



DDI8003 – Week 2

Goal and scope according to ISO, function, functional unit, reference flows, product system and system boundary

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and Pr. Laure Patouillard)



POLYTECHNIQUE
MONTRÉAL

UQÀM EPFL Hes-so

On the agenda today

- Reminder:
 - **select/define LCA project and groups**
 - **basic concepts of the LCA framework**
- Definition of the scope study scope
 - **List of ISO 14044 elements to include in the « scope »**
 - **Functional unit**
 - **Reference flows and key parameters**
 - **Product system and process tree**
- Case studies
- Homework

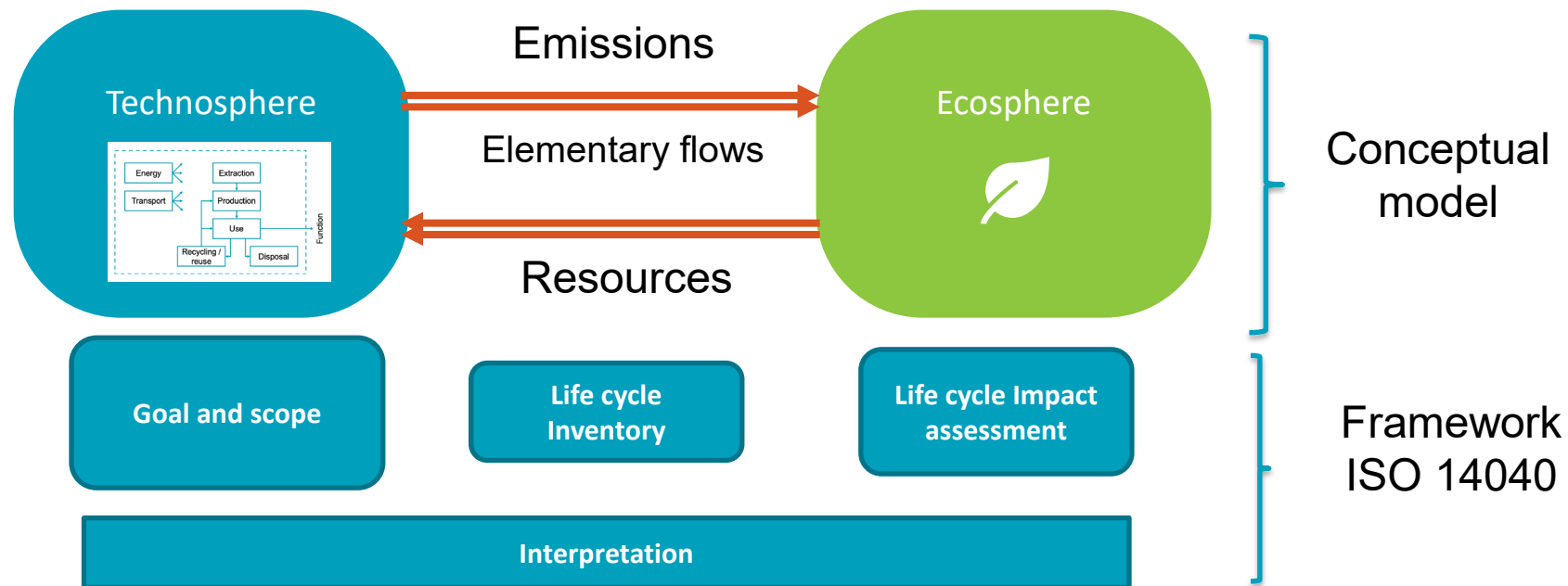
Quick reminder from last week

BASIC CONCEPTS

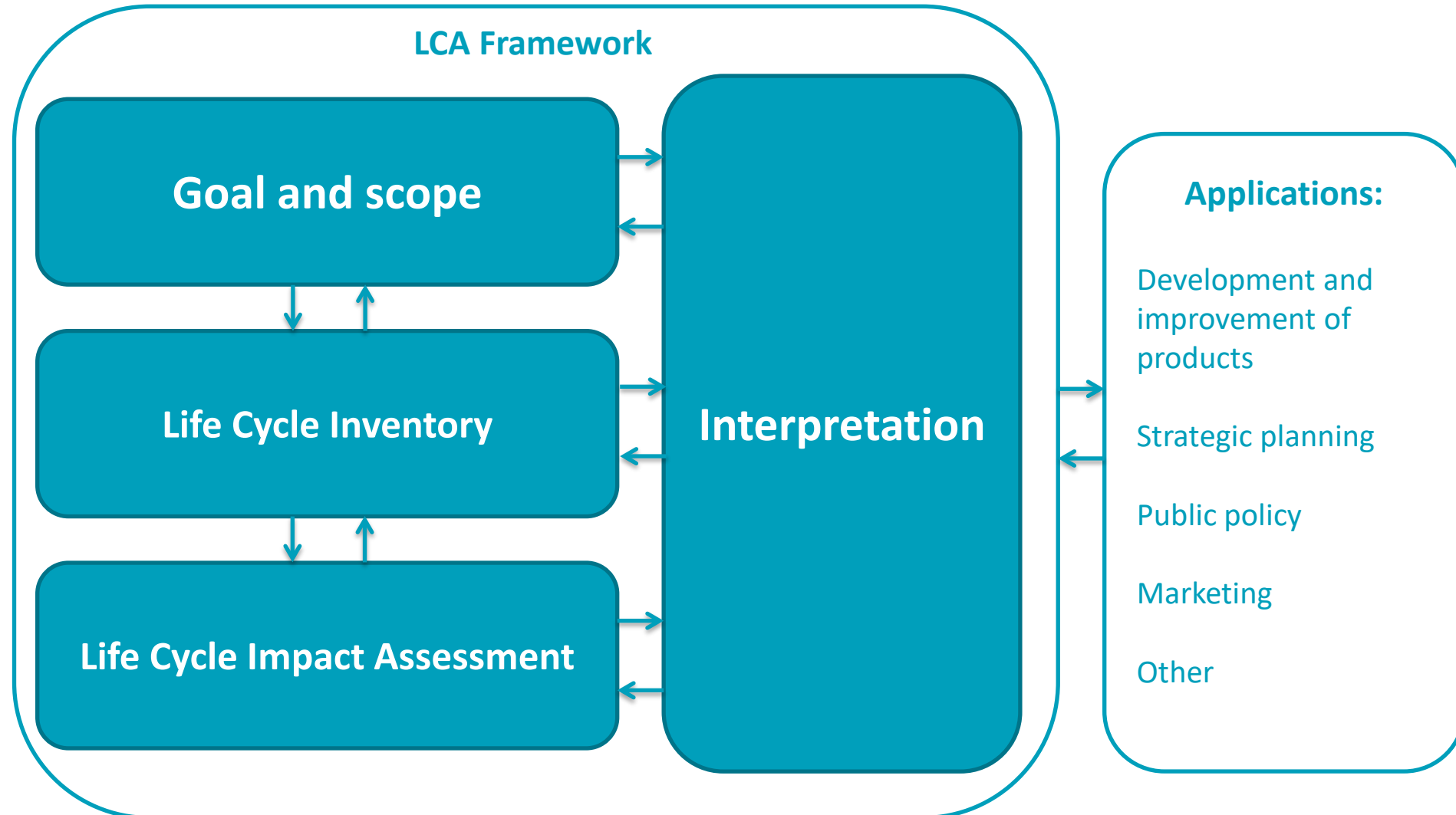
Conceptual model and framework of analysis ISO 14040

In sum, an LCA consists of...

1. Defining the product system (activities related to a product/service)
2. Calculating all the exchanges between the product-system and the environment (environmental flows)
3. Calculating the potential environmental impacts related to these elementary flows
4. ... without forgetting to interpret the results in relation to the goals of the study (ISO 14040)



LCA Framework and applications (ISO 14040)



Goal and scope

DEFINITION OF THE GOAL OF THE STUDY

Goal of the study:

The commissioner of the study and those executing it need to define:

Why?

the reasons
for carrying
out the study

For whom?

the intended
audience

For what purpose?

The intended
application

Defining the goal: Why - the reasons for carrying out the study

Why?

- The reasons to conduct an LCA study can be multiple.
 - Some examples:
 - **Determine environmental impacts of a product, service or technology**
 - **Identify the environmental hotspots along its whole life cycle**
 - **Improve the design of a product, service or technology**
 - **Compare two products, services or technologies**
 - **Elaboration of environmental policies and/or assess the consequences of a policy on environmental impacts**
 - **Prove the environmental superiority of a material towards other materials**
 - **And many more...!**

Of course, the « why », the « for whom » and the « for what purpose » are closely interconnected

Defining the goal: For whom - intended audience

For whom?

- The intended audience:
 - **Internal:** the sole commissioner has access to results (e.g. engineers, designers)
 - **« External, restricted »:** the results will be disseminated to identified actors, (e.g. a supplier or a client)
 - **Public:** any interested party will have access to the results, or the result will be part of a marketing strategy.

Will the public be "technical" or "non-technical"? Communication may need to be tailored to the target audience.

→ Third party report

Defining the goal: For whom - intended audience

The specific case of comparative LCA to be disclosed to the public

Comparative assertion?

For this specific case:

- « **environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function** »

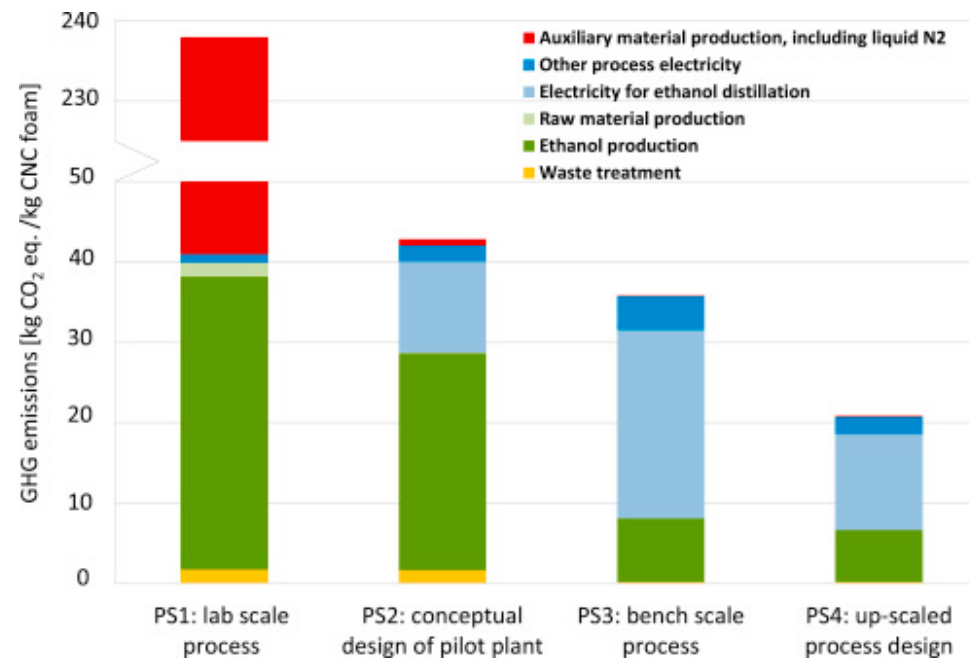
The ISO14040 standard will need special requirements (documentation, external critical review, etc.)

Defining the goal: For what purpose - intended applications

For what purpose?

- Improving products/services

- Identifying performance indicators
- Prioritising changes to a process or product (« hot spots analysis »)
- Ecodesign, design-for-recycling



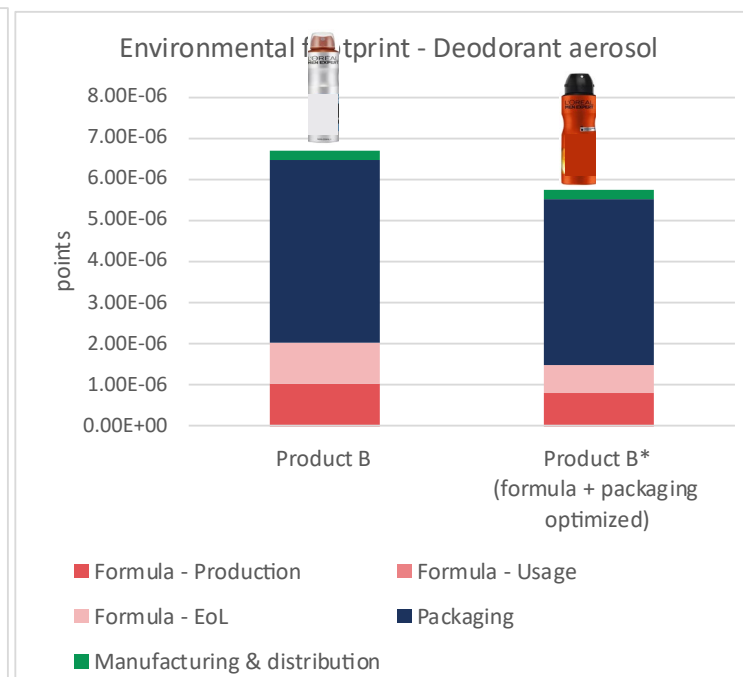
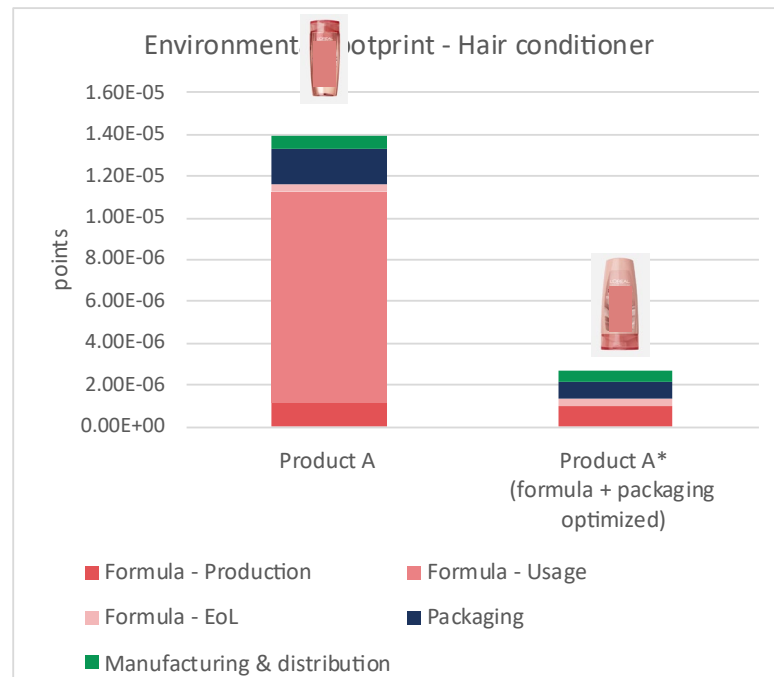
cellulose nanocrystals (CNC) foam at different development stages



Defining the goal: For what purpose - intended applications

For what purpose?

- Improving products/services
 - Identifying performance indicators
 - Prioritising changes to a process or product (« hot spots analysis »)
 - Ecodesign, design-for-recycling

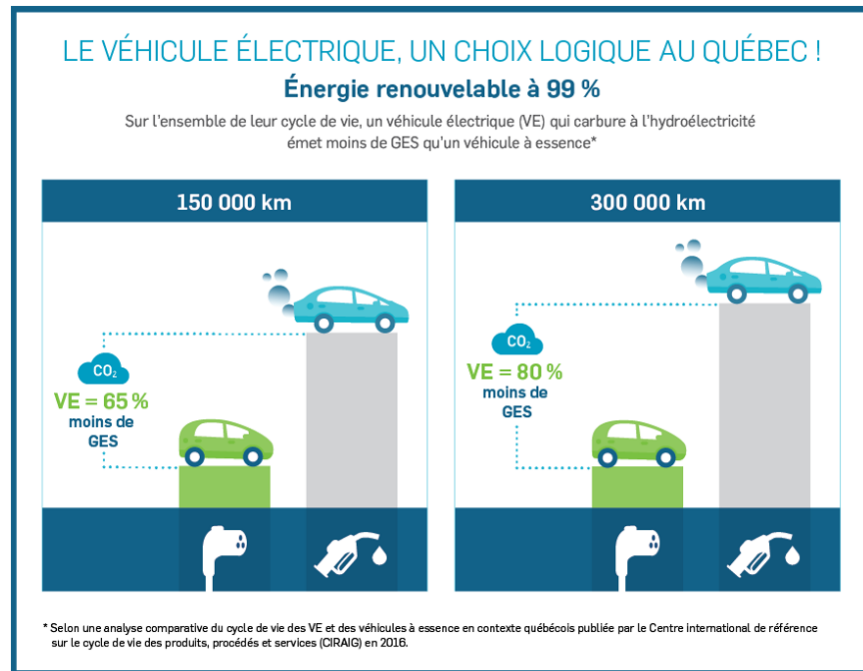


L'ORÉAL

Defining the goal: For what purpose - intended applications

For what purpose?

