Ciências
ULisboa

Faculdade
de Ciências
da Universidade
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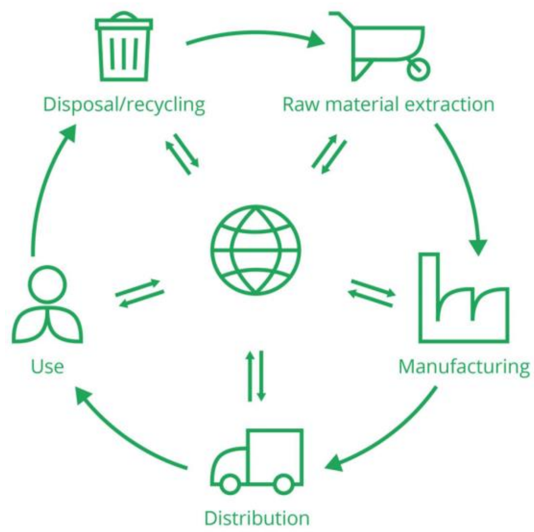
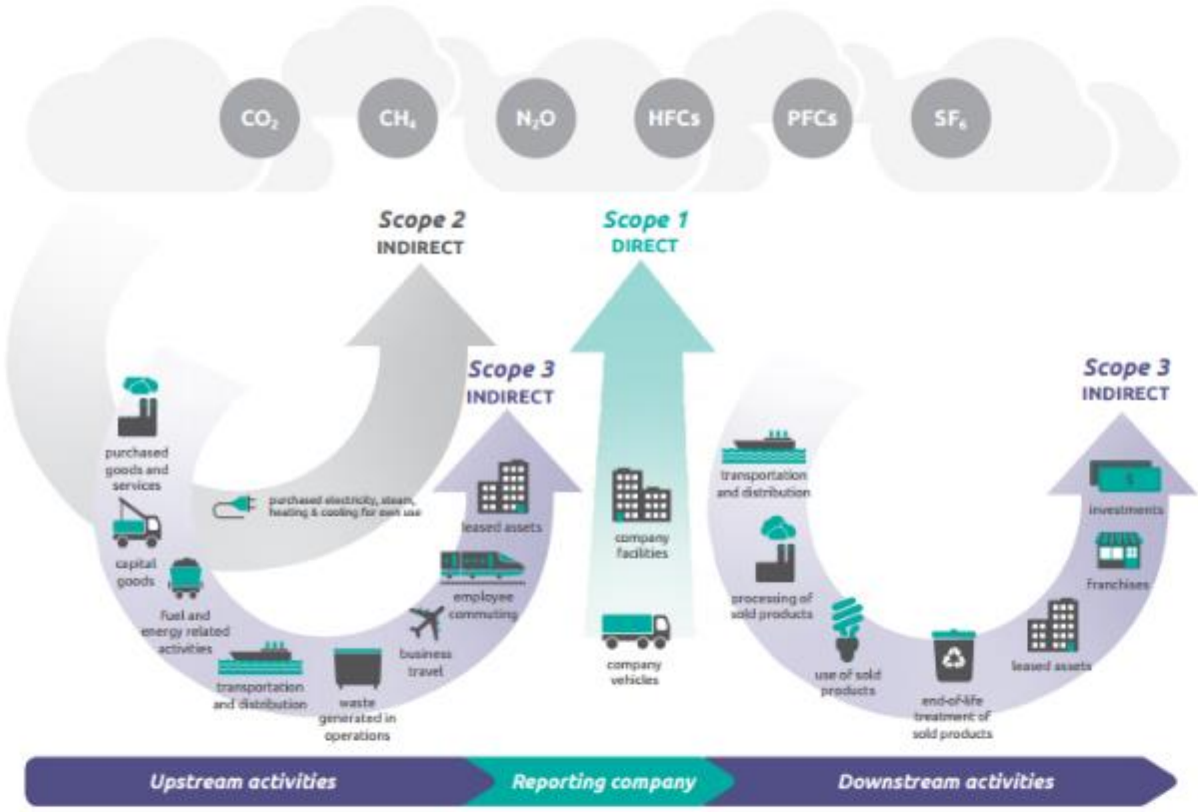
Eng Energy & Environment



