INSTITUTO SUPERIOR TÉCNICO

# Industrial Ecology: 2012/2013

Class # 7

## *Life-Cycle Assessment*

Goal and Scope, Inventory

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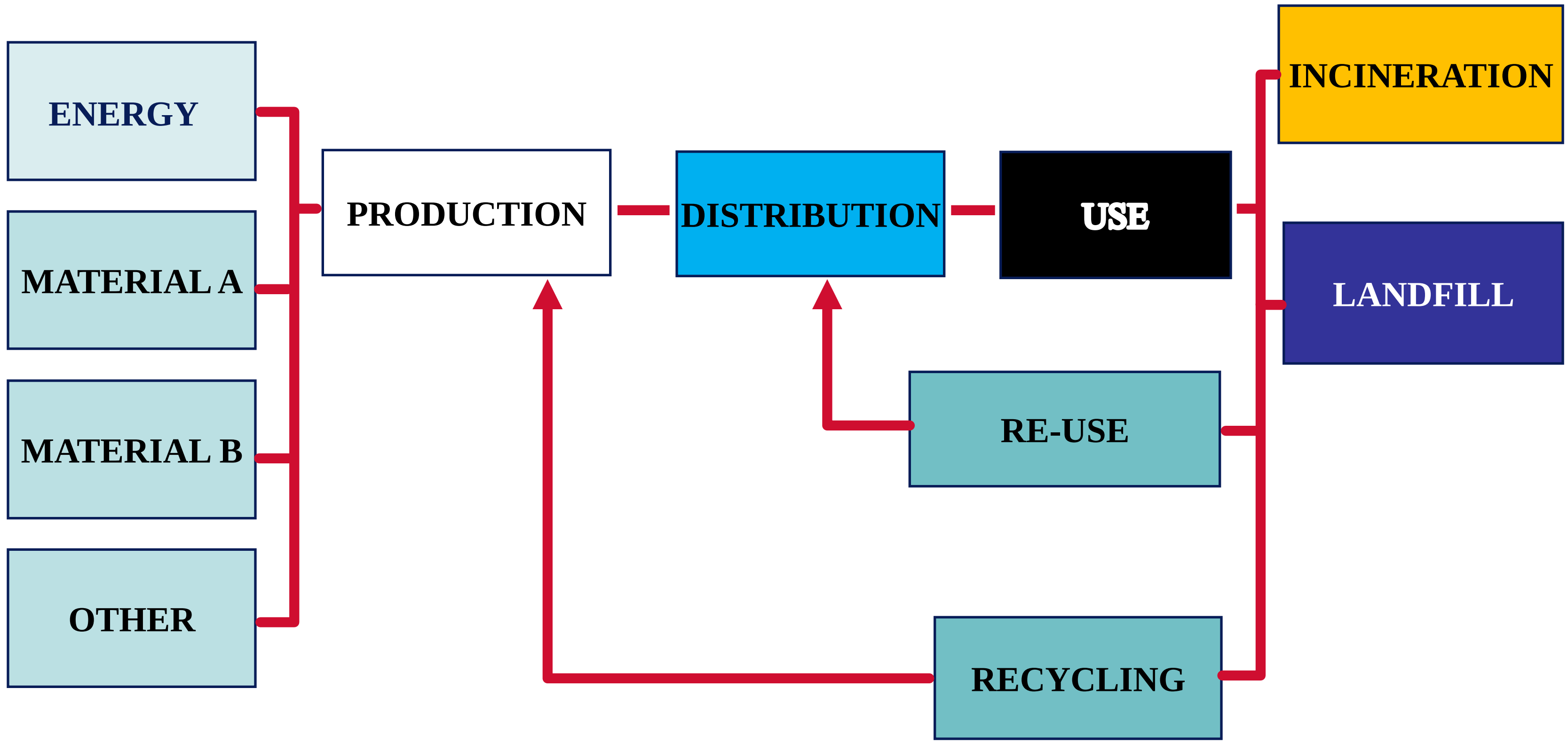
# Life Cycle Assessment



**Definition of LCA according to ISO 14040:**

**LCA is a technique […] compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; and interpreting the results of the inventory and impact phases in relation to the objectives of the study.**

# LCA Stages and characteristics

## Normative References

- Two procedural LCA Standards
  - ISO 14040 - Principles and framework (2006)
  - ISO 14044 - Requirements and guidelines (2006)
    - Replaced:
      - ISO 14041 - Goal and scope definition and inventory analysis (1998 – 2006)
      - ISO 14042 - Life cycle impact assessment (2000 – 2006)
      - ISO 14043 - Life cycle interpretation (2000 - 2006)