- **Comparison of products/services**
 - Product A vs product B,
 - Technology A vs technology B
 - Comparison to a competitor average
 - Choice of a supplier



Defining the goal: For what purpose - intended applications

For what purpose?

- **Communication B2C**
 - Provide information for ecolabels
 - Communicate the environmental profile on several env. indicators

Nutrition Facts			
Serving Size 2/3 cup (55g)			
Servings Per Container About 8			
Amount Per Serving			
Calories	230	Calories from Fat 40	
% Daily Value*			
Total Fat	8g		12%
Saturated Fat	1g		5%
Trans Fat	0g		
Cholesterol	0mg		0%
Sodium	160mg		7%
Total Carbohydrate	37g		12%
Dietary Fiber	4g		16%
Sugars	1g		
Protein	3g		
Vitamin A			10%
Vitamin C			8%
Calcium			20%
Iron			45%
* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs.			
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Life Cycle Impacts	
(per m ²)	
Declared unit: 1 m ² of concrete	
OPERATIONAL IMPACTS	
Non-renewable primary energy (MJ)	
Renewable primary energy (MJ)	
Total primary energy (MJ)	
Non-renewable material resource (kg)	
Renewable material resource (kg)	
On-site waste disposal (hazardous) (kg)	
On-site waste disposal (non-hazardous) (kg)	
ENVIRONMENTAL IMPACTS	
Climate change (kg CO ₂ -eq)	
Acidification (kg SO ₂ -eq)	
Eutrophication (kg PO ₄ eq)	
Photochemical ozone creation (kg O ₃ eq)	

Defining the goal: For what purpose - intended applications

For what purpose?

- **Communication B2C**
 - Provide information for ecolabels
 - Communicate the environmental profile on several env. indicators

L'Occitane
Valeurs calculées pour un soin des mains :

Consommation d'eau	Ressources non renouvelables	Impact sur le climat
1,5 cl	0,4 g équivalent pétrole	1,5 g équivalent CO ₂

La fabrication de ce produit consomme 3,8L d'eau par unité. L'OCCITANE s'engage à réduire sa consommation d'eau dans le respect des normes d'hygiène strictes.

Le transport de ce produit en boutique se fait à l'international majoritairement en bateau. Néanmoins, ce produit a été livré en boutique par un camion.

Le tube en aluminium émet du CO₂ lors de sa fabrication. En le triant, vous participez à son recyclage et limitez l'impact de votre achat sur les changements climatiques.

Weleda
Impact environnemental *

- écotoxicité aquatique: Faible (A) 0,3 eq CO₂
- gaz à effet de serre: 56 g eq CO₂
- consommation d'eau: 5,4 litres

Ducray
Impact Environnemental du produit

- Emission de gaz à effet de serre: 35,2 g eq CO₂
- Consommation d'eau: 7,3 litres
- Ecotoxicité Aquatique: 2,4 eq CO₂

Le Petit Marseillais

- Emissions de gaz à effet de serre: 55g CO₂eq
- Consommation d'eau: 9 Litres
- Ecotoxicité aquatique: 0,03 CTUe

SHAMPOOING ULTRA DOUX Garnier À L'AMANDE DOUCE ET FLEUR DE LOTUS

- Les émissions de gaz à effet de serre: 60 g* eq CO₂ (équivalent 343m parcourus par une voiture (175g/km))
- La consommation d'eau: 9,6 L* (équivalent 6,4 bouteilles d'eau minérale de 1,5 L)
- La pollution aquatique: 1995 L (équivalent 0,8 pechies de jardin (3,4m²))

Exemple d'étiquetage sur le marché de l'hygiène/beauté

Defining the goal: For what purpose - intended applications

For what purpose?

- **Communication**
 - Provide information for ecolabels
 - Communicate the environmental profile, on several env. indicators
 - Need of Product category rules (PCR) and Environmental Product Declarations (EPD)

Eurobarometer

[Home](#) [Browse all surveys](#) [Browse by category](#) ▾ [About Eurobarometer](#) ▾

Attitudes of Europeans towards building the single market for green products

PAGE CONTENTS

[Abstract](#)

[Attachments](#)

[Details](#)

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Abstract

According to this survey, most Europeans would be prepared to change their purchasing habits and buy more environmentally-friendly products, but many feel they lack information and distrust manufacturers' environmental claims. The survey also indicates that 77% of respondents are willing to pay more for environmentally-friendly products if they were confident that the products are truly environmentally-friendly. However, only 55% feel informed about the environmental impacts of the products they buy and use.

Defining the goal: For what purpose - intended applications

For what purpose?

- **Communication**

- Provide information for ecolabels
- Communicate the environmental profile, on several env. indicators
- Need of Product category rules (PCR) and Environmental Product Declarations (EPD)

Green Business

Environmental Footprint methods

The European Commission has proposed the Product Environmental Footprint and Organisation Environmental Footprint methods as a common way of measuring environmental performance.

PAGE CONTENTS

[Overview](#)

[The Environmental Footprint transition phase](#)

[Related Documents](#)

Overview

Companies that wish to market a product as environmentally friendly in the EU face a range of choices of methods and initiatives. Without a reliable, state of the art, life cycle assessment, companies are not able to make the right decision to improve their environmental performance. This results in costs for companies, lack of clarity for consumers and potentially a missed opportunity to promote truly sustainable products that are respectful of the environment.

In December 2021, the Commission adopted a revised [Recommendation on the use of Environmental Footprint methods](#), helping companies to calculate their environmental performance based on reliable, verifiable and comparable information. It also allows other actors (public administrations, NGOs, business partners, for example) to have access to such information. The [European Commission's Joint Research Centre](#) has been driving the scientific and technical developments to ensure robustness and impartiality.

Defining the goal: For what purpose - intended applications

For what purpose?

- **Communication B2B**
 - Provide information for ecolabels
 - Communicate the environmental profile, on several env. indicators
 - Need of Product category rules (PCR) and Environmental Product Declarations (EPD)



Further examples
<https://www.environmentaldec.com/library>

Defining the goal: For what purpose - intended applications

For what purpose?

- **Support policy making**
 - Analysis and prospective for technologies (energy, electricity, water, waste treatment, transport, etc.)
 - Identifying groups of products to maximize the reduction of environmental impacts

**Ordonnance
sur l'imposition des huiles minérales
(Oimpmin)**

641.611

Swiss mineral oil tax regulation

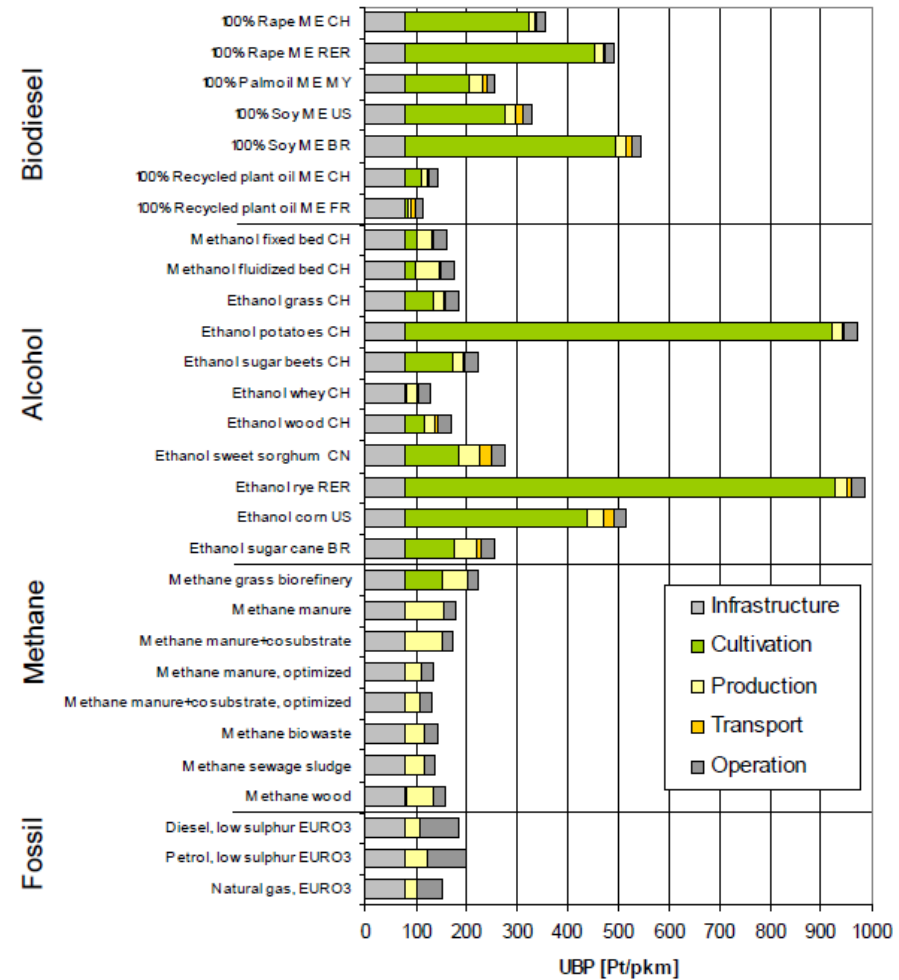
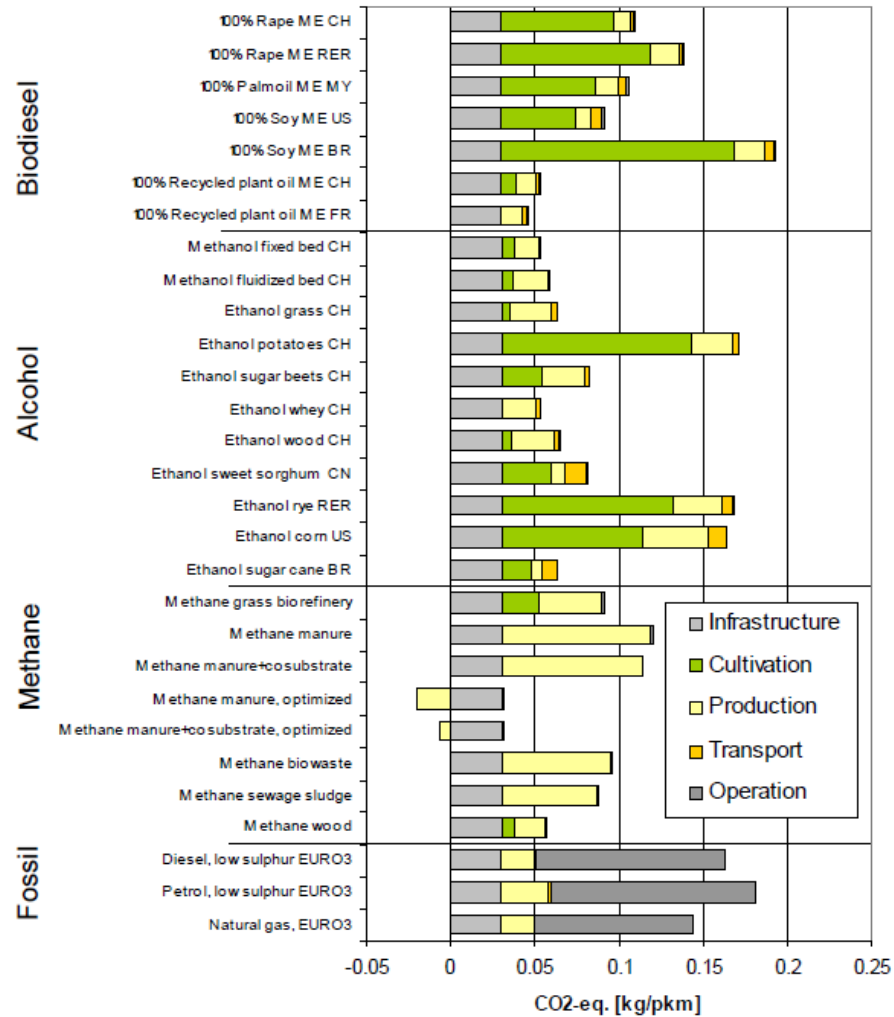
du 20 novembre 1996 (Etat le 1^{er} janvier 2017)

Le Conseil fédéral suisse,

vu la loi du 21 juin 1996 sur l'imposition des huiles minérales (Limpmin¹)²,

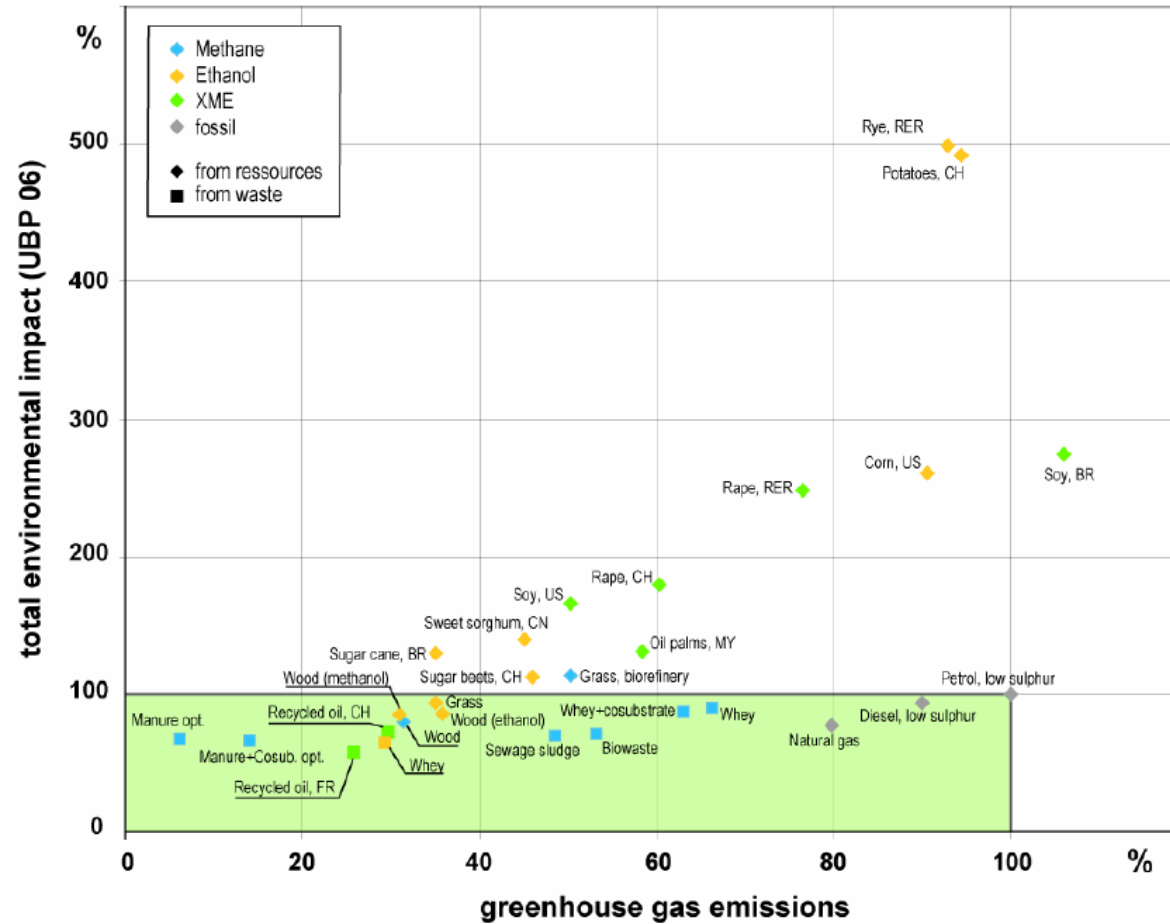
arrête:

Life cycle assessment of biofuels vs. fossil fuels



(Zah, et al. 2007. Life cycle assessment of energy products: environmental impact assessment of biofuels. BFE, BAFU, BLW. <https://www.osti.gov/etdeweb/servlets/purl/21208801>)

Life cycle assessment of biofuels vs. fossil fuels



(Zah, et al. 2007. Life cycle assessment of energy products: environmental impact assessment of biofuels. BAFU)

Defining the goal: For what purpose - intended applications

For what purpose?

- Support policy making

tax relief for biofuels

Art. 19b Allégement fiscal pour les biocarburants

L'allégement fiscal pour les biocarburants est accordé sur demande conformément au tarif figurant à l'annexe 2.

Art. 19c Exigences écologiques

¹ Les exigences visées à l'art. 12b, al. 1, let. a à c, Limpmin (exigences écologiques) sont remplies:

- a. si, depuis la production des matières premières jusqu'à leur utilisation, les biocarburants émettent au moins 40 % de gaz à effet de serre en moins que l'essence fossile; **release less than 40% of GHG**
- b. si, depuis la production des matières premières jusqu'à leur utilisation, les biocarburants ne nuisent globalement pas à l'environnement de plus de 25 % que l'essence fossile, et **do not globally harm the environment more than 25%**
- c. si les matières premières n'ont pas été produites sur des surfaces ayant fait l'objet d'un changement d'affectation après le 1^{er} janvier 2008 et ayant présenté avant le changement d'affectation un important stock de carbone ou une grande diversité biologique. **do not generate land use change**

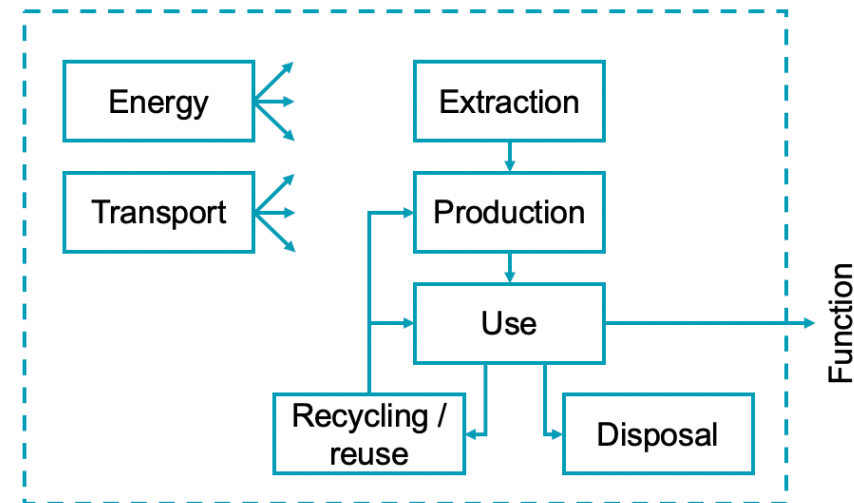
Ordonnance
sur l'imposition des huiles minérales
(Oimpmin)

Function, Functional unit and reference flows

DEFINITION OF THE SCOPE OF THE STUDY

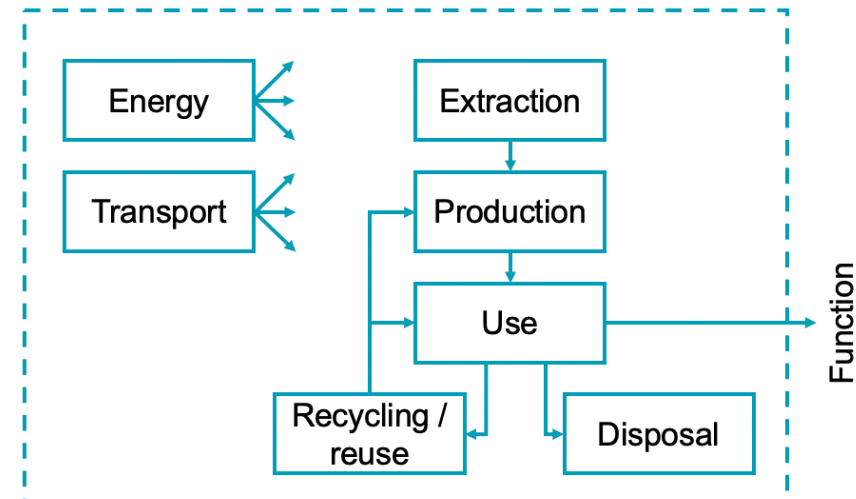
Defining the scope

- « Goal » and « Scope » in « goal and scope »
 - **Goal:** « **why** are we analysing? »
 - **Scope:** « **what** are we analysing and **how** will we analyse it? »
- We define the following elements:
 - **The product system to study**
 - **Functions of the system**
 - **The functional unit**
 - **Reference flows**
 - **The system boundary**
 - **Allocation rules (week 6)**
 - **The type of question (attributional vs consequential)**



Defining the scope

- We define the following elements (continuation):
 - **The impact categories & indicators, as well as the impact assessment methods used (weeks 8-9)**
 - **Requirements for data sources and quality**
 - **Assumptions**
 - **Limitations**
 - **Type of critical review**
 - **Format of the report (deliverables)**



Defining the scope



The conclusions of an **LCA** are only valid inside the **defined scope of the study**. It is dangerous to extrapolate for other technologies, use profiles, geographical contexts, years, etc.

Defining the scope: function and functional unit

Function (qualitative)

One needs to ask the following questions:

- For what is the product useful?
- How is it actually used by consumers?
- What is the service provided?
- Must be consistent with the goals of the study
- Mandatory properties vs. Optional properties



In LCA, the comparison is based on a functional unit in order to allow comparing different product systems on a **common basis**

Function of a product system

... it is traditionally defined by an **action verb**

Define the function of those 3 different products:

- For what is the product useful?
- What is the service provided? **[part 1: service provided]**
- How is it actually used by consumers? **[part 2: context]**
- Must be consistent with the goals of the study
- Mandatory properties vs. Optional properties **[part 3: inclusion criteria]**



Function of a product system

... it is traditionally defined by an **action verb**

Define the function of those 3 different products:

- For what is the product useful?
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- How is it actually used by consumers? **[part 2: context]**
- Must be consistent with the goals of the study
- Mandatory properties vs. Optional properties **[part 3: inclusion criteria]**



*Fx: sit & rest comfortable
(+ sleep function?)*



*Fx: to serve
(hot?) drink*



*Fx: protect the feet
(+ protect from the cold?
+ protect from water?)*

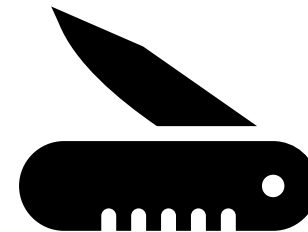
... in « given location X », in « year Y ».

Defining the scope: function and functional unit

« Multifunctional » products

- Some products provide other functions in addition to the « primary function »
- It is important to understand the importance of these secondary functions to determine if the different options considered are actually comparable.

(week 6)



Functional unit (FU): definition

A measure quantifying the different dimensions of the service delivered by the system

- **Mesurable and additive**
- **Basis on which scenarios are compared**
 - **Must ensure a fair comparison**

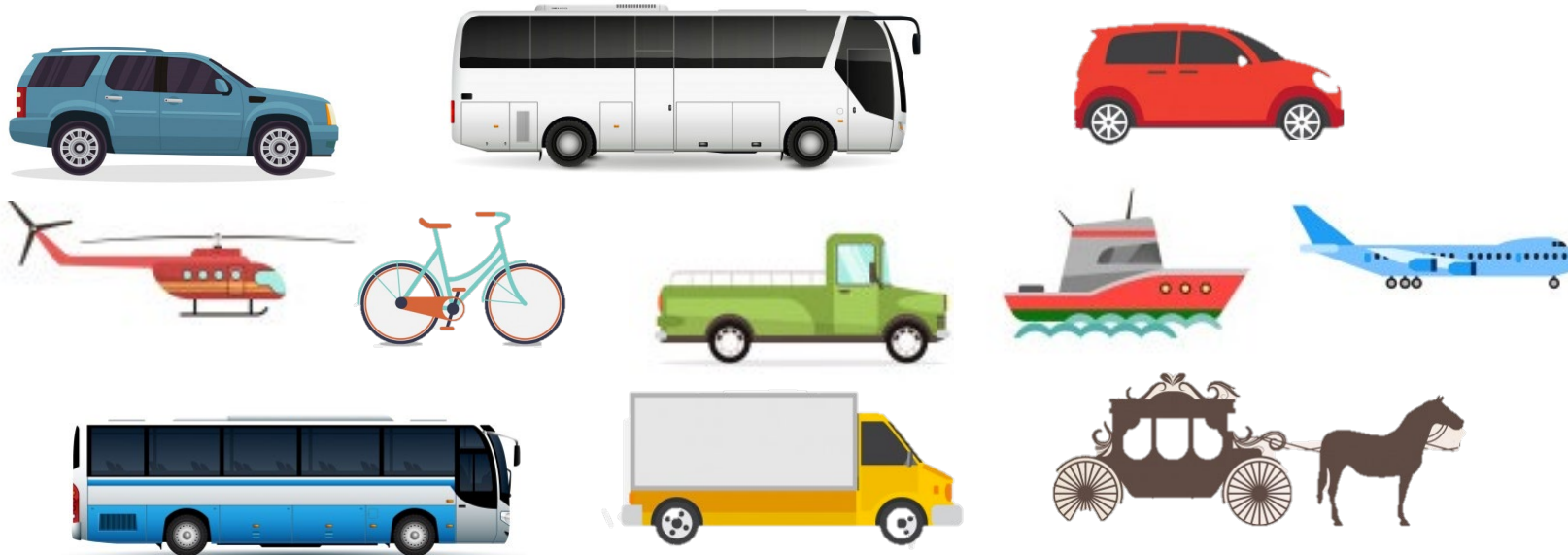
“quantified performance of a product system for use as a reference unit” in a LCA (ISO 14044)

Example: function and functional unit

Function: Transport

Functional unit: ?

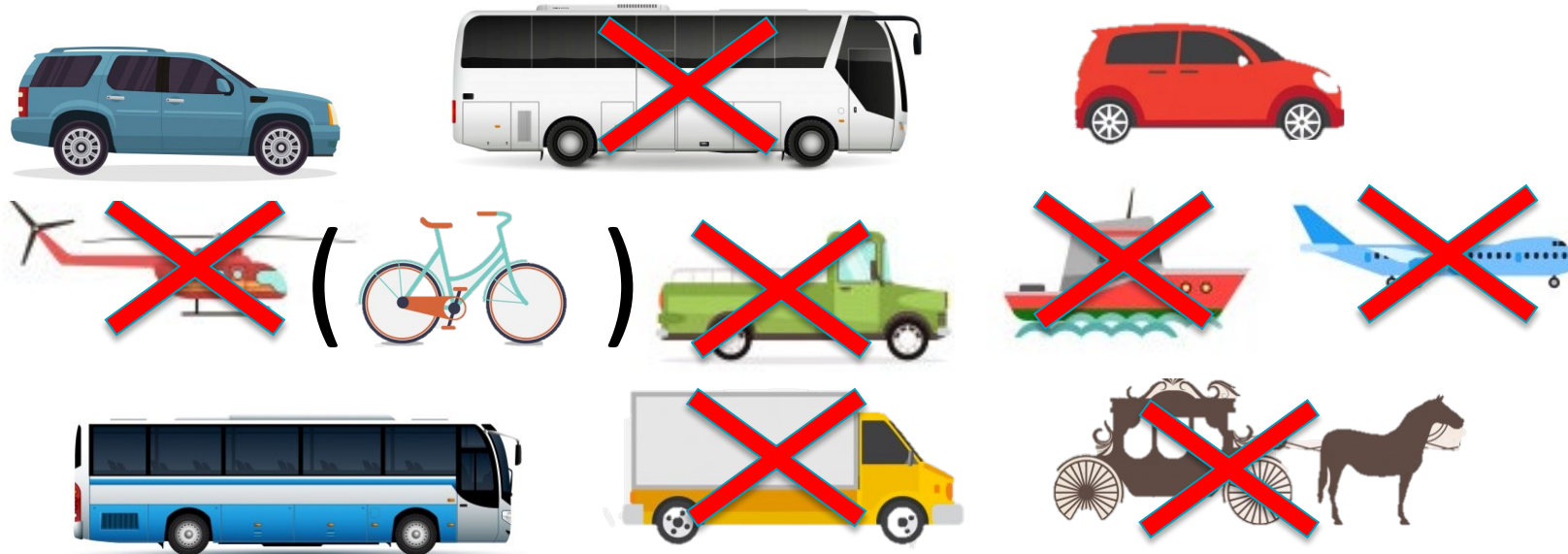
It is important to be specific when defining the function and functional unit



Example: function and functional unit

Function: *Ground transport of persons for commuting, in Montréal in 2025, at minimum 10 km/h speed.*

Functional unit: transporting 1 person over 5 km = 5 person*km



Example: Functional unit ground transportation for commuting

Functional unit:

It can be advantageous to define your functional unit *at a scale* that is representative of the actual demand → more evocative for decision makers

Functional unit: person*km = transporting 1 person over 5 km *during 1 year*

= 1 person * 220 days/year x 5km/trip x 2 trips/days = **2200 person*km**



Defining the functional unit

The FU should quantify the different dimensions of the service rendered:

- Does the usefulness of your product scale over time?
→ FU should include a time dimension (e.g. $m^2 \times \text{year}$)
- The different dimensions are typically *multiplied* (e.g. $m^2 \times \text{year}$, ton x km).
- A FU is not an intensive property (km/h, kg/m^3 , etc.).
These are properties that do not measure the amount of service delivered
→ but they can be inclusion/exclusion criteria.

Functional unit

... it describes the function **quantitatively**

Define the functional unit of those 3 different products:

How much of what is provided for how long / times?



Functional unit

... it describes the function **quantitatively**

Define the functional unit of those 3 different products:

How much of what is provided for how long / times?



*FU: 2h/d*7d/w*52w/yr*10yr
= support 730h of rest*

*(or 10 years of rest at
a given use intensity)*



*FU: deliver 1 hot
beverage (3dl)*

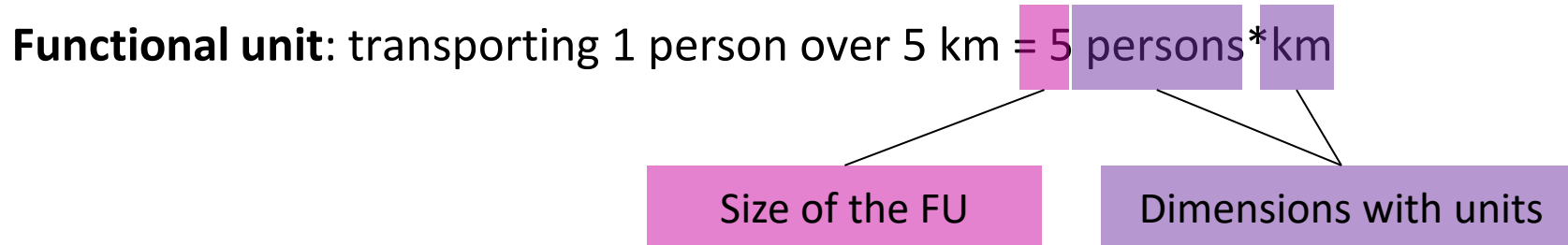
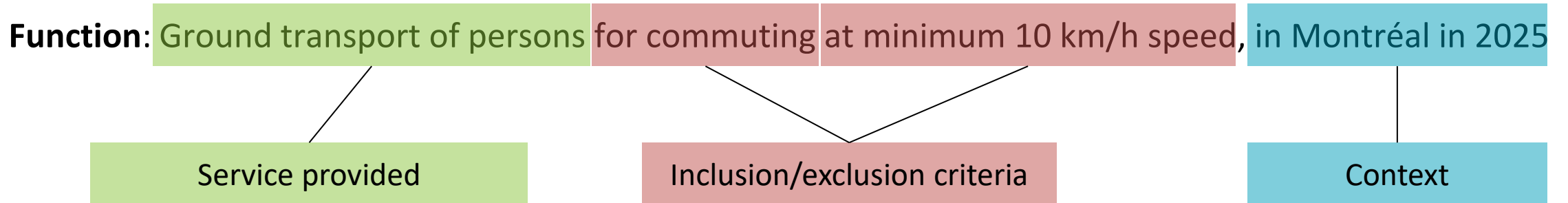


*FU: 8h/day*365d/yr*2yr
= 10'160 h of feet protection*

(or 2 years of feet protection at **CIRAIG** *a given use intensity)*

Recap function and functional unit

Basis of a fair comparison → should be the same for all compared products



Checking your function and functional unit

Don't over complicate function and FU → often quite straightforward

Check if your FU is relevant as a fair basis for comparison: Does it capture the main characteristics of each system?

- If a supplier charged me a fee proportional to this unit, would that be fair?
 - If I promised a functional unit to an evil genius in a fable, could he trap me?
 - **Me: "I promise to carry a kilogram of stones (UF: 1 kg) in exchange for a wish."**
 - **Genie: "Granted! But you didn't specify how far you'd carry these stones... you'll carry them to the ends of the universe! Mouahaha!"**
- **Missing a dimension, underspecified function... I got screwed.**

Check if the additivity of your FU makes sense:

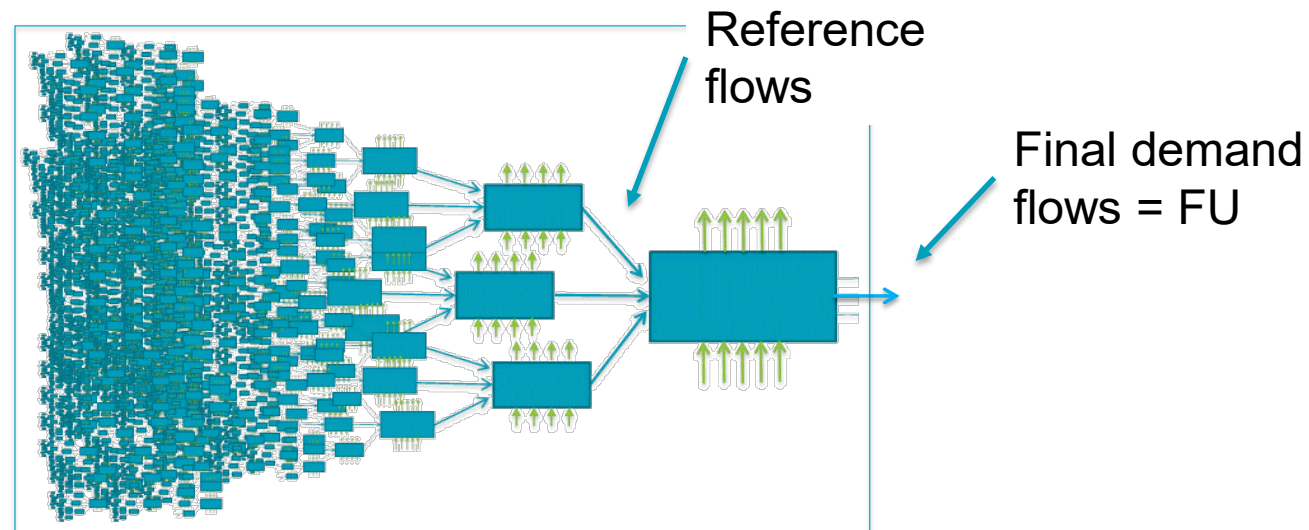
- If I individually double each of the dimensions of my functional unit, do I logically double the service rendered every time?

Scope of the study - Definitions

Final demand flows: Economic flows that provide the **functional unit**

Reference flows (RF): Product flows necessary to provide the final demand flow. These are the flows directly used by the process that delivers the final demand. Expressed in *Quantity of product/Functional unit*

Key parameters (KP): Data used to *calculate* the reference flows per FU



Reference flows

Alternative definition: « *Quantities of products needed and purchased to fill a given functional unit* »

(Jolliet et al. 2019)

A reference flow is generally « experienced by the consumer »

« what needs to be bought to provide the service of the FU »



Keep in mind that in the case of product/service comparisons, the functional units are the same, but the reference flows are different

Definition: key parameters

“Key parameters are the quantities necessary to calculate the reference flows starting from the functional unit »

Examples:

- **Lifespan**
- **Number of re-uses possible**
- **Quantity of material / energy used by a service rendered**
- **Efficiency**
- ...

Sometimes we need more than one key parameter to link a reference flow to the functional unit

Example to calculate a reference flow



Shoe A (good quality)

function :
Protect the feet

Comparison



Shoe B (low quality)

functional unit :
To protect the feet during 1 year

Lifespan shoes: 4 years

Key parameter

Lifespan shoes: ½ year

1/4 pairs of shoe A

Reference flows:

2 pairs of shoe B

$$RF_A = 1\text{yr}/FU * 1 \text{ p.shoes}/4\text{yr} = 1/4 \text{ shoes}$$

$$RF_B = 1\text{yr}/FU * 1 \text{ p.shoes}/0.5 \text{ yr} = 2 \text{ shoes}$$

Example : cups



Function:

Serve (hot) beverages



Functional unit:

Serve 365 (hot) beverages of 3dl daily during 1 yr

Key parameters:

Reference flows:

Example : cups



Function:
Serve (hot) beverages



Functional unit:

Serve 1 (hot) beverages of 3dl daily during 1 yr
= 365 beverages of 3dl

Vol: 3dl/cup
Lifetime : 500 servings/cup
Nb. washes/serving: 1

Key parameters:

Vol: 3dl/cup
Lifetime: 1 serving/cup

Reference flows:

Example: transport



Function:

Commuting people in Montreal in 2025, at minimum 10 km/h speed

Functional unit:

Commuting 1 person over 5 km during 1 year
= 2200 p*km

Key parameters:

Reference flow:

Example: transport



Function:

Commuting people in Montreal in 2025, at minimum 10 km/h speed

Functional unit:

Commuting 1 person over 5 km during 1 year
= 2200 p*km

Consumption: 0.08 L/vkm
Lifetime: 180 000 km
Occupancy rate: 1.2 p/v

Key parameters:

Consumption: 0.75 lt/vkm
Lifetime: 800 000 km
Occupancy rate: 15 p/v

Reference flow:

Ex.: reference flow calculation - # of tiles per functional unit

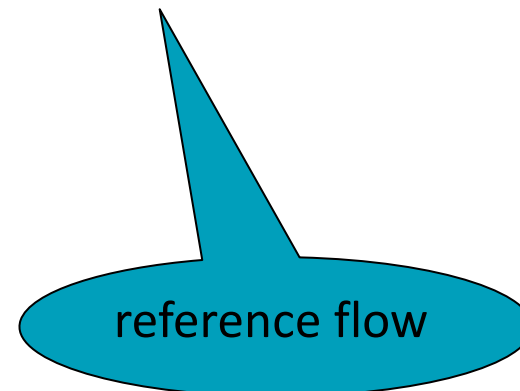
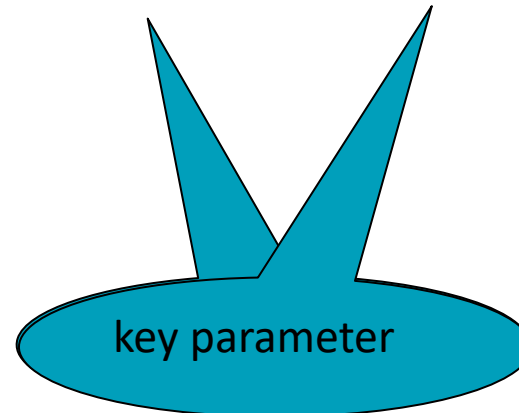
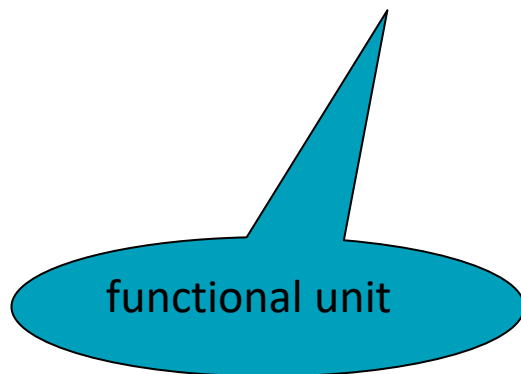
FU = Cover 50 m² of a wall over 10 years.

In this case, we do 50m² x 10 years = 500 m².year.



one ceramic tile lasts 10 years and covers 0.01 m².

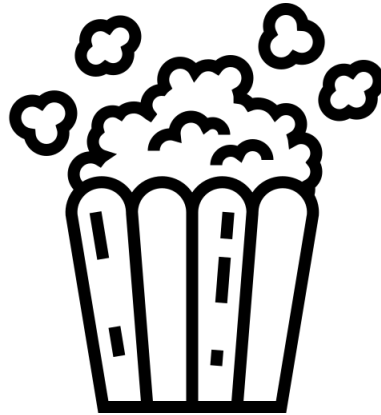
$$\text{RF_tiles} = (500 \text{ m}^2.\text{year}) \times (1 \text{ tile}/0,01\text{m}^2) \times (1/10 \text{ years}) = 5000 \text{ tiles.}$$



Importance to define the right functional unit

EXAMPLE ON PACKAGING

Popcorn vs polystyrene as a packaging material



VS



Which is the environmentally preferable solution?

Popcorn vs polystyrene as a packaging material

Main differences between the 2 scenarios

Traditional scenario: expanded polystyrene « chips »

- -
- -



Alternative scenario studied: popcorn

- -
- -
- -



Adapted from Jolliet, Saadé et Crettaz (2005).
Analyse du cycle de vie: Comprendre et réaliser un écobilan.

Popcorn vs polystyrene as a packaging material

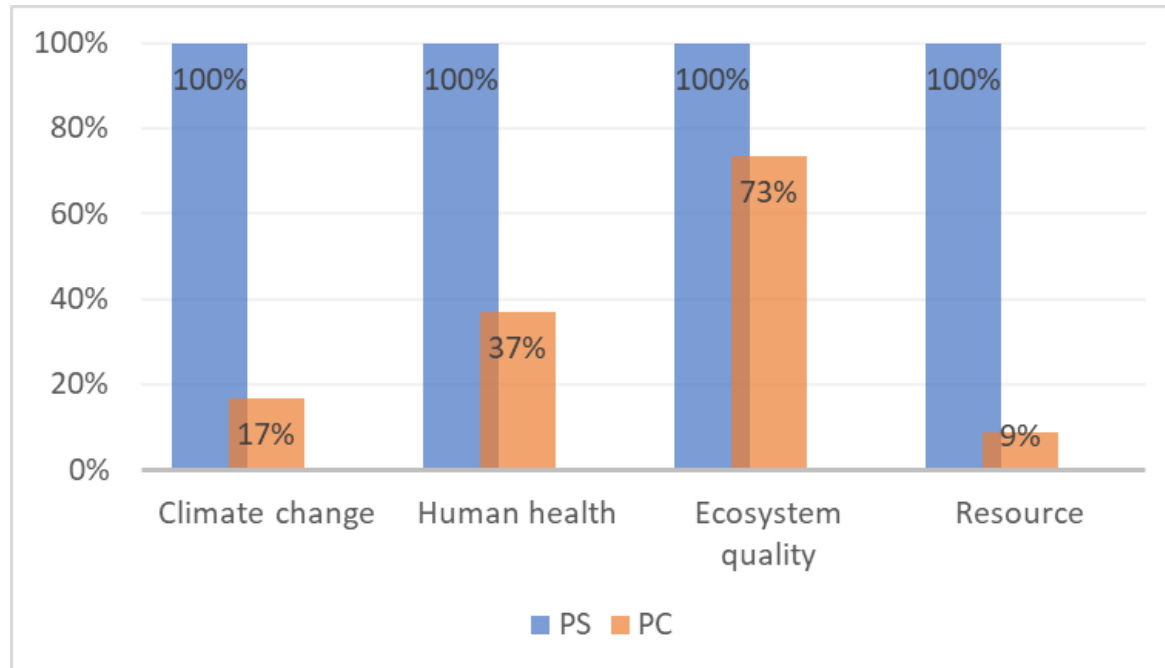
Functional unit: 1 kg packaging material

Emission	Popcorn	Polystyrène
CO ₂	570 g	3440 g
CH ₄	2 g	34 g
N ₂ O	0.53 g	0.03 g
Particle matter	0.5 g	1 g
NH ₃	1.5 g	0.07 g
Nitrates	14 g	0.45 g
Non renewable energy	9 MJ	103 MJ

+ hundreds of other elementary flows

Popcorn vs polystyrene as a packaging material

Functional unit: 1 kg of material



popcorn is the most preferred option?



Per kg of materials, **popcorn** is the preferred solution across all the impact categories

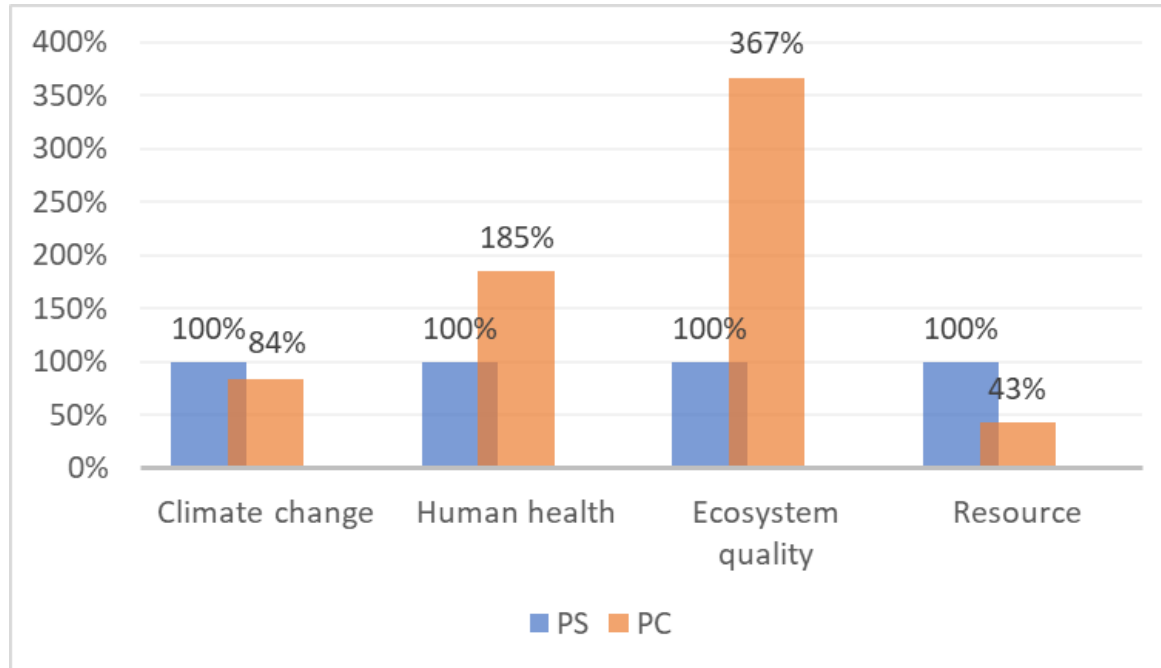
Example: pop corn VS polystyrene

Problem: function not defined properly!

- The function of the packaging material is to fill in a volume
 - **example of a functional unit: fill in 1 m³**
- The comparison of the materials on the basis of their mass doesn't make sense in the present context: Popcorn density is 5 times higher than polystyrene

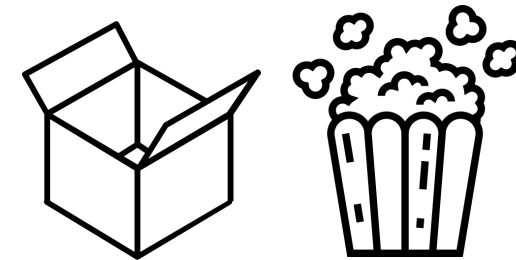
Example: pop corn VS polystyrene

Functional unit: fill in 1m³



popcorn impacts are increased by a factor 5

Results are nuanced



By comparing PC and PS on a functional unit expressed in terms of volume, the impacts of popcorn are directly multiplied by 5x

Example: pop corn VS polystyrene

The advantage of polystyrene becomes even more important when we consider that this material is easier to reuse than popcorn.

If we reuse the polystyrene chips 4 times and popcorn once, we would have to divide the impacts of these materials respectively by a factor 4 and 1, further increasing the gap between these two materials.

- **For a consumption product, this may not be true, but in a B2B context, reuse is the norm.**
- **We should have probably specified this in the goal & scope**
- **« Renewable » ≠ fewer impacts**

Example: pop corn VS polystyrene

Proper definition of FU key parameters and reference flows

FU = 1 m³

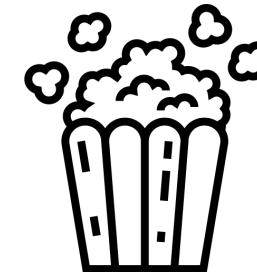
$$\frac{1 \text{ m}^3}{UF} * \frac{7 \text{ kg}}{\text{m}^3} * \frac{1}{4 \text{ ut}} = \frac{2 \text{ kg polystyrène}}{UF}$$



Key parameters

Reference flows

$$\frac{1 \text{ m}^3}{UF} * \frac{35 \text{ kg}}{\text{m}^3} * \frac{1}{1 \text{ ut}} = \frac{35 \text{ kg pop corn}}{UF}$$



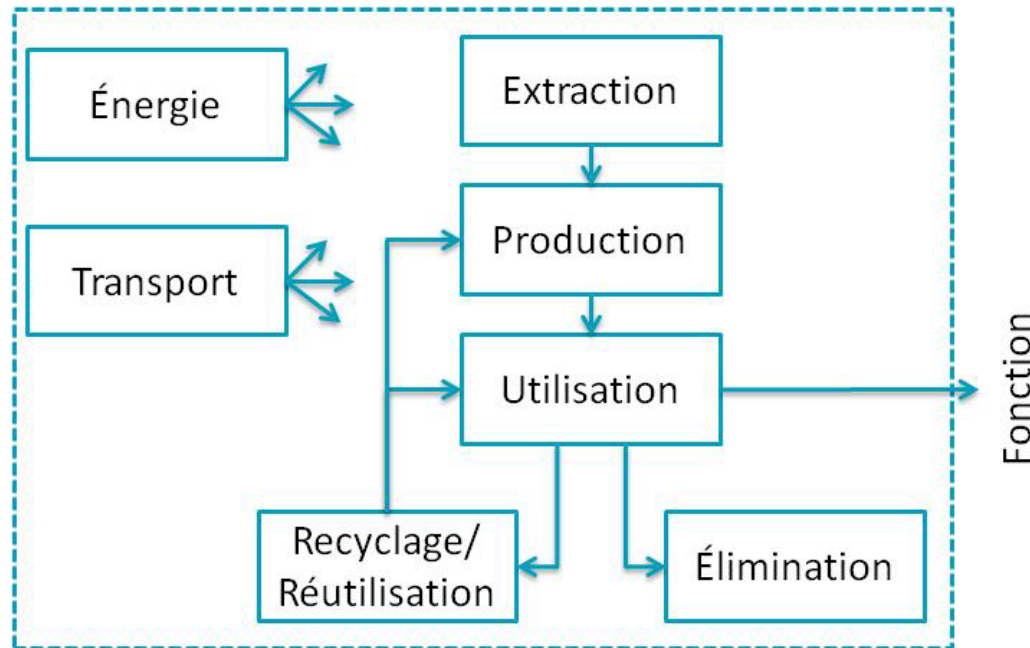
Density

Reuse rate

Product system & boundaries

DEFINITION OF THE SCOPE OF THE STUDY

Simplified representation of a « product system »

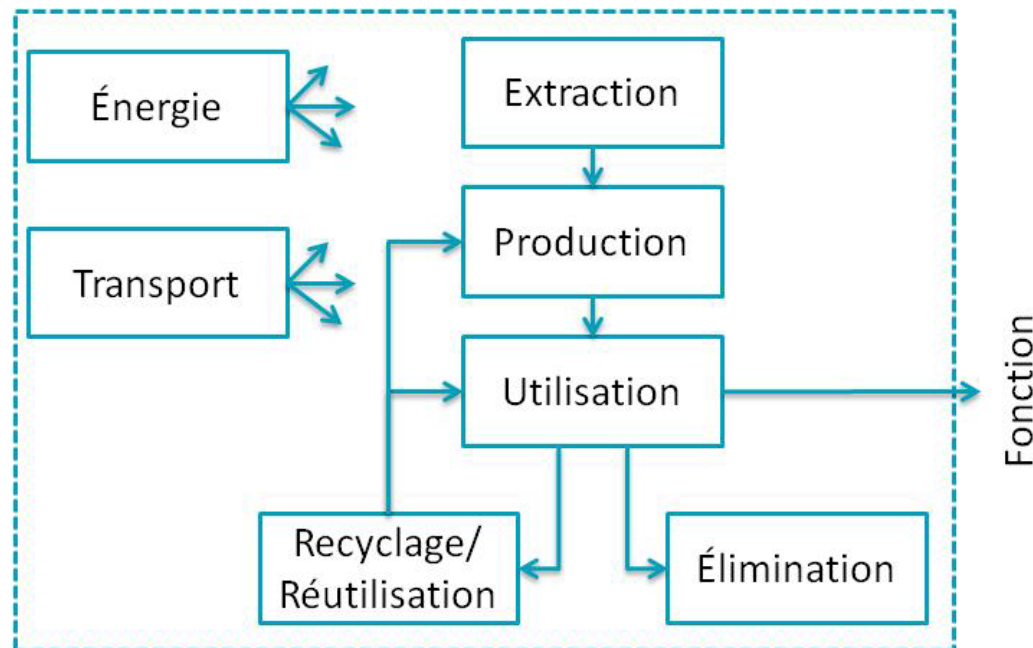


*“collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product”
(ISO 14044)*

Definition of a product system

Basic elements of a product system: unit processes

- Black boxes describing activities like extraction, production, consumption, etc.

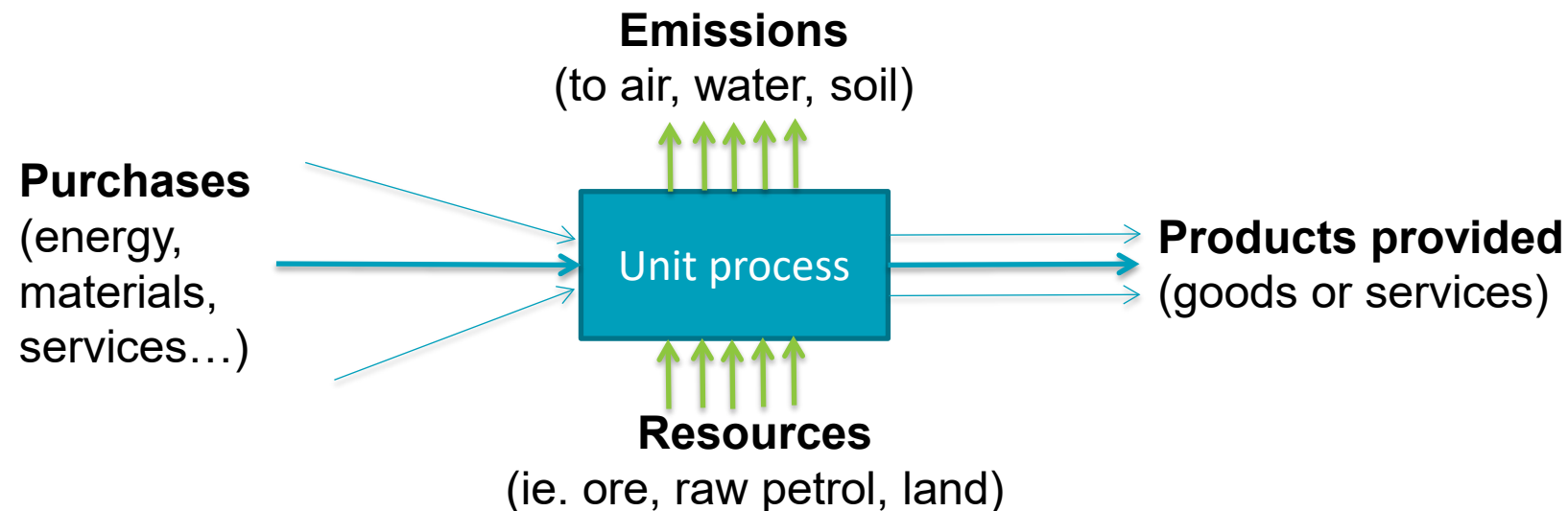


“smallest element considered in the life cycle inventory analysis for which input and output data are quantified” (ISO 14044)

Definition of a unit process

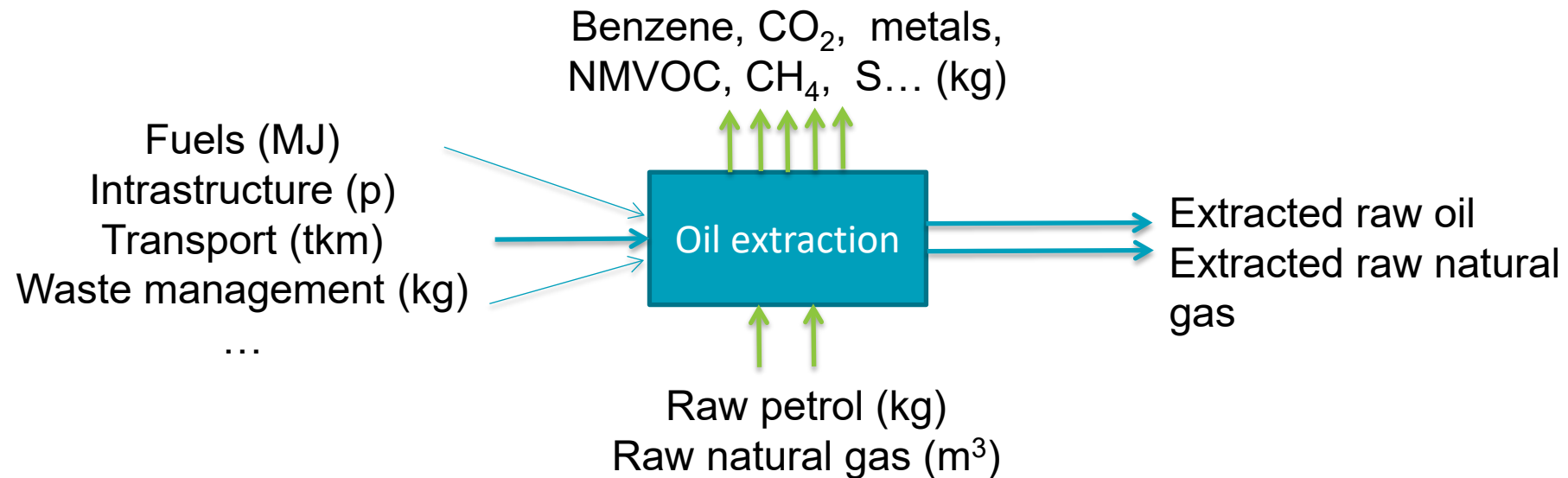
Basic elements of a product system: unit processes

- Black boxes describing activities like extraction, production, consumption, etc.
 - **Elementary flows: emissions/resources exchanged directly with the environment**
 - **Intermediary flows: products and services → Links with other unit processes OR to the function of the study**



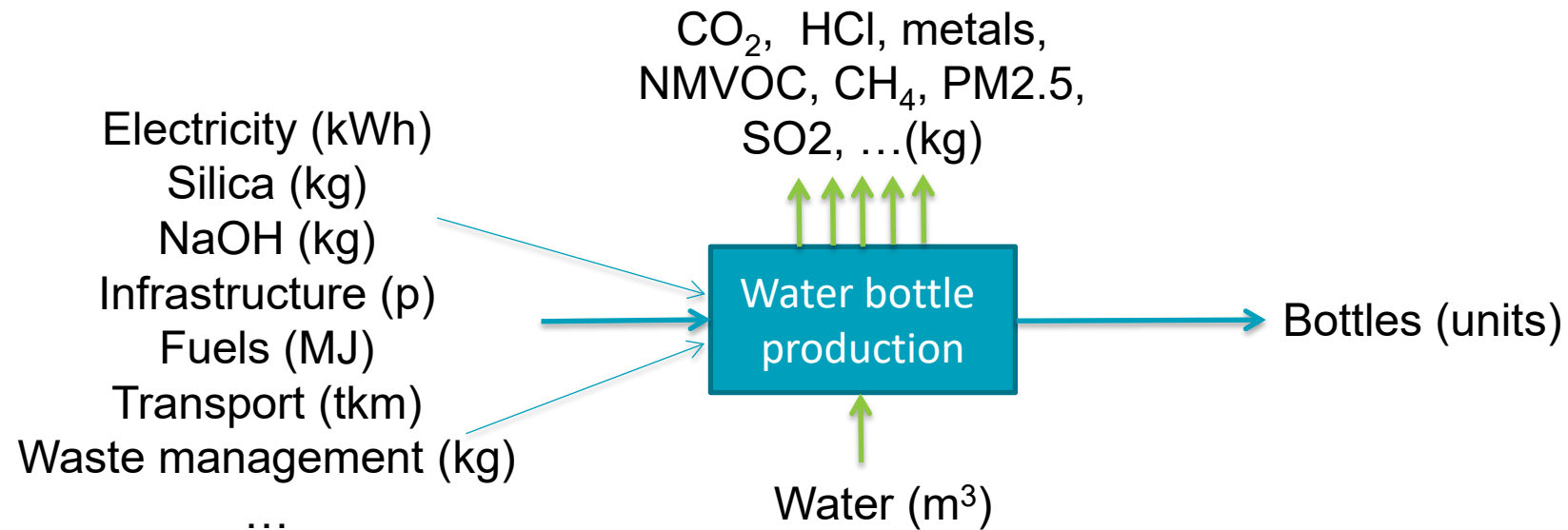
Unit processes

- Black boxes describing activities
- Examples:



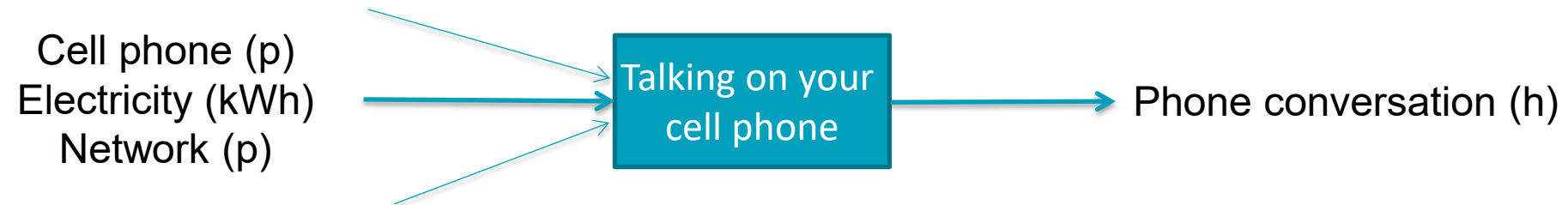
Unit processes

- Black boxes describing activities
- Examples:



Unit processes

- Black boxes describing activities
- Examples:



Recap

Unit process, intermediary flow or elementary flow?

- A beam of steel
- Iron in ore
- Water from the tap
- Water from the river
- CO₂ added to water to make sparkling water
- Producing sparkling water
- Emission of CO₂ from a sparkling water factory
- Waste sent to a landfill site
- Land use to practice agriculture

Unit processes– Notes

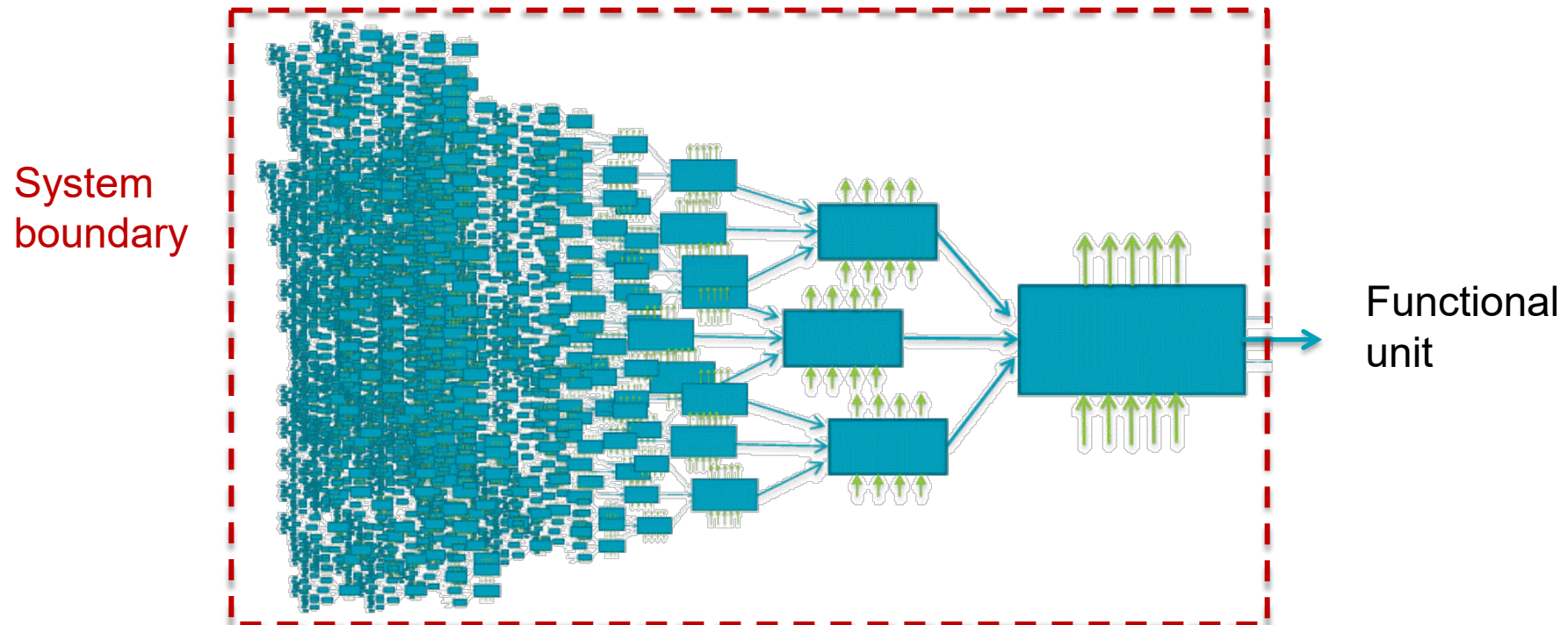
- We often use « unit process » or « elementary process » or « activity ». They are all synonyms, but ISO only uses « **unit process** ».
- In the course, we will use the terms « **economic flows** » and « **intermediary flows** »
 - **in ISO and Joliet et al.: intermediary flow**
 - **in openLCA: product flow**
 - **in SimaPro: technosphere flow**
 - **in ecoinvent: intermediary exchange**
 - **in Brightway: exchange from the technosphere**

Synonyms!

Definition of a product system

Product system:

- Model of the life cycle of a product
- Encompass all unit processes involved of the product life cycle
- Each unit process needs the **intermediary flows** of other unit processes...
- Only ONE intermediary flow leaves the **system boundary**: the flow associated to the FU



Definition of a product system

Product system:

- Usually what's included in the system boundary:
 - Extraction of raw materials and production of components and energy transformation
 - Availability of infrastructure, machines and incoming flows
 - Transportation, distribution
 - Main manufacturing/production stage
 - Use phase of products (including maintenance)
 - Waste treatment stage (landfill, valorisation, reuse, recycling...)

Process tree – a simplified representation of a product system

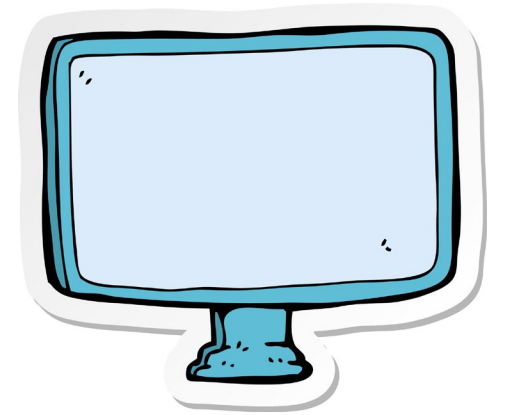


The process tree is a simplified representation of a product system

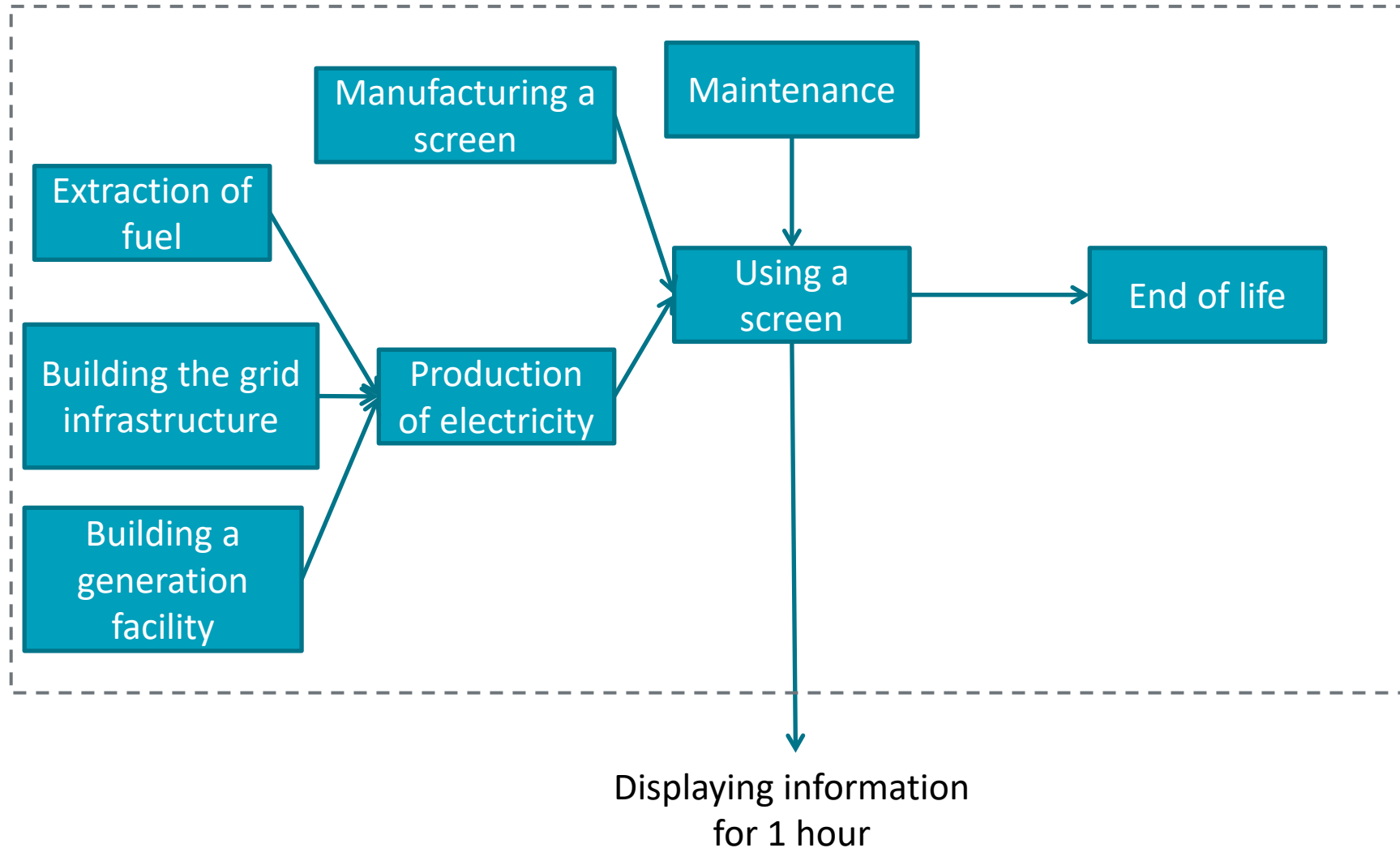
- You have lots of freedom to create your process tree, but stick to the following principles:
 - **Simple enough to be readable**
 - **Complete enough to understand what is overall included in the study**
 - **Coherent in the direction of the arrows**
- There are no calculations to be done to make a process tree. It's a qualitative representation of the product system for communication purpose in your report.

Example of using a computer screen

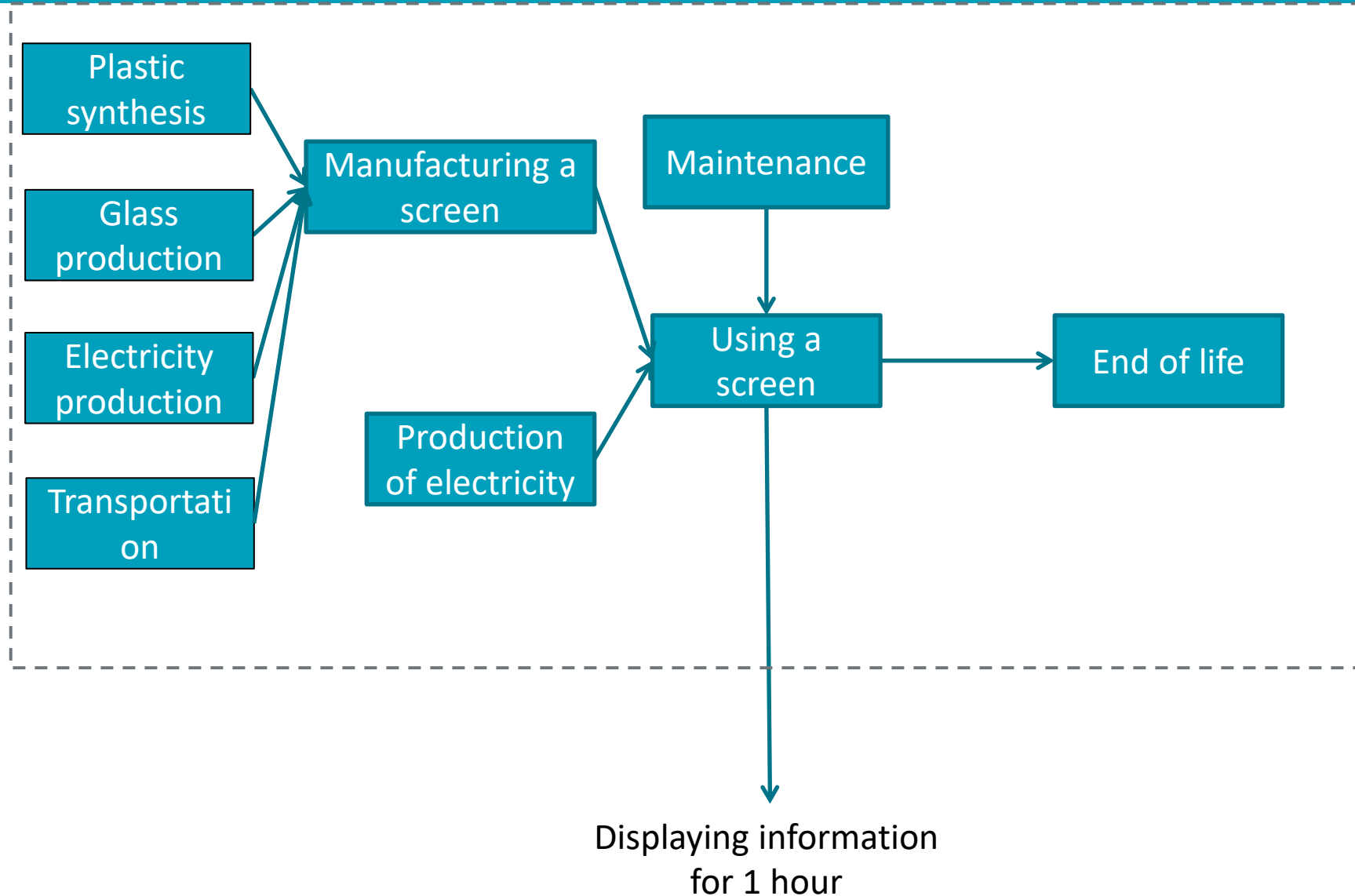
- Function, functional unit and reference flows
 - **Function: displaying information sent by a computer on a screen (min/max size, image quality, etc. should be specified here)**
 - **FU: 1 hour of information displayed on the screen**
 - **RF: screen, electricity, cleaning product, scrap**
- There are no calculations to be done to make a process tree. It's a qualitative representation of the product system.



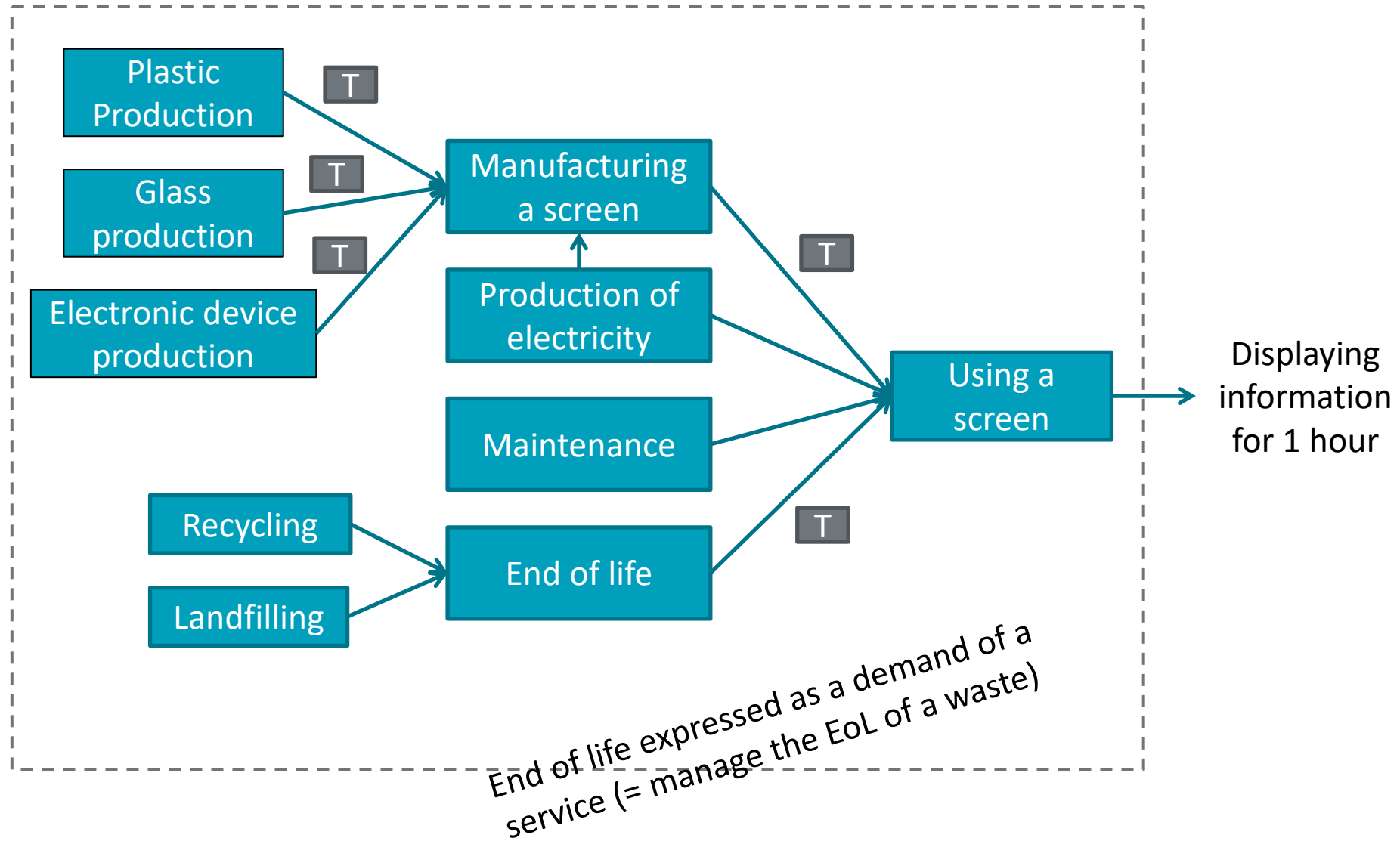
Example of product system: using a computer screen



Example of product system: using a computer screen



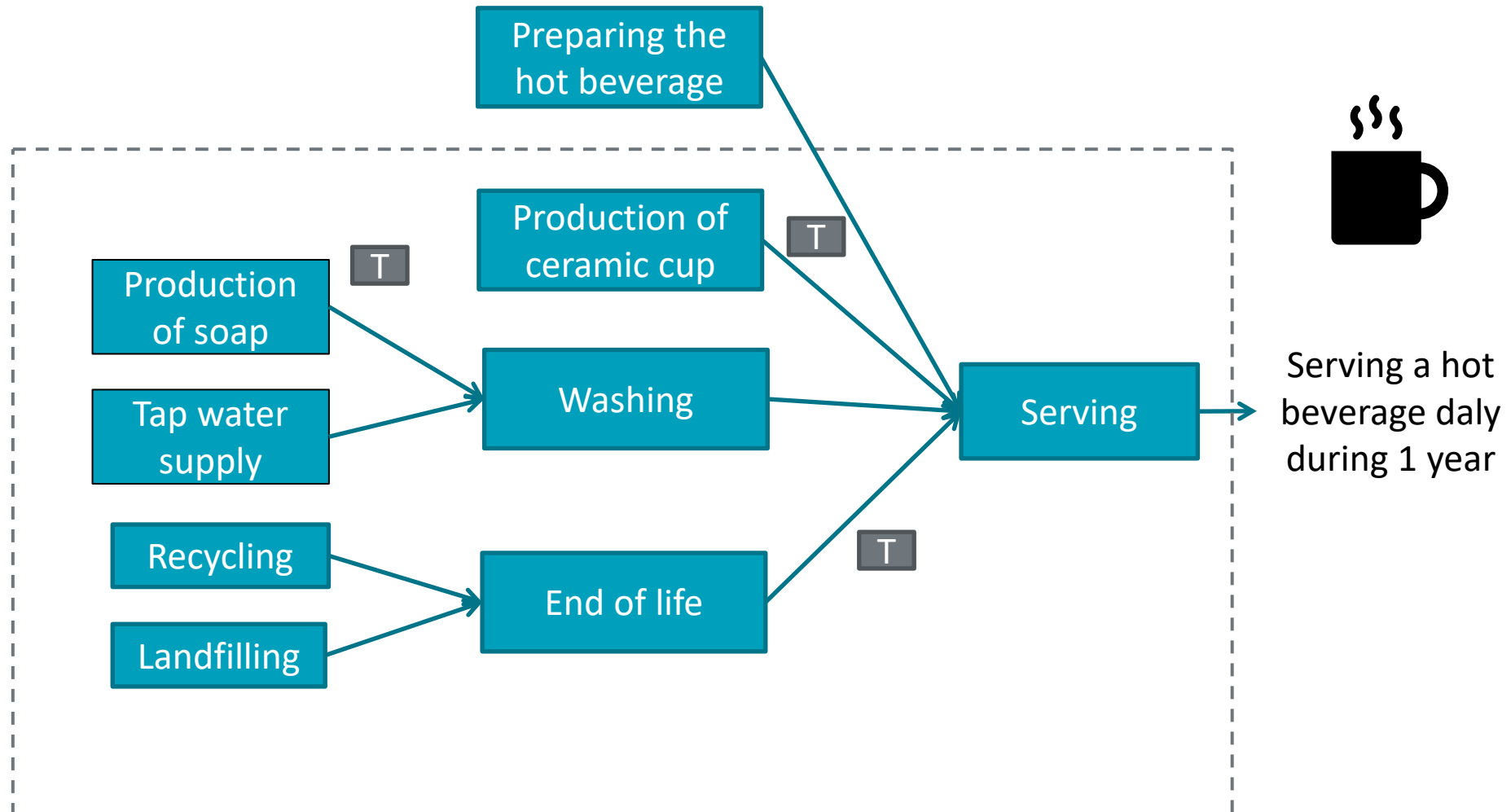
Example of product system: using a computer screen



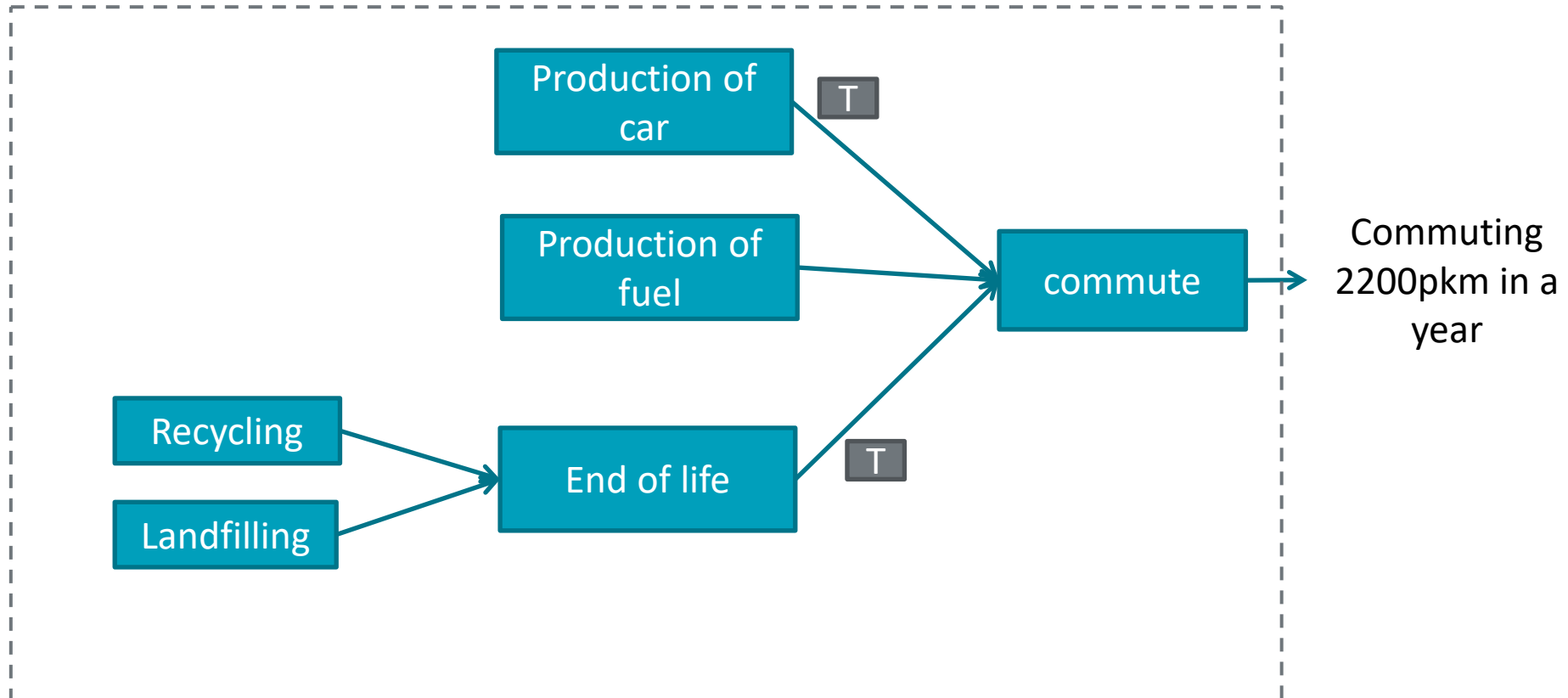
The process tree is useful to visualize the product system and to communicate the results

- You cannot draw everything in your process tree
- You will need to put what is important, and group processes in bigger classes
 - **ie. A box « aluminum production » implicitly contains extraction of bauxite, transportation, production of alumine, and productino of all intermediary products necessary...**
- Note that boxes are processes (activities) not products (result of an activity). You can write the products or the elementary flows on the arrows if there is enough space

Example of product system: serving hot beverages daily during 1 year



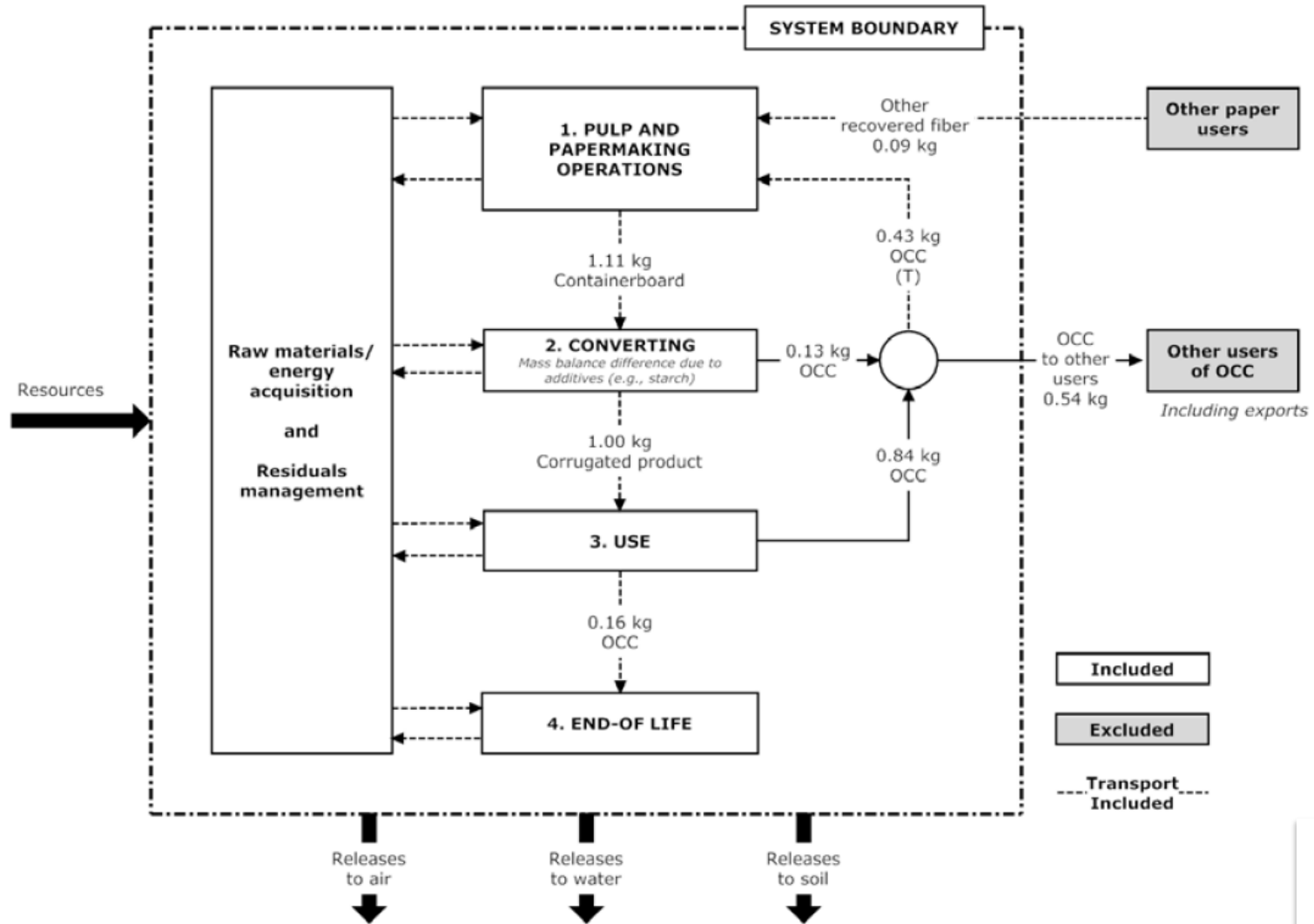
Example of product system: commuting 2200 pkm in a year



Examples of a process tree

ncasi

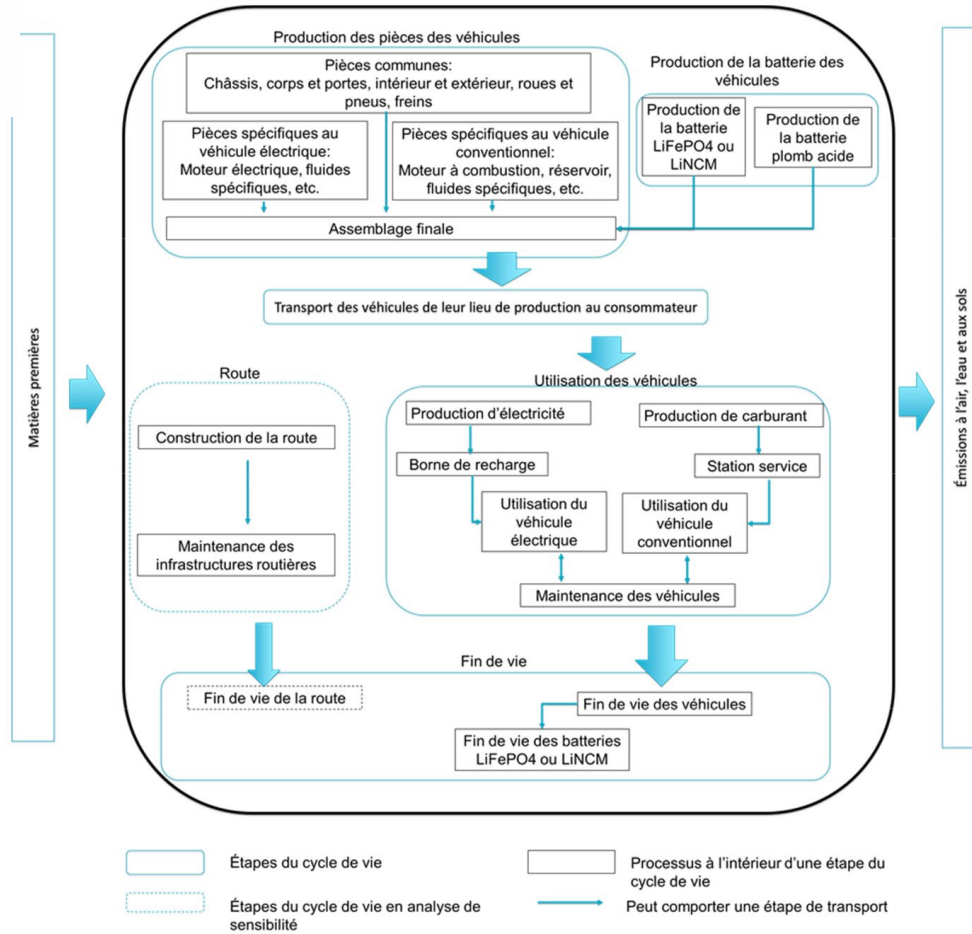
NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT



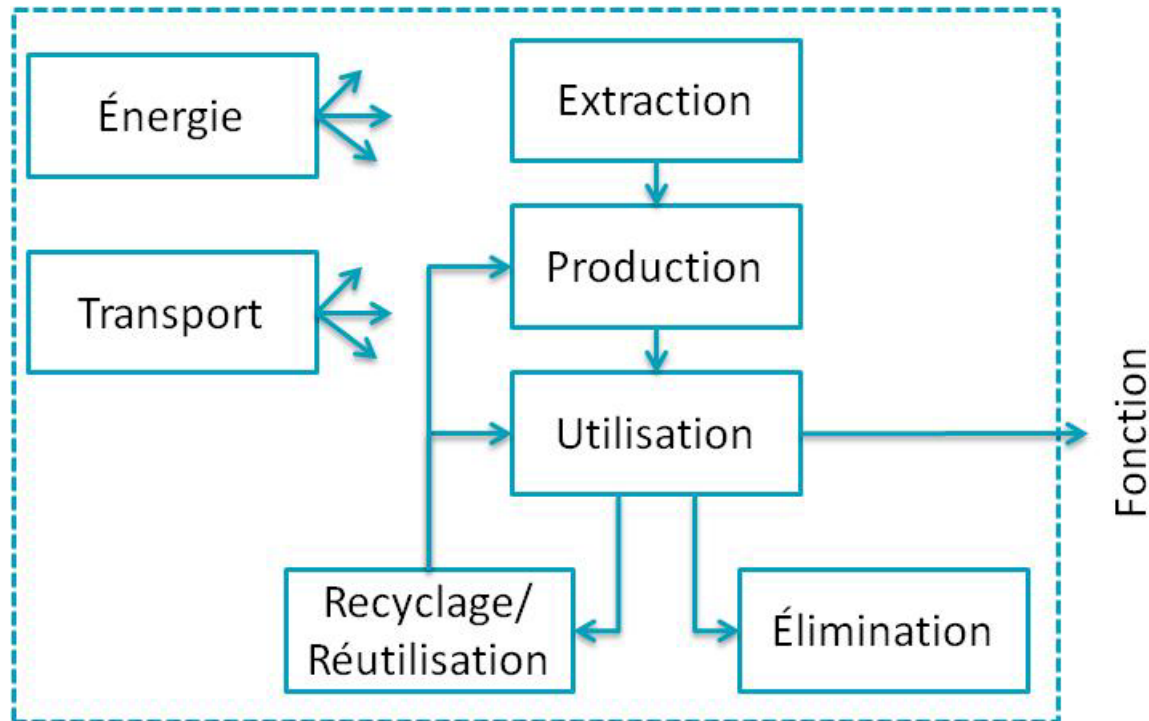
Examples of a process tree



<http://www.hydroquebec.com/data/developpement-durable/pdf/analyse-comparaison-vehicule-electrique-vehicule-conventionnel.pdf>



Three important rules for defining the system boundary



1. The system boundary must cover the same functional reality in all scenarios

2. Identical steps in all scenarios may be excluded only if it doesn't affect the functional equivalence between the scenarios

3. The included processes must contribute above the cut-off criteria

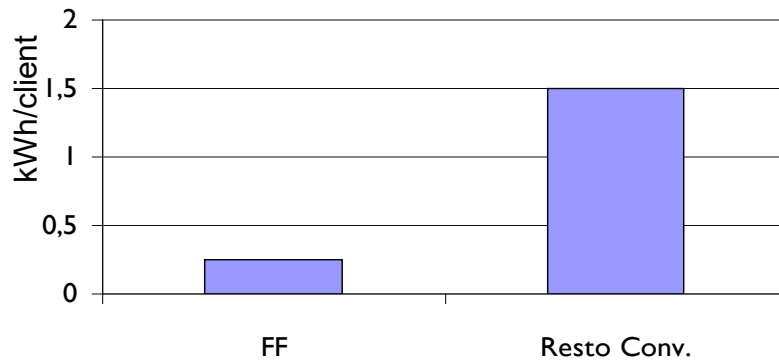
Rule 1: Same functional reality

- The compared alternatives must cover the same functional reality in all scenarios = deliver the same quantity & quality of *function*
- Not comparable:
 - 1 pair of shoes with a lifespan of 4 years vs. 1 pair of shoes with a lifespan of 6 months (quantity of function is different)
 - Meal in a 5-star restaurant vs. Meal in a fast-food restaurant (quality is too different, unless we define a FU strictly in terms of nutritional value)
 - Landfill of 1kg of waste vs. Incinerating 1kg of waste (heat as supplementary function in the case of incineration)
- The product system must include all the activities so that the functions covered by both systems are equivalent

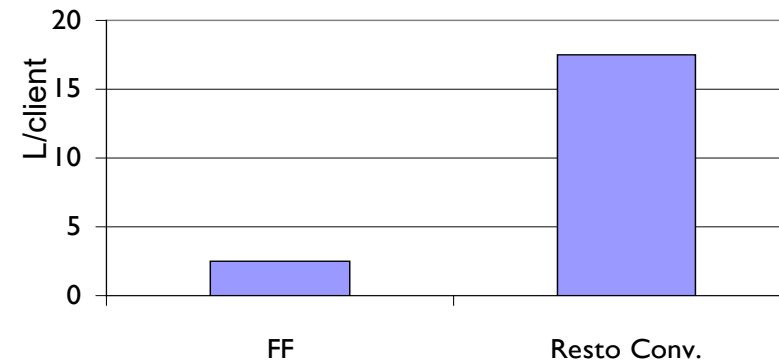
Rule 1: Same functional reality

- Example of an error with regards to Rule 1 (same functional reality)
- According to a study performed in 1990, a fast-food restaurant consumes **less energy**, **less water** and produces **less waste** than a conventional restaurant.

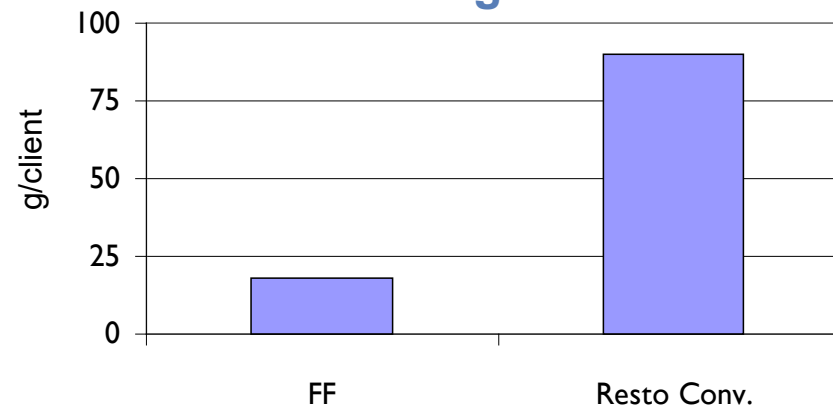
Energy consumption



Water consumption



Waste generation



Rule 1: Same functional reality

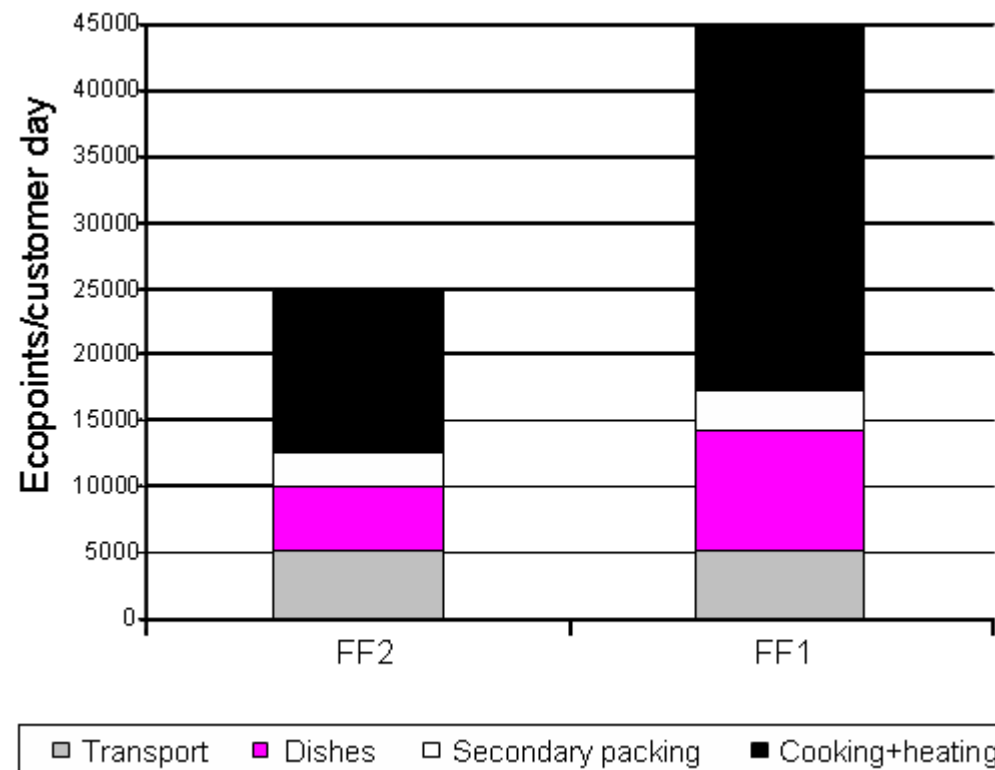
- The system boundaries considered for both restaurants were within the walls of the restaurant
- The only processes occurring within the restaurant walls were compared
 - **The fast-food restaurant receives much more food conditioned externally**
 - **A conventional restaurant has much more preparation and dishes are cleaned**

Fast-food	Restaurant conventionnel
Agro food supply chain	Chaîne de production agricole
Transport	Transport
Centralized food conditioning (hamburger preparation, salad, etc.)	
Disposable tableware production	Ceramic dishes to be cleaned
Cooking	Food conditioning and cooking
leaning, heating, lighting of the restaurant	leaning, heating, lighting of the restaurant
Management of packaging and food waste	Management of packaging and food waste

Rule 1: Same functional reality

The study was redone by other analysts (Lang et al., 1994)

The fast-food in study 1 (FF1) was compared to another fast-food restaurant where the food was served in reusable plates when the client attend the restaurant (FF2) encompassing the full life cycle



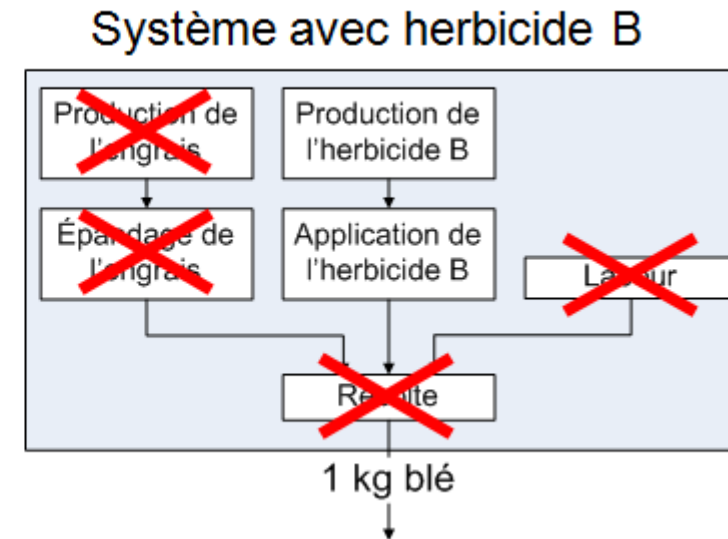
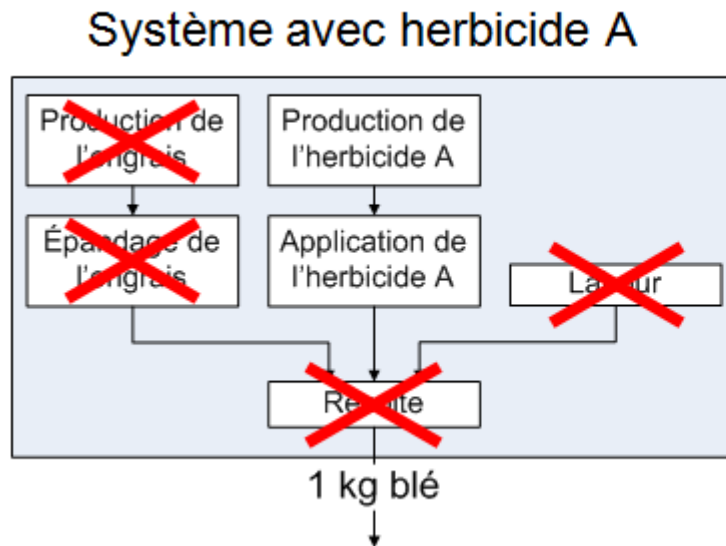
Rule 2: identical steps may be excluded

- Identical steps in all scenarios may be excluded **at the condition that** the reference flows affected by these processes are exactly the same (quality & quantity) → conservation of functional equivalence between the scenarios
- Examples
 - **Comparison of two herbicides for wheat production**
 - **Cradle-to-gate LCA**
 - **Gate-to-grave LCA**

Rule 2: identical steps may be excluded

Example of comparison of two herbicides for wheat production

- Why not exclude the production and spraying of fertilizer, as well as labour and harvesting since all of these steps are in both systems?
- Simplification is possible IF AND ONLY IF the crop yield is identical with both herbicides!



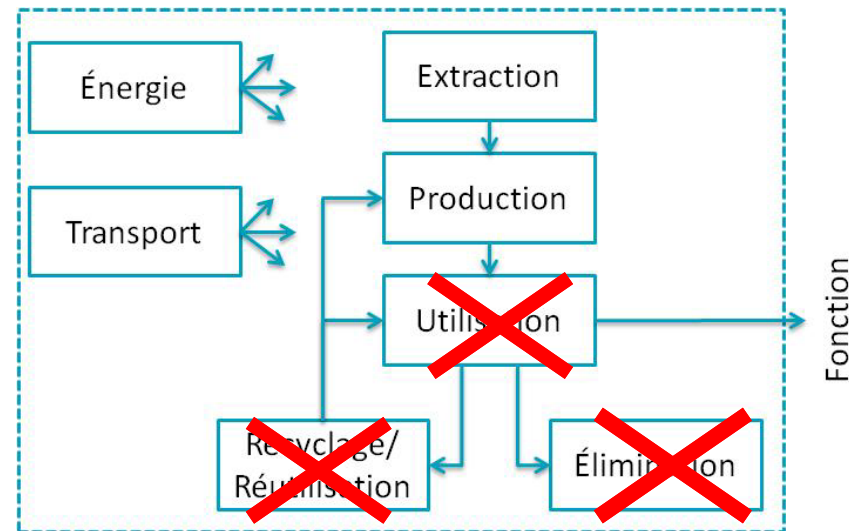
Rule 2: identical steps may be excluded

Example of comparison of two herbicides for wheat production

- If the choice of herbicide changes the yield
 - **Herbicide A: 4000kg/ha. Herbicide B: 5000kg/ha**
- The production of 1kg of wheat therefore needs
 - **25% more land using herbicide A rather than herbicide B**
 - **25% more area of spraying fertilizer, labour and harvesting is needed!**
- Since reference flows and emissions per functional unit are different, all of these processes must be included

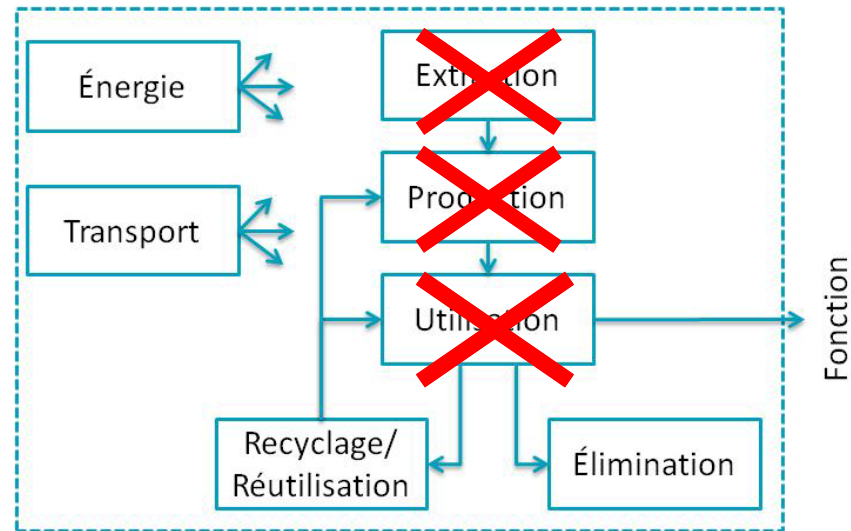
Rule 2: excluding identical steps « cradle-to-gate »

- LCA comparing different processes to manufacture the same product
 - so that their use phase and end of life would be equivalent
- LCA aiming to evaluate the production of a given material

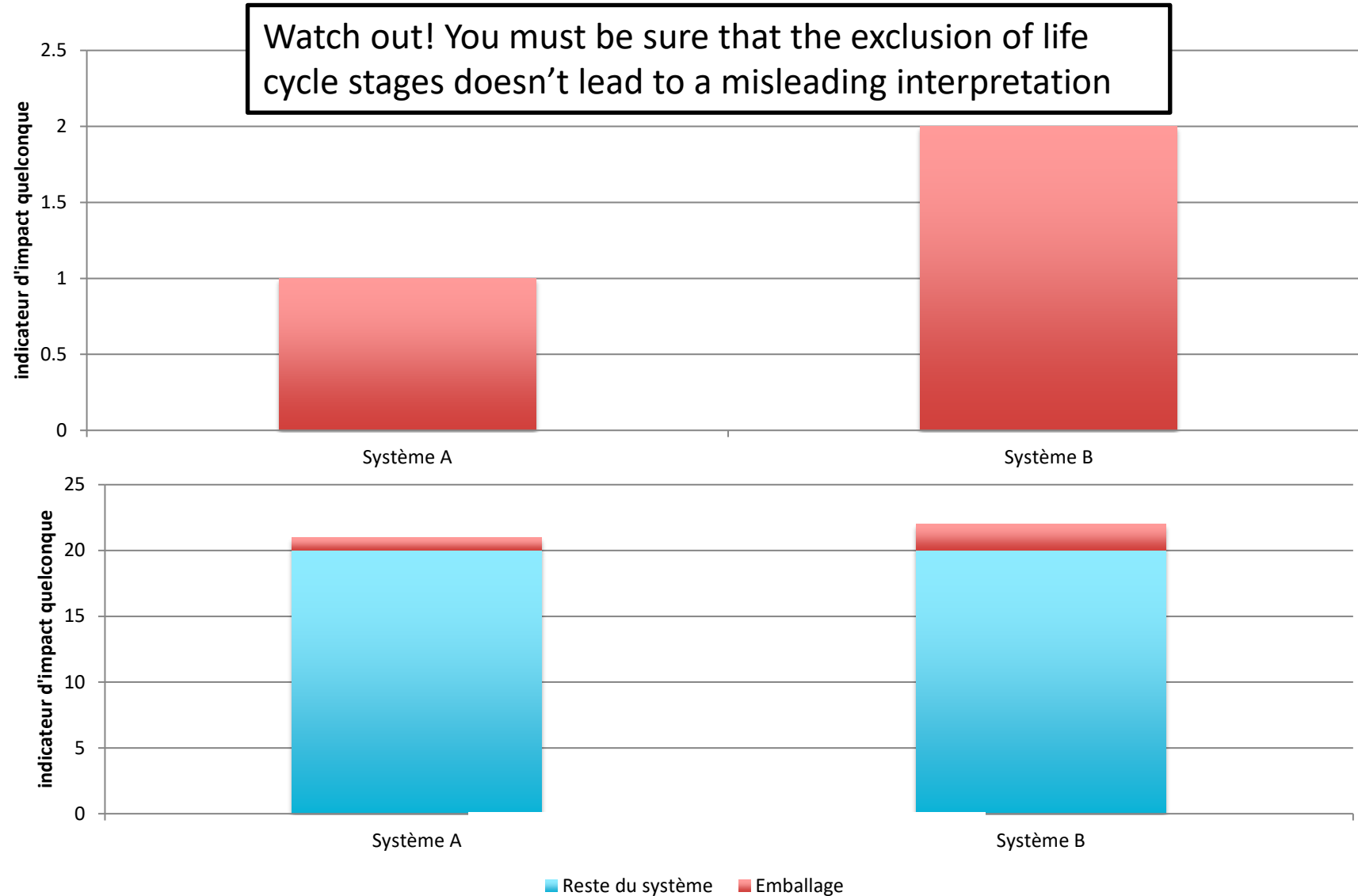


Rule 2: excluding identical steps « gate-to-grave »

- LCA comparing different means of managing waste at the end of life
 - The steps preceding disposal won't have an influence on the comparison



System boundary: excluding identical steps



Rule 3: Cut-off criteria

- The chosen processes contribute at least to...
 - **x% of the mass of inputs**
 - **x% of the energy consumption**
 - **x% of the environmental relevance**

where x is a threshold defined beforehand
 - This rule is difficult to use in practice
 - **To know if a unit process contributes less than x% of impacts, we need to evaluate its contribution.**
 - **If the effort necessary to evaluate these impacts is already done, there isn't any reason to exclude it.**
 - **In practice, we use proxies and/or judge by experience**
- This exclusion must be mentioned in the LCA report**

CONCLUSION

Conclusion

The goal and scope is the first step to conduct a LCA. It is important to well define well the different requirements, because it will have a big influence on all the study.

- Goal
 - Why?
 - To whom?
 - For what purpose?
- Scope
 - Functions of the system
 - The functional unit
 - Reference flows (calculated form key parameters)
 - The product system to study
 - ...
 - Allocation rule (week 6)
 - ...