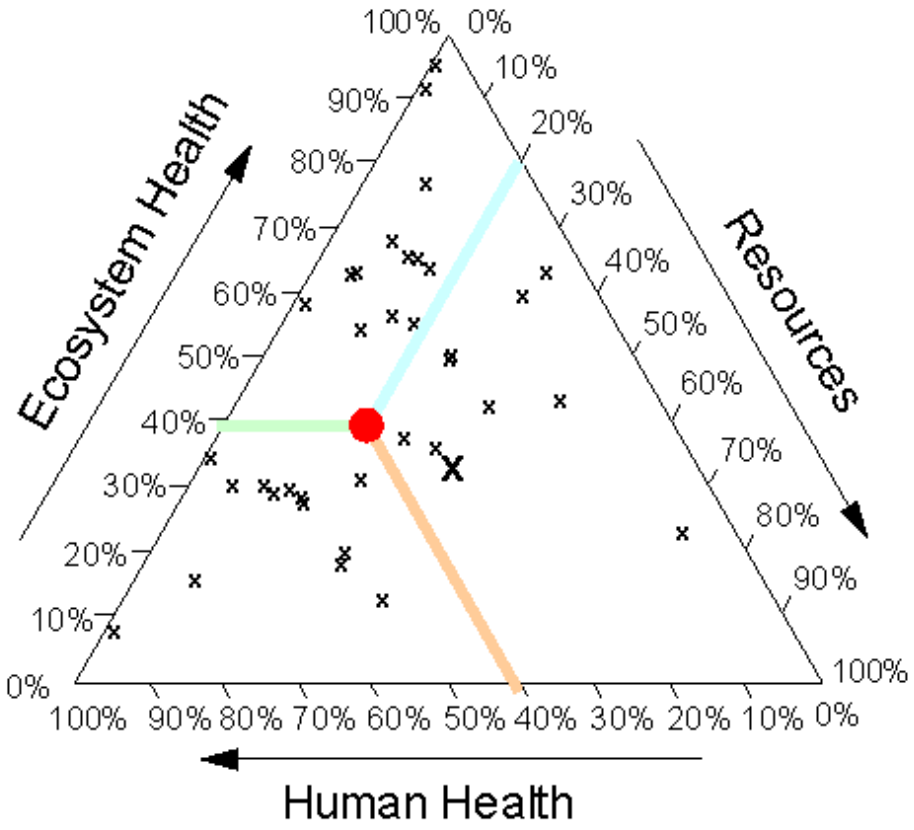
- Weighting relates the relative importance of impact categories
- Eco-Indicator 99
  - Questionnaire sent to 365 Swiss LCA interest groups
  - Panel members ranked and weighted three damage categories
- SUBJECTIVE

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



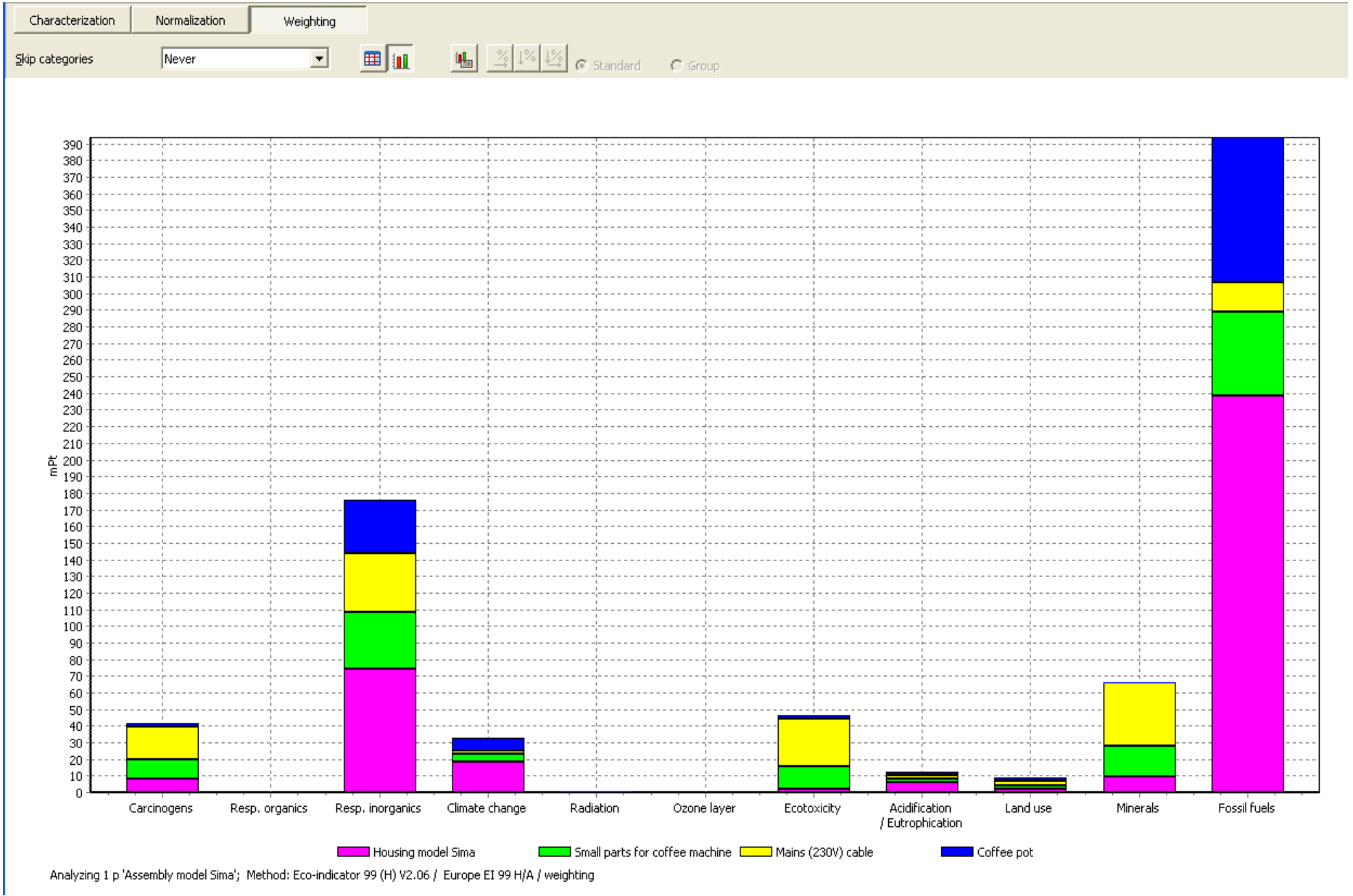
[Mettier 1999] Mettier T.: Der Vergleich von Schutzguetern - Ausgewaehlte Resultate einer Panel-Befragung. In: Hofstetter P., Mettier T., Tietje O. (eds.), *Ansaetze zum Vergleich von Umweltschaeden, Nachbearbeitung des 9. Diskussionsforums Oekobilanzen vom 4. Dezember 1998*, ETH Zürich, Switzerland,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

Impact Assessment: Weighting Triangle

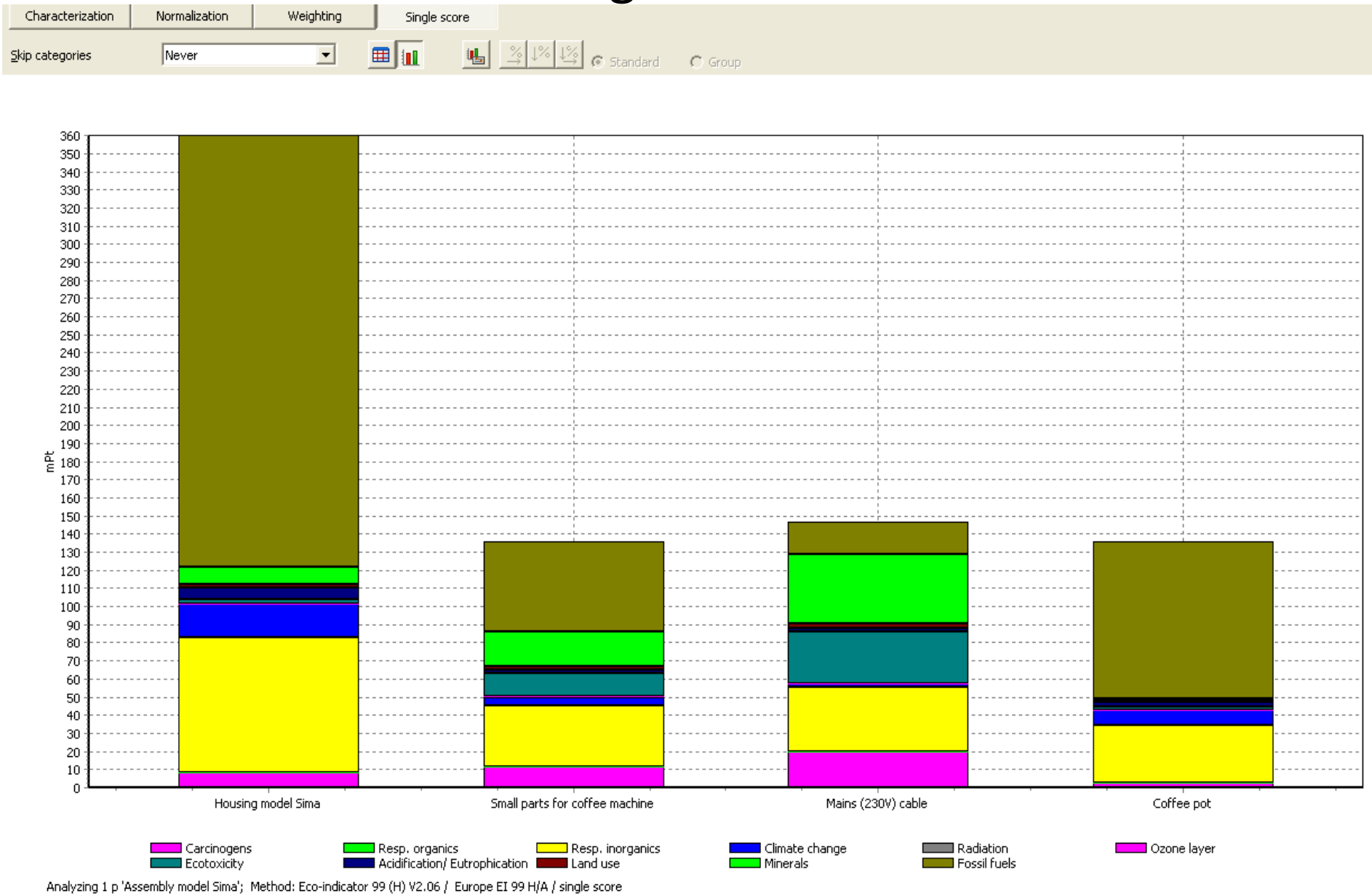


Red dot represents the average weights used for Eco-Indicator 99

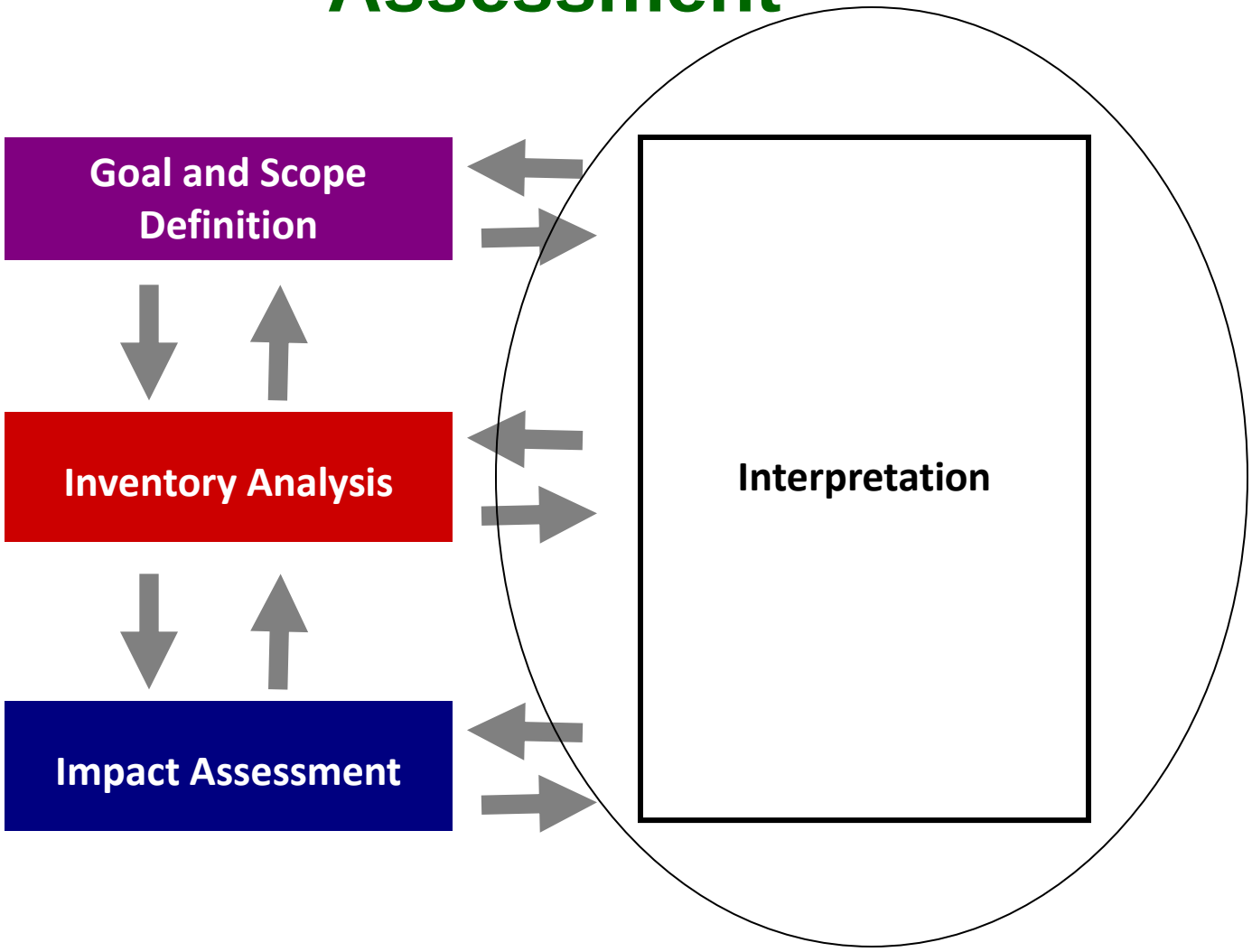
Impact Assessment
Weighting



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
- Life cycle impact assessment
- Classification
- Characterization factor
- Normalization
- Weighting
- Single Score
- Life cycle interpretation