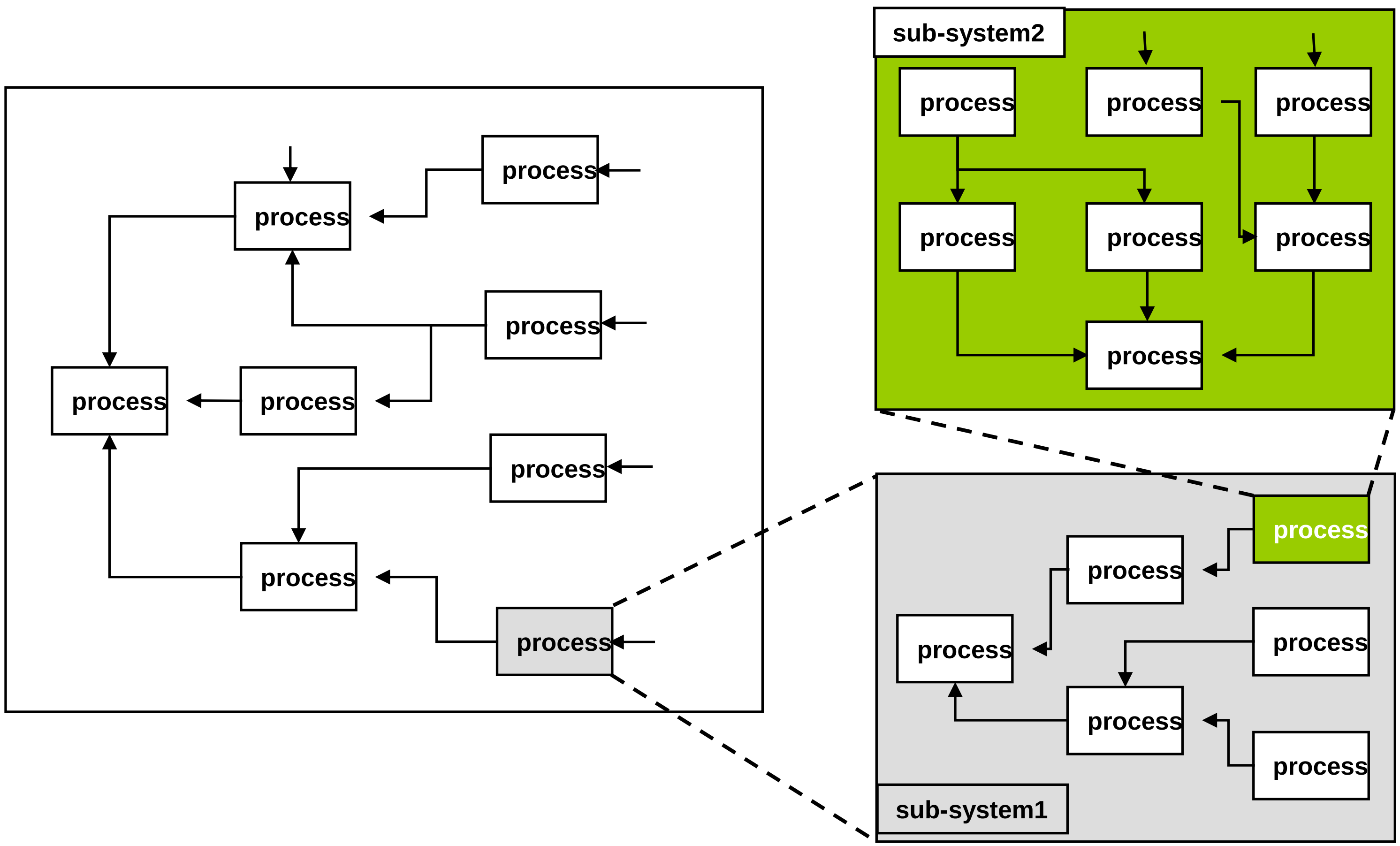
- Others LCA ISO standards
  - ISO 14047 - Examples of application of ISO 14042 (2003)
  - ISO 14048 - Data documentation format (2002)
  - ISO 14049 - Examples of application of ISO 14041 to goal and scope definition and inventory analysis (2000)

## Normative References

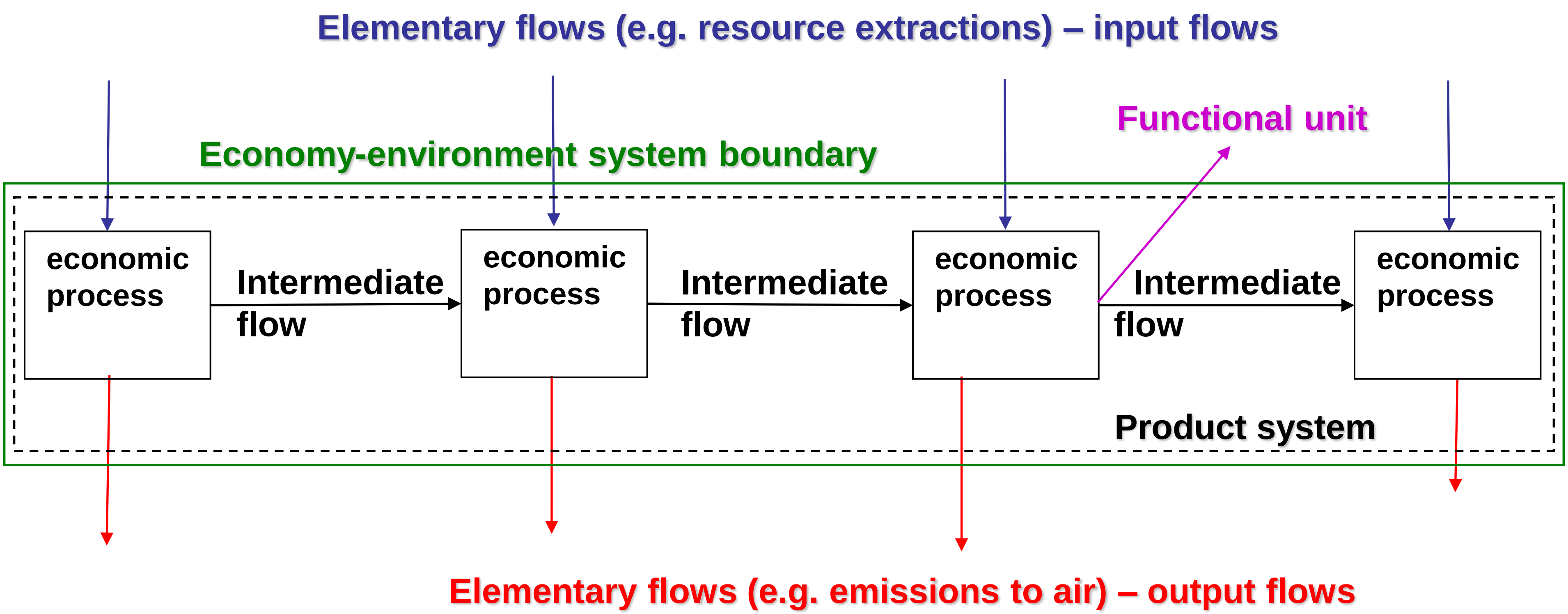
- Other standards with relevance to LCA
  - ISO 14025 – Environmental product declarations (2006)
  - ISO 14064 – Quantification and mitigation of greenhouse gases (2006)
  - PAS 2050 – GHG accounting of product systems

- Important aspect of LCA ISO norms
  - LCA cannot be certified, as in ISO 14001
  - LCA is a relative methodology due to its nature
  - Recommendations and guidelines are goal and scope dependent

# Structure of a Process-based LCA Model

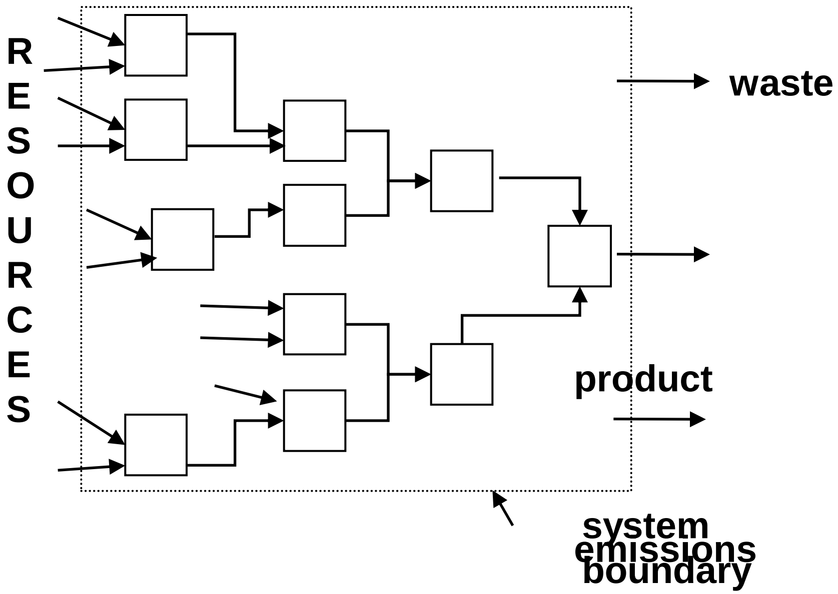


# Life cycle assessment terminology (ISO 14040:2006)



# Circularity Effects

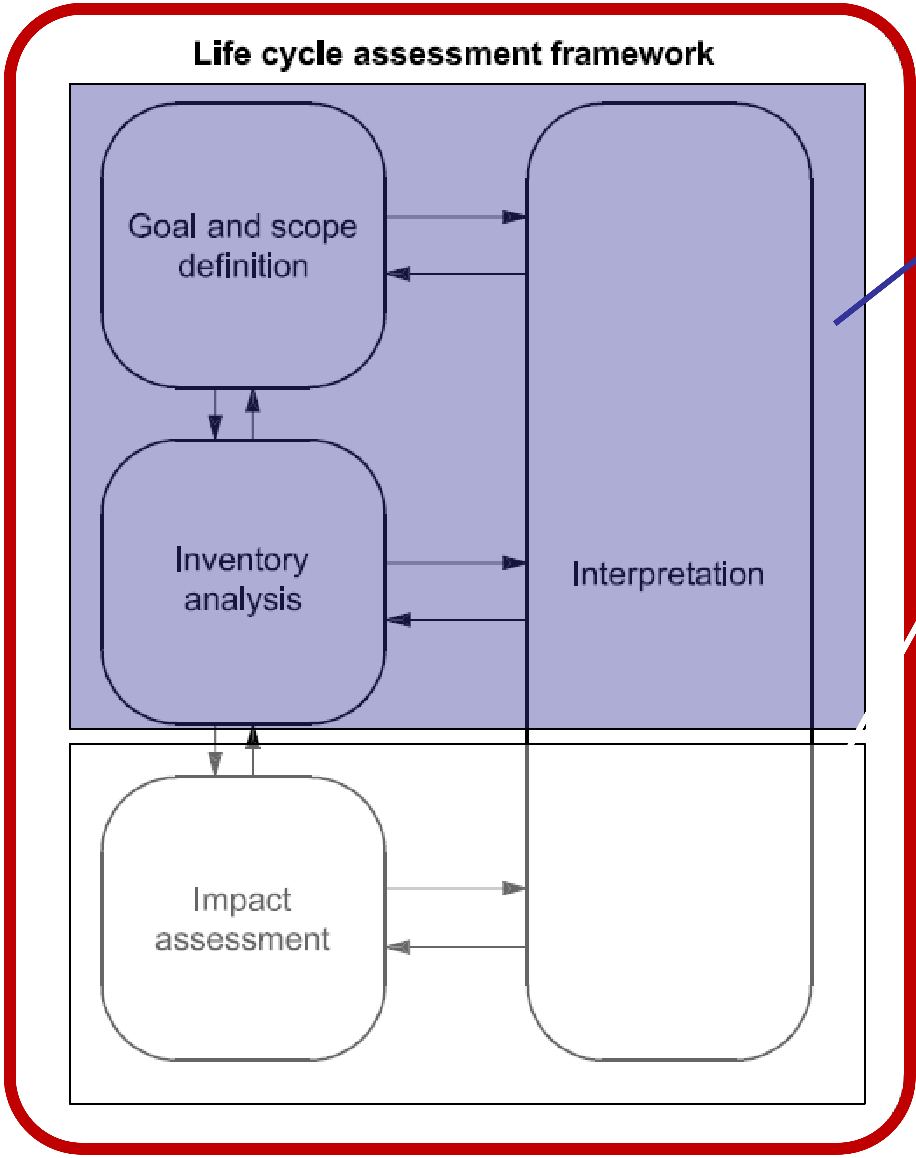
- Circularity effects in the economy must be accounted for: cars are made from steel, steel is made with iron ore, coal, steel machinery, etc. Iron ore and coal are mined using steel machinery, energy, etc...



# LCA - Main stages

- Goal and scope – in which the reasons for the study, the intended audience, the functional unit, etc. are defined.
- Inventory– in which the data describing the system is collected and converted to a standard format to provide a description of the physical characteristics of the system of interest.
- Impact assessment – in which the physical flows are translated into potential environmental impacts
- Interpretation – in which the results are evaluated and interpreted in context of their significant, uncertainty, etc.
- *Improvement – in which the system is modified in some way to reduce or ameliorate the observed environmental impacts.*

# ISO 14040…




LCI – Life Cycle Inventory

LCA – Life Cycle Assessment

*Fundamental concept always associated*

**Product /Service:**

**Functional Unit**

## Functional Unit

- The functional unit describes the primary function(s) fulfilled by a (product) system, and indicates how much of this function is to be considered in the intended LCA study.

- It will be used as a basis for selecting one or more alternative (product) systems that can provide these function(s). The functional unit enables different systems to be treated as functionally equivalent and allows reference flows to be determined for each of them.

- Having defined the functional unit, the amount of product which is necessary to fulfill the function shall be quantified. The result of this quantification is the reference flow.

# Principles of LCA

- Life cycle perspective
  - Through such a systematic overview and perspective, the shifting of a potential environmental burden between life cycle stages or individual processes can be identified and possibly avoided
- Environmental focus
  - Address the environmental aspects and impacts of a product system. Economic and social aspects and impacts are, typically, outside the scope of the LCA. Other tools may be combined with LCA for more extensive assessments
- Relative approach and functional unit
  - Relative approach, structured around a functional unit. This functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit, as all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit

According with ISO 14040(2006)

# Principles of LCA

- Iterative approach
  - Approach within and between the phases contributes to the comprehensiveness and consistency of the study and the reported results
- Transparency
  - Due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCA, in order to ensure a proper interpretation of the results
- Comprehensiveness
  - Considers all attributes or aspects of natural environment, human health and resources. By considering all attributes and aspects within one study in a cross-media perspective, potential trade-offs can be identified and assessed.

According with ISO 14040(2006)

# Advantages and limitations of LCA

- Some advantages
  - Holistic view
  - Assessment of global and regional environmental impacts
  - Adds objectivity to impact assessment
  - Provides information for improvements, communication, etc.
  - LCA is an evolving methodology (e.g. databases, impact assessment, etc.)

- Some limitations
  - LCA is a model of a complex reality, thus a simplification of reality
  - Scope dependent
  - Data availability
  - Could be time consuming, depending on the scope and objectives
  - Not a triple bottom assessment (social and economic assessment, typically out)

# When LCA could be useful?

- Internally
  - Compare environmental impacts of different products with the same function
  - Compare a product environmental impact with reference to a standard
  - Identify the most environmentally most dominant phases in a product life cycle
  - In eco-design, identify opportunities for improvement
  - Help the company internal strategy definition

- Externally
  - Marketing
  - Information and education
  - Lobbying
  - Labeling purposes

# When LCA should not to be used?

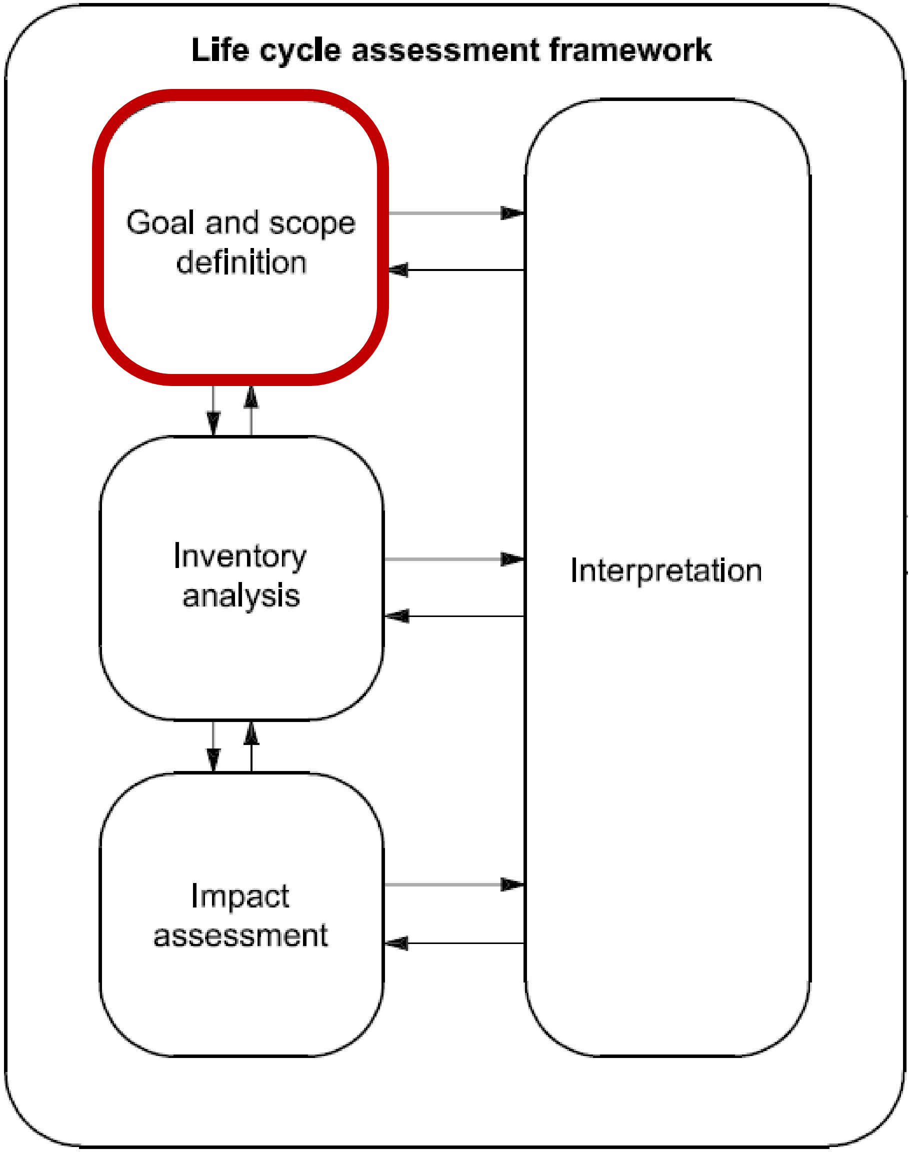
- Compare environmental impacts of totally different products
- It is not a substitute for location dependent assessments (e.g. EIA – Environmental Impact Assessment), but is complementary
- The same thing for risk analysis

# Overview

- Goal and scope
- Inventory analysis
- Impact assessment
- Interpretation

# Goal and scope definition

# Step 1 - Goal and scope




**LCA step 1**

**Goal and Scope Definition**

- Goal Definition
  - The purpose of the analysis
  - The intended use of the results
  - The study stakeholders

## Scope definition

- Scope definition
  - Product system to be studied
  - Functions of the product system or, in the case of comparative studies, the systems
  - Functional unit
  - System boundary (process included)
  - Allocation procedures
  - Methodology of impact assessment, impact categories selected and subsequent interpretation to be used
  - Data requirements (temporal, spatial and technological coverage)
  - Assumptions
  - Limitations
  - Initial data quality requirements

## Scope definition

- Type of critical review, if any
- Type and format of the report required for the study

The scope should be sufficiently well defined to ensure that the depth and detail of the study are compatible and sufficient to address the stated goal

- Nevertheless, the initial goal and scope definition (LCA step 1) is to be revised interactively, according with intermediary and final results, as well with choices made during the LCA (e.g. allocation made in specific process)

- Document, Document, Document…

# System boundaries cut-off rules

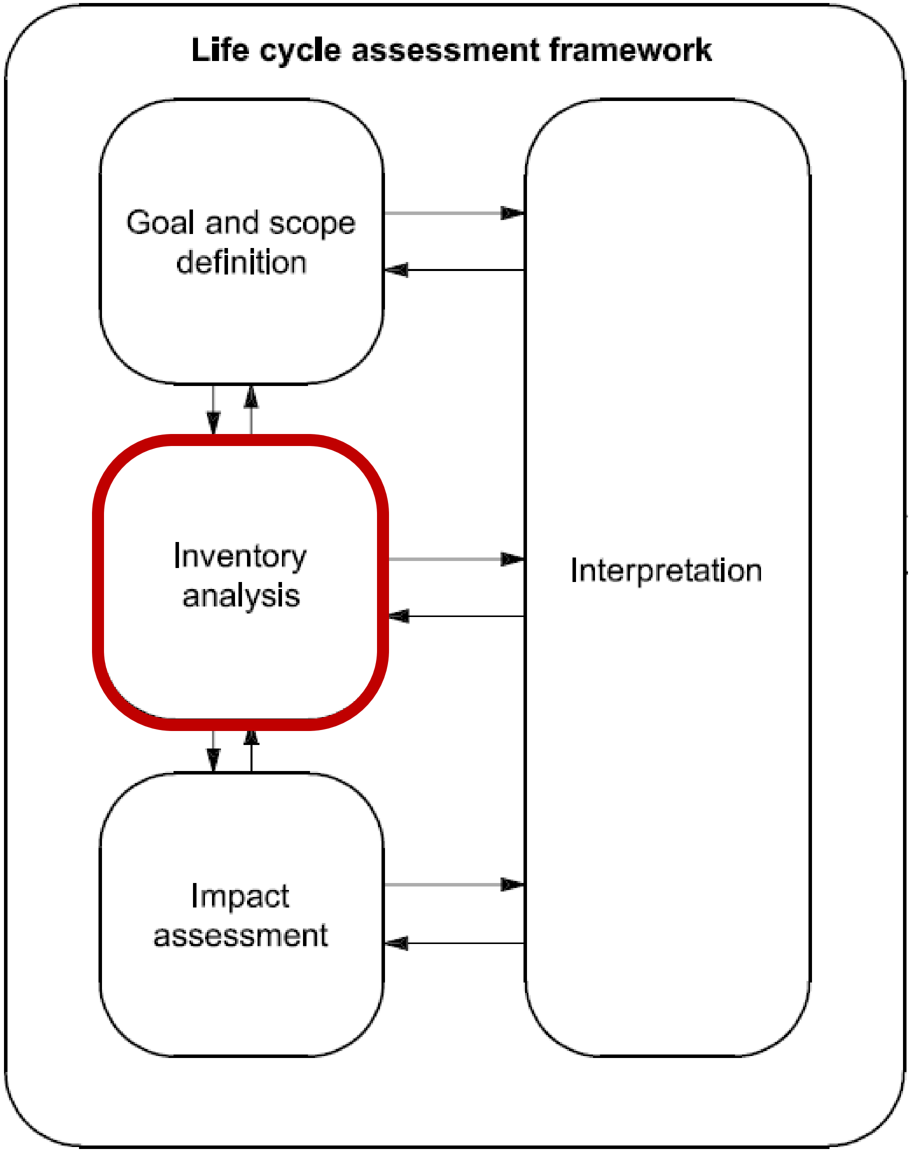
- Cut-off rules (system boundaries)

| | ISO 14044 (2006) | Concept |
|---|---|---|
| 1 | % of total mass (e.g. 5%) | Materials and energy |
| 2 | % of Energy | Excluding capital goods |
| 3 | % of environmental relevance | Including capital goods |

↓

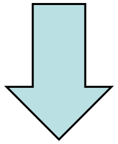
Best!
But how to do it? In this stage we still have no result…

# Step 2 – Inventory analysis




**LCA Step 2**

**Inventory analysis**



**LCI – Life Cycle Inventory Analysis**

- Inventory Analysis
  - The inputs and outputs of all life-cycle processes have to be determined in terms of material and energy.
  - Produce a process tree or a flow-chart classifying the events in a product's life-cycle which are to be considered in the LCA, plus their interrelations.
  - Next, start collecting the relevant data for each event: the emissions from each process and the resources (back to raw materials) used.
  - Establish (correct) material and energy balance(s) for each process stage and event.

# Example of a material/energy balance

- Example of a simplified material/energy balance

| Resources | | | Atmospheric emissions | | | Water emissions | | |
|---|---|---|---|---|---|---|---|---|
| Hydroelectric energy | 594,0 | MJ | $CO_2$ | 748000,0 | g | Residual water | 1,7 | m3 |
| Natural gas (vol) | 14,5 | m3 | $SO_x$ | 2690,0 | g | Cl | 63900,0 | g |
| Uranium | 4,8 | g | $NO_x$ | 2310,0 | g | Inorganic subst. | 39500,0 | g |
| Process water | 1,0 | m3 | VOC | 1640,0 | g | Suspension solids | 5030,0 | g |
| Glass cullet | 625,0 | kg | Dust | 1300,0 | g | Sulphates | 627,0 | g |
| Sand | 253,0 | kg | CO | 787,0 | g | Oils | 283,0 | g |
| Fuel oil | 183,0 | kg | Metane | 781,0 | g | VOC | 74,0 | g |
| Lime stone | 110,0 | kg | HCl | 67,9 | g | Metallic ions | 59,3 | g |
| Rock salt | 108,0 | kg | Pb | 44,6 | g | $NH_4^+$ | 29,3 | g |
| Calcium carbonate | 80,5 | kg | Ammonia | 38,2 | g | Ba | 24,3 | g |
| Coal | 49,1 | kg | HF | 15,8 | g | Fe | 23,6 | g |
| Rock | 35,5 | kg | metals | 4,2 | g | Al | 20,3 | g |
| Anthracite | 13,0 | kg | $C_xH_y$ aromatic | 3,8 | g | N tot | 9,9 | g |
| | | | $N_2O$ | 2,0 | g | COD | 9,6 | g |
| | | | Benzene | 1,9 | g | $C_xH_y$ aromatics | 7,8 | g |
| | | | Ni | 0,4 | g | Nitrates | 6,3 | g |

# Data

- Data collection
  - Energy inputs, raw material inputs, ancillary inputs, other physical inputs
  - Products, co-products and waste
  - Emissions to air, discharges to water and soil
  - Other environmental aspects
- Data calculation
  - Validation of raw data
  - Relating data to unit process
  - Relating data to functional unit and reference flow

- Intensive aspect – constrains should be stated in the report (goal and scope)

# Allocation

- Allocation
  - Most industrial processes yield more than one product and they recycle intermediate or discarded products as raw materials
  - Examples:
    - Cow: milk, meat, leather
    - Salt electrolysis: chlorine, caustic soda and hydrogen

- What we are talking about is how to allocate environmental impacts for each product
  - As for the functional unit, “Good” allocation procedures are essential for an effective LCA study
  - Probably the most controversial aspect in LCA

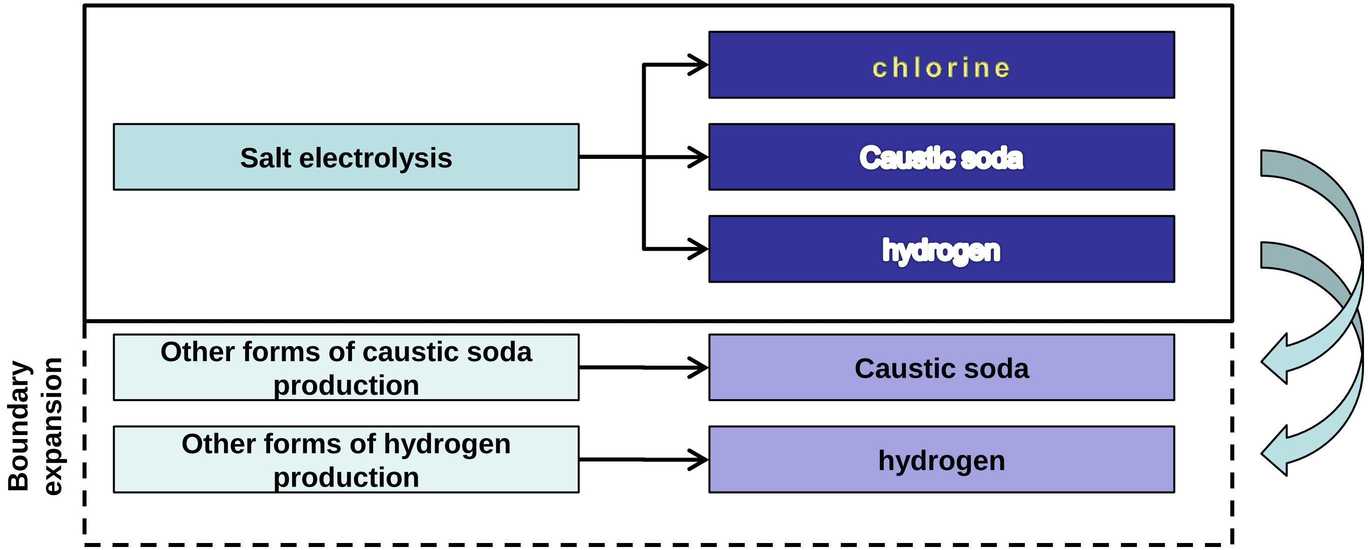
# Allocation

- How to proceed?
  1. Avoid allocation in the first place
  2. Allocate impacts to the different products (allocation)

- Avoid allocation
  – By splitting the process in such a way that it can be described as two separate processes that each has a single output
  – Often this is not possible, for example wooden planks and saw dust are both an economic outputs of a saw mill, but one cannot split the sawing process into a part that is responsible for the saw dust and one that is responsible for the planks.

# Avoid allocation

- Other option: Expand system boundaries
  - Inventory of alternative process that can produce the same product
  - Subtraction of the emissions from these process from the main output
  - When we don’t know the substitute process, we chose the worst case scenario - avoided product with less environmental impacts



# General allocation

- Allocation strategies:
  1. Use of physical causality (mass allocation, but energy could be also applied, e.g. incineration – electricity and heat), and if not possible
  2. Use other relationships (economic allocation)

| | Mass allocation (mass percentage) | Economic allocation (added value allocation) |
|---|---|---|
| Wooden planks | 60% | 95% |
| Saw dust | 40% | 5% |

## General allocation

- When one of the outputs is waste, that should be taken that into account and the waste must be "discounted" from the allocation (unless it's a sub-product)

- Economic allocation
  - Prices can fluctuate significantly (interferes in the analysis)
  - Economic values are not always easy to obtain

- It is always wise to perform a sensitivity analysis to know if the allocation method is relevant for the final result

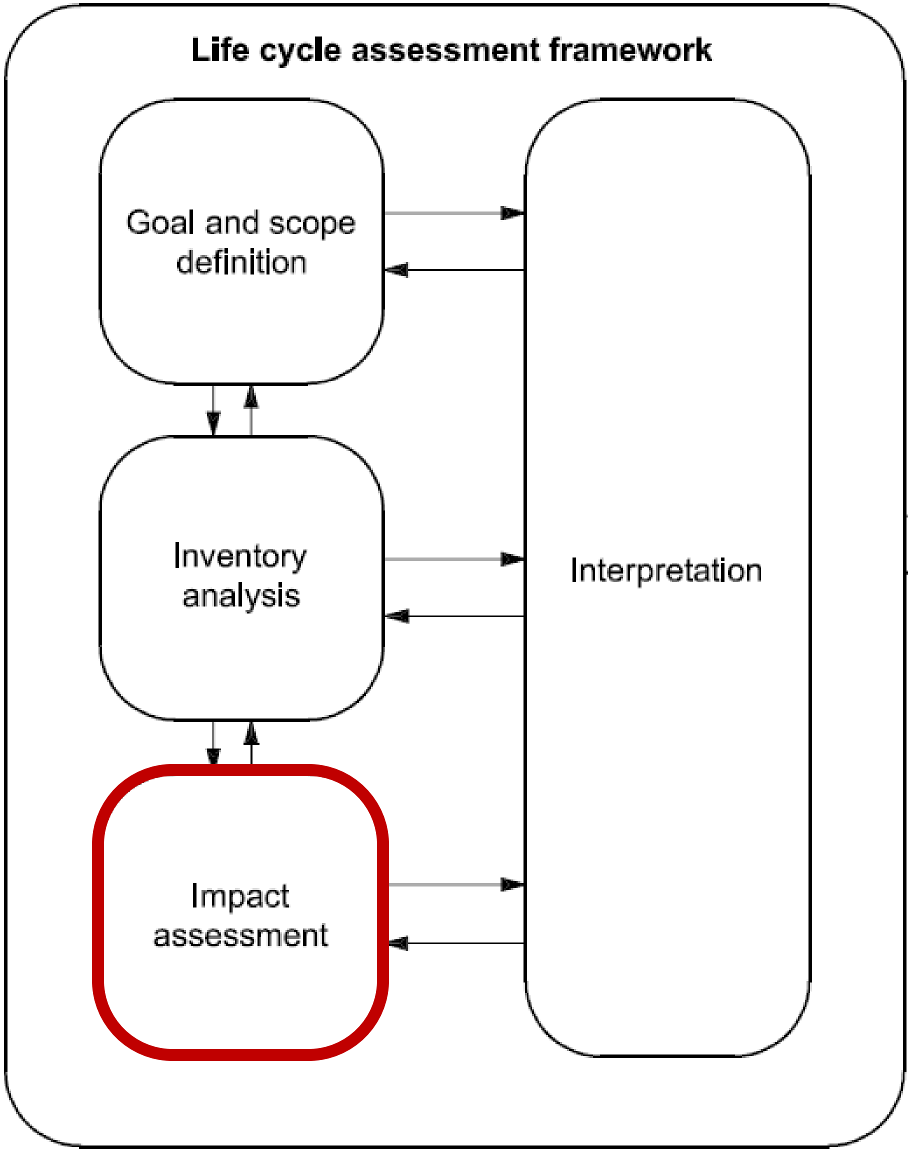
# End-of-Life allocation

- Where no changes occur in the inherent properties of the recycled material, the allocation problem is avoided because the use of secondary material displaces the use of virgin (primary) materials
  - However, the first use of virgin materials in applicable open-loop product systems may follow an open-loop allocation procedure

- When changes occur in open-loop system, there should be allocation based on the following order:
  - Physical properties (e.g. mass), Economic properties, Number of subsequent uses of the recycled material

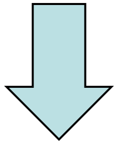
- How to do economic allocation?
  - Market value of the scrap material or recycled material in relation to market value of primary material
  - Ratio between waste (Product system 1 to recycling) or secondary material (recycling to Product system 2) prices, in relation with their sum. -> Who drives the market?

# Step 3 – Impact assessment




**LCA step 3**

**Impact assessment**



**LCIA – Life Cycle Impact Assessment**