Environmental Impact & LCA

System input/output

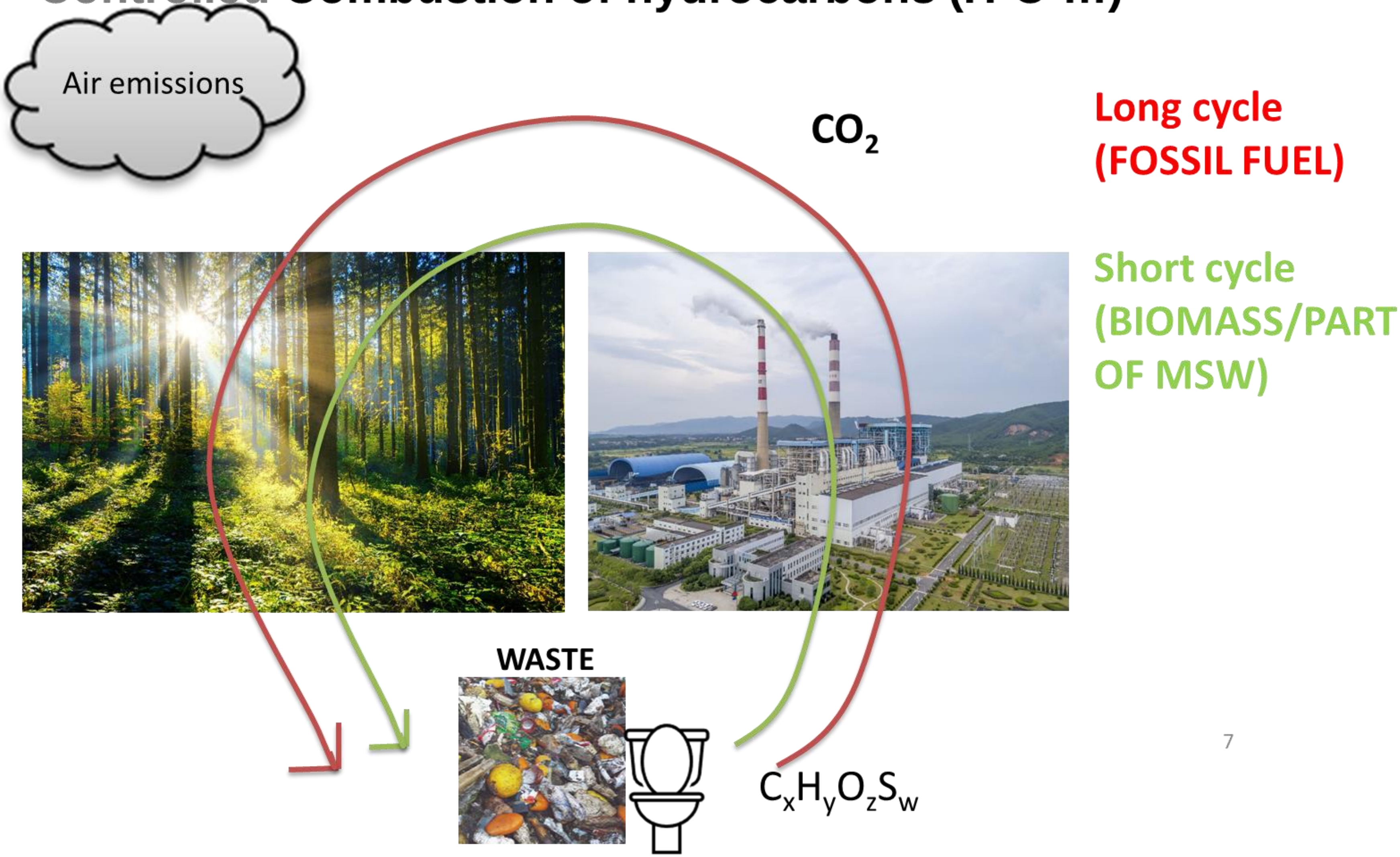
LCA- Life Cycle Assessment



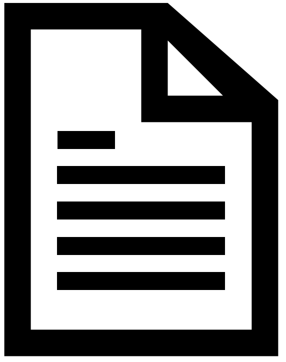
Based on LCA but specific for one environmental impact that is **climate change – GWP 100 – CO_2e**

LCA- Life Cycle Assessment

Controlled Combustion of hydrocarbons (H-C-…)

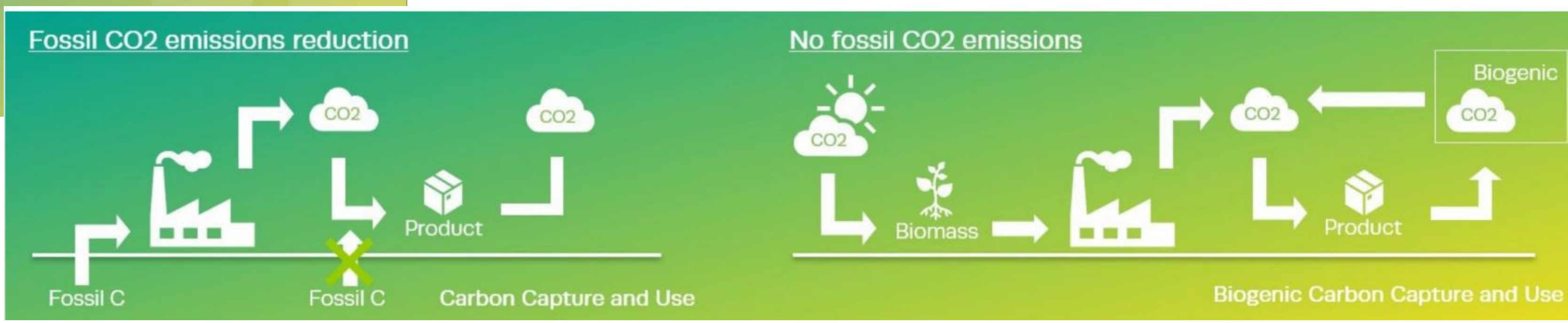


Biogenic emissions are usually reported separately for informative purposes and not accounted for the carbon footprint



LCA- Life Cycle Assessment

Fossil *versus* Biogenic carbon capture and use



End-of-Life

~1/3 fossil

- European Union Waste Framework Directive 5 July 2023 revision **Directive 2008_98_EC on waste**

~2/3 biogenic

End-of-Life

Reciclagem/ recycling

Valorização energética/ waste incineration with energy recovery

Aterro/ landfill

~ 1/3 fossil

~ 2/3 biogenic

End-of-Life

Preventing waste is the preferred option, and sending waste to landfill should be the last resort.

- European Union Waste Framework Directive 5 July 2023 revision **Directive 2008_98_EC on waste**

Landfill – direct emissions

Direct emissions

Landfill

Biodegradable, compostable waste from homes, businesses, institutions, and industrial sources. Examples include **food scraps, yard and garden trimmings, food-soiled paper products and biosolids**

Landfill – direct emissions

Direct emissions

Landfill

Landfill – direct emissions

Landfill

Biogenic carbon

Direct emissions

Landfill gas (LFG) is a natural byproduct of the decomposition of **organic material** in landfills. LFG is composed of **roughly 50 percent methane (the primary component of natural gas), 50 percent carbon dioxide (CO_2)** and a small amount of non-methane organic compounds

Landfill – direct emissions

Direct emissions

Methane (CH_4) is emitted during the anaerobic decomposition of organic waste disposed of in solid waste disposal sites (SWDS). **Organic waste decomposes at a diminishing rate and takes many years to decompose completely.**

Landfill

Methane (CH_4) is accountable for GWP100

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LCA- Life Cycle Assessment

$$mCO_{2eq} = m_{CO2}*1+m_{CH4}*EQ_{CH4}+m_{N2O}*EQ_{N2O}+...$$

$GWP_{100years}$

AR = Assessment report IPCC
EQ = Equivalence

Substance	AR1 (1990)	AR2 (1995)	AR3 (2001)	AR4 (2007)	AR5 (2013)
Carbon dioxide, fossil (CO_2)	1	1	1	1	1
Methane, fossil (CH_4)	21	21	23	25	28
Methane, biogenic (CH_4)	18.25	18.25	20.25	22.25	25.25
Dinitrogen monoxide (N_2O)	290	310	296	298	265
HCFC-141b	440	-	700	725	782
HFC-134a	1200	1300	1300	1430	1300
HCFC-22	1500	-	1700	1810	1760
HCFC-142b	1600	-	2400	2310	1980
CFC-11	3500	-	4600	4750	4660
CFC-12	7300	-	10600	10900	10200
Sulfur hexafluoride	-	23900	22200	22800	23500

37

Landfill – direct emissions

Greenhouse Gas	100-Year Time Period				20-Year Time Period			
	AR4 2007	AR5 2014		AR6 2021	AR4 2007	AR5 2014		AR6 2021
	Feedback Not Included		*Feedback Included*		*Feedback Not Included*		*Feedback Included*	
CO_2	1	1	1	1	1	1	1	1
$CH_{4\ \text{fossil origin}}$	25	28	34	29.8	72	84	86	82.5
$CH_{4\ \text{non fossil origin}}$				27.2				80.8
N_2O	298	265	298	273	289	264	268	273

IPCC AR6

Landfill

Landfill – direct emissions

Landfill

Air emissions

Direct emissions

CO_2 emitido

BIOGÉNICO

CH_4 emitido

CH_4 recuperado

CH_4 oxidado

EQUATION 5.3

$$CH_4 \text{ emissions (Gg/yr)} = [(MSW_T \bullet MSW_F \bullet L_0) - R] \bullet (1 - OX)$$

Lixo total

Fracção que vai para aterro

Função da parte orgânica

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Landfill – direct emissions

Air emissions

Direct emissions

Default method – Tier 1

The default method is based on the following equation:

EQUATION 5.3

$$CH_4 \text{ emissions (Gg/yr)} = [(MSW_T \bullet MSW_F \bullet L_0) - R] \bullet (1 - OX)$$

Where:

MSW_T = Total MSW generated (Gg/yr)

MSW_F = Fraction of MSW disposed at SWDS

L_0 = Methane generation potential [MCF • DOC • DOC_F • F • 16 / 12 (Gg CH_4/Gg waste)]

MCF = Methane correction factor (fraction)

DOC = Degradable organic carbon [fraction (Gg C/Gg MSW)]

DOC_F = Fraction DOC dissimilated

F = Fraction by volume of CH_4 in landfill gas

R = Recovered CH_4 (Gg/yr)

OX = Oxidation factor (fraction)

Landfill

0.5

The default is 0.1

The default value for methane recovery is zero

IPCC Guidelines provide a default value of 0.77 for DOC_F

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Landfill – direct emissions

Air emissions

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Direct emissions

TABLE 5.1
SWDS CLASSIFICATION AND METHANE CORRECTION FACTORS

Type of Site	Methane Correction Factor (MCF) Default Values
Managed [a]	1.0
Unmanaged – deep (≥5 m waste)	0.8
Unmanaged – shallow (<5 m waste)	0.4
Uncategorised SWDS [b]	0.6

[a] Managed SWDS must have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include some of the following: cover material, mechanical compacting or levelling of waste.
[b] The default value of 0.6 for uncategorised SWDS may be inappropriate for developing countries with a high percentage of unmanaged shallow sites, as it will probably lead to overestimation of emissions. Therefore, inventory agencies in developing countries are encouraged to use 0.4 as their MCF, unless they have documented data that indicates managed landfill practices in their country.

Source: Reference Manual of the *IPCC Guidelines*.

Landfill

Parâmetro Lo

L_0 = Methane generation potential [MCF • DOC • DOC_F • F • 16 / 12 (Gg CH_4/Gg waste)]

Default

Landfill – direct emissions

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Direct emissions

Parâmetro Lo

L_0 = Methane generation potential [MCF • DOC • DOC_F • F • 16 / 12 (Gg CH_4/Gg waste)]

Landfill

EQUATION 5.4

$$DOC = (0.4 \bullet A) + (0.17 \bullet B) + (0.15 \bullet C) + (0.3 \bullet D)$$

Where:

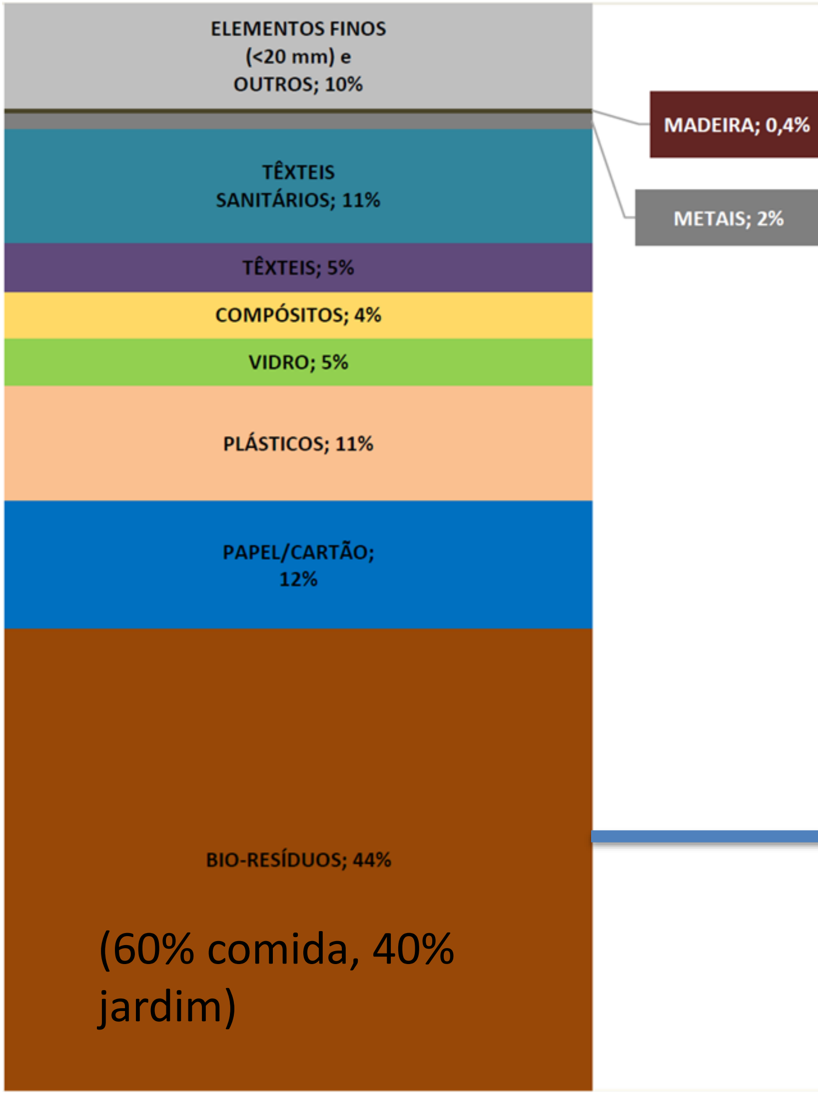
A = Fraction of MSW that is paper and textiles

B = Fraction of MSW that is garden waste, park waste or other non-food organic putrescibles

C = Fraction of MSW that is food waste

D = Fraction of MSW that is wood or straw

Landfill – direct emissions



10 ton colocadas em aterro vão ser responsáveis por que libertação de CH_4?

i)Qual o potencial de aquecimento global em 100 anos (GWP100), expresso em CO_2eq para OX=0.1 e OX=1?

ii)Para OX=0.1, se o CH_4 for 100% reencaminhado para queima e geração de eletricidade com eficiência 35%, qual a eletricidade produzida?

Landfill?

Landfill – direct emissions

Default method – Tier 1

The default method is based on the following equation:

EQUATION 5.3

$$CH_4 \text{ emissions (Gg/yr)} = [(MSW_T \bullet MSW_F \bullet L_0) - R] \bullet (1 - OX)$$

Where:

MSW_T = Total MSW generated (Gg/yr)

MSW_F = Fraction of MSW disposed at SWDS

Landfill

MSW_T MSW_F = 10 Ton

R = 0

OX = 0.1

L_0 = Methane generation potential [MCF • DOC • DOC_F • F • 16 / 12 (Gg CH_4/Gg waste)]

MCF = 0.6

DOC_F= 0.77

F = 0.5

Landfill – direct emissions

EQUATION 5.4

$$DOC = (0.4 \bullet A) + (0.17 \bullet B) + (0.15 \bullet C) + (0.3 \bullet D)$$

Where:

A = Fraction of MSW that is paper and textiles

B = Fraction of MSW that is garden waste, park waste or other non-food organic putrescibles

C = Fraction of MSW that is food waste

D = Fraction of MSW that is wood or straw

Air emissions

A = (16+12)/100 = 0.28

B = (40*44)/10000 =17.6/100 = 0.176

C = 26.4/100 = 0.264

D = 0.4/100 = 0.004

DOC = 0.4*0.28+0.17*0.176+0.15*0.264+0.3*0.004 = **0.183**

Landfill

Landfill – direct emissions

Default method – Tier 1

The default method is based on the following equation:

EQUATION 5.3

$$CH_4 \text{ emissions (Gg/yr)} = [(MSW_T \bullet MSW_F \bullet L_0) - R] \bullet (1 - OX)$$

Where:

MSW_T = Total MSW generated (Gg/yr)

MSW_F = Fraction of MSW disposed at SWDS

Landfill

MSW_T MSW_F = 10 Ton

R = 0

OX = 0.1

L_0 = Methane generation potential [MCF • DOC • DOC_F • F • 16 / 12 (Gg CH_4/Gg waste)]

MCF = 0.6

DOC_F= 0.77

F = 0.5

0.183

Landfill – direct emissions

IPCC AR6

CH_4 = 10 ton * 0.6* 0.183*0.77*0.5*16/12*0.9 = 0.51 Ton

Emissões diretas 0.51*27.2 = 13.9 Ton CO_2e

10 ton

1.39 kg CO_2e/kg waste

Landfill

Landfill – direct emissions

i) Qual o potencial de aquecimento global em 100 anos (GWP100), expresso em CO_2eq para OX=0.1 e OX=1?

IPCC AR6

Emissões diretas 0.51*27.2 = 13.9 Ton CO_2e

10 ton

Landfill

1.39 kg CO_2e/kg waste

Landfill – direct emissions

i)Qual o potencial de aquecimento global em 100 anos (GWP100), expresso em CO_2eq para OX=0.1 e OX=1?

Se OX=1 (oxida tudo a CO_2 que é biogénico)

CH_4 = 10 ton * 0.6* 0.183*0.77*0.5*16/12*0 = 0 Ton

Emissões diretas 0*27.2 = 0 Ton CO_2e

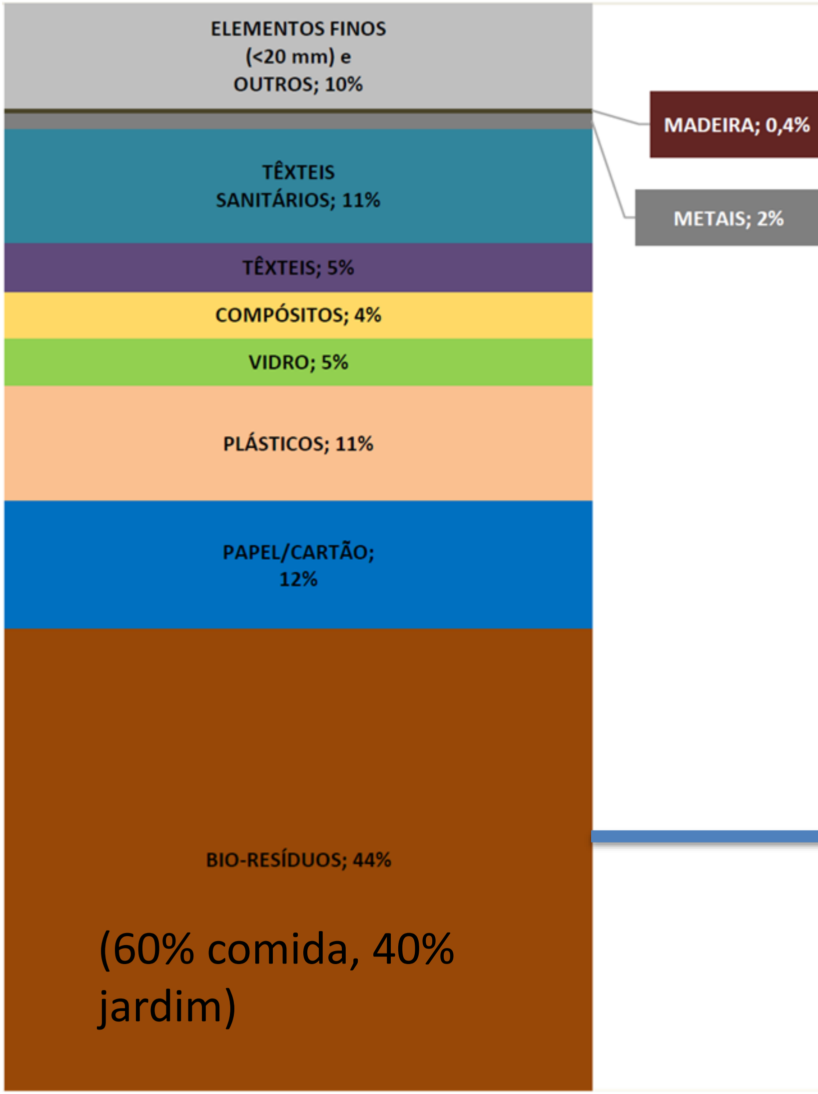
10 ton

Landfill

0 kg CO_2e/kg waste

Biogenic carbon

Landfill – direct emissions



10 ton colocadas em aterro vão ser responsáveis por que libertação de CH_4?

i)Qual o potencial de aquecimento global em 100 anos (GWP100), expresso em CO_2eq para OX=0.1 e OX=1?

ii)Para OX=0.1, se o CH_4 for 100% reencaminhado para queima e geração de eletricidade com eficiência 35%, qual a eletricidade produzida? E emissão direta?

Landfill?

Landfill with energy recovery – direct emissions

CH_4 = 10 ton * 0.6* 0.183*0.77*0.5*16/12*0.9 = 0.51 Ton

Poder calorifico CH_4 = 50 MJ/kg

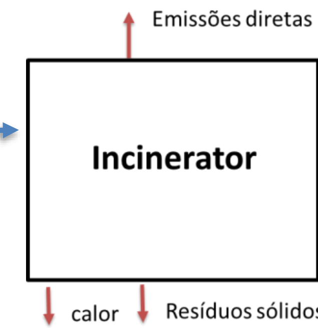
Emissões diretas biogénicas não entram para o GWP 0.51*44/16 = 1.4 Ton CO_2

10 ton

Landfill

0.51 ton

CH_4



0.35*X

0.35*510 kg*50 MJ/kg*1/3.6 MJ/kWh = **2479 kWh**

Landfill with energy recovery – direct emissions

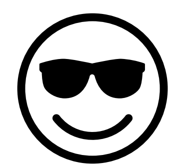
ii)Para OX=0.1, se o CH4 for 100% reencaminhado para queima e geração de eletricidade com eficiência 35%, qual a eletricidade produzida? E emissão direta?

Se este processo estiver a evitar a produção de eletricidade por gás natural ciclo combinado (350 gCO_2/kWh)

O processo **Evita** a emissão de 350 g/kWh*2479 kWh = 0.87 ton CO_2

Emissão direta = - 0.87 ton CO_2

-0.087 kg CO_2e/kg waste



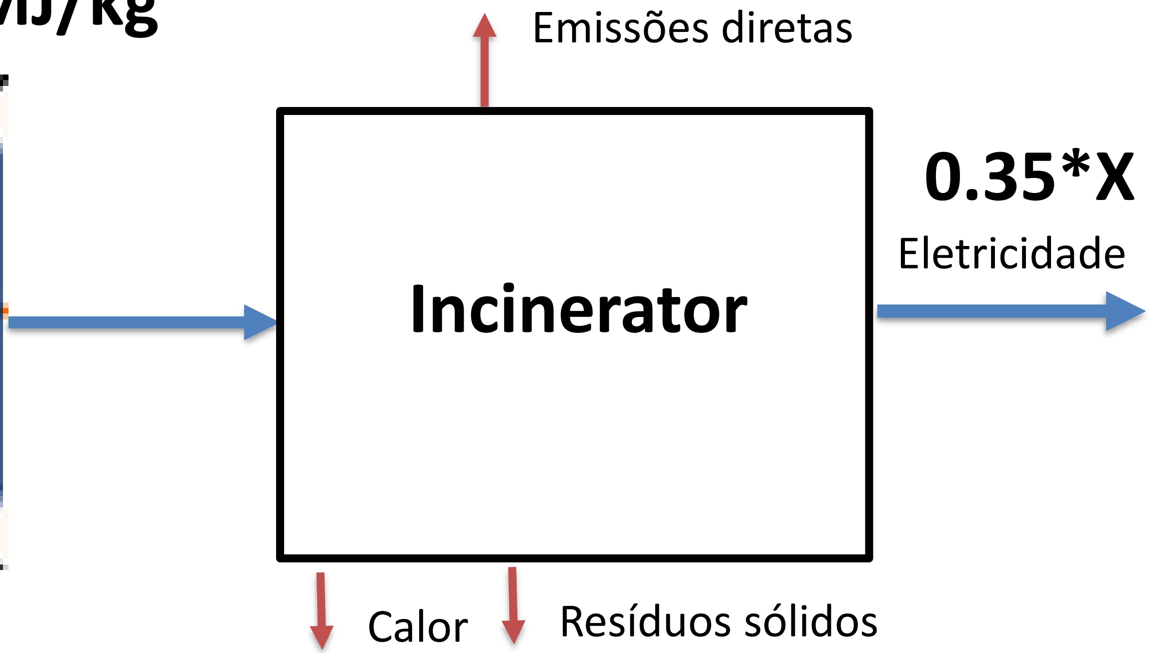
End-of-Life

Preventing waste is the preferred option, and sending waste to landfill should be the last resort.

- European Union Waste Framework Directive 5 July 2023 revision **Directive 2008_98_EC on waste**

Incineration – direct emissions

Energy content X MJ/kg



~1/3 fossil

~2/3 biogenic

Incineration – direct emissions

Emissões diretas

CO_2 emitido

EQUATION 5.11

$$CO_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i \bullet CCW_i \bullet FCF_i \bullet EF_i \bullet 44 / 12)$$

- IW_i: Quantidade de lixo que vai para incineração
- CCW_i: Conteúdo carbónico
- FCF_i: Fracção de carbono fóssil
- EF_i: Eficiência incineração
- $44 / 12$: Massa molar CO_2/ massa molar C

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Incineration – direct emissions

EQUATION 5.11

$$CO_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i \bullet CCW_i \bullet FCF_i \bullet EF_i \bullet 44/12)$$

Where:

i = MSW: municipal solid waste
HW: hazardous waste
CW: clinical waste
SS: sewage sludge

Tipos de lixo

IW_i = Amount of incinerated waste of type i (Gg/yr) → Lixo encaminhado incineração

CCW_i = Fraction of carbon content in waste of type i → 0.4 Default

FCF_i = Fraction of fossil carbon in waste of type i → 0.4 Default

EF_i = Burn out efficiency of combustion of incinerators for waste of type i (fraction) → 0.95 Default

44 / 12 = Conversion from C to CO_2

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Incineration – direct emissions

TABLE 5.6
DEFAULT DATA FOR ESTIMATION OF CO_2 EMISSIONS FROM WASTE INCINERATION

	MSW	Sewage Sludge	Clinical Waste	Hazardous Waste
C Content of Waste	33-50% of waste (wet) default: 40%	10-40% of sludge (dry matter) default: 30%	50-70% of waste (dry matter) [a] default: 60%:	1-95% of waste (wet) default: 50%
Fossil Carbon as % of Total Carbon	30-50% default: 40%	0%	30-50% default: 40% more information is needed	90-100% [b] default: 90%
Efficiency of Combustion [c]	95-99% default: 95%	95%	50-99.5% default: 95%	95–99.5% default: 99.5%

[a] Clinical waste contains mainly paper and plastics. The carbon content can be estimated from the following factors: C-content of paper: 50% and C-content of plastics: 75-85%.
[b] The fossil carbon may be reduced if it includes carbon from packaging material and similar materials.
[c] Depends on plant design, maintenance and age.

Source: Judgement by Expert Group (see Co-chairs, Editors and Experts; Emissions from Waste Incineration).

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf

Incineration – direct emissions

10 Ton

Energy content 20 MJ/kg

Emissões diretas??

Incinerator

?? kWh??

Calor

Resíduos sólidos

~ 1/3 fossil

~ 2/3 biogenic

Incineration – direct emissions

10 Ton 

~ **1/3** fossil

Emissões diretas??

10 ton*0.4***1/3***0.95*44/12 = 4.8 ton CO_2

0.48 ton CO_2/ton waste

Energy content 20 MJ/kg

Eletricidade produzida?? kWh??

10000 kg*20 MJ/kg *1/(3.6 MJ/kWh) = 5555.6 kWh

Fator de emissão desta eletricidade = 4800000/5555.6 = 858 g CO_2/kWh

Incineration – direct emissions

Se este processo estiver a evitar a produção de eletricidade por gás natural ciclo combinado (350 gCO_2/kWh)

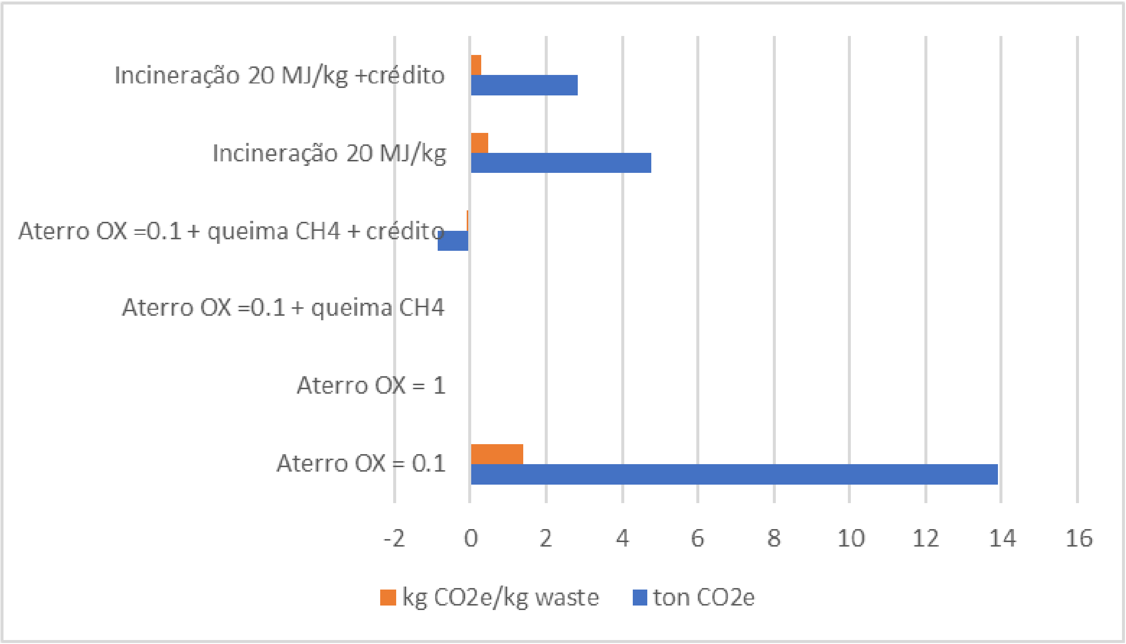
O processo **Evita** a emissão de 350*5555.6- 4800000 = - 2.85 ton CO_2

+ 0.285 kg CO_2e/kg waste

Emissão direta = 2.85 ton CO_2

End-of-Life – direct emissions

Conclusões



Emissões diretas (âmbito 1 para empresa gestora de "lixo")

End-of-Life – direct emissions

Conclusões

De acordo com a hierarquia dos resíduos o último destino é o aterro e pelo que vimos é melhor se tiver aproveitamento energético (conversão CH_4 para eletricidade).

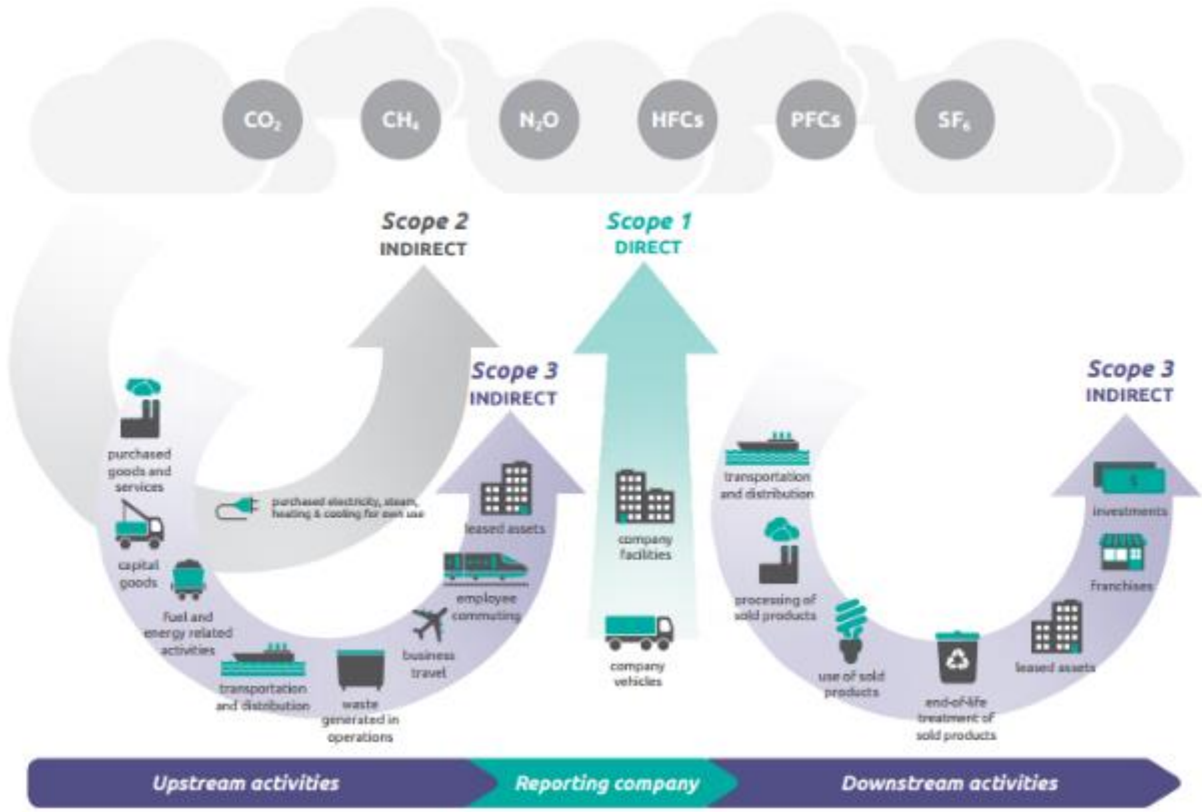
Na realidade há fugas de CH_4 que não foram contabilizadas e que poderiam fazer o cenário de incineração preferível...

Para além da questão da área ocupada....

Preventing waste is the preferred option, and sending waste to landfill should be the last resort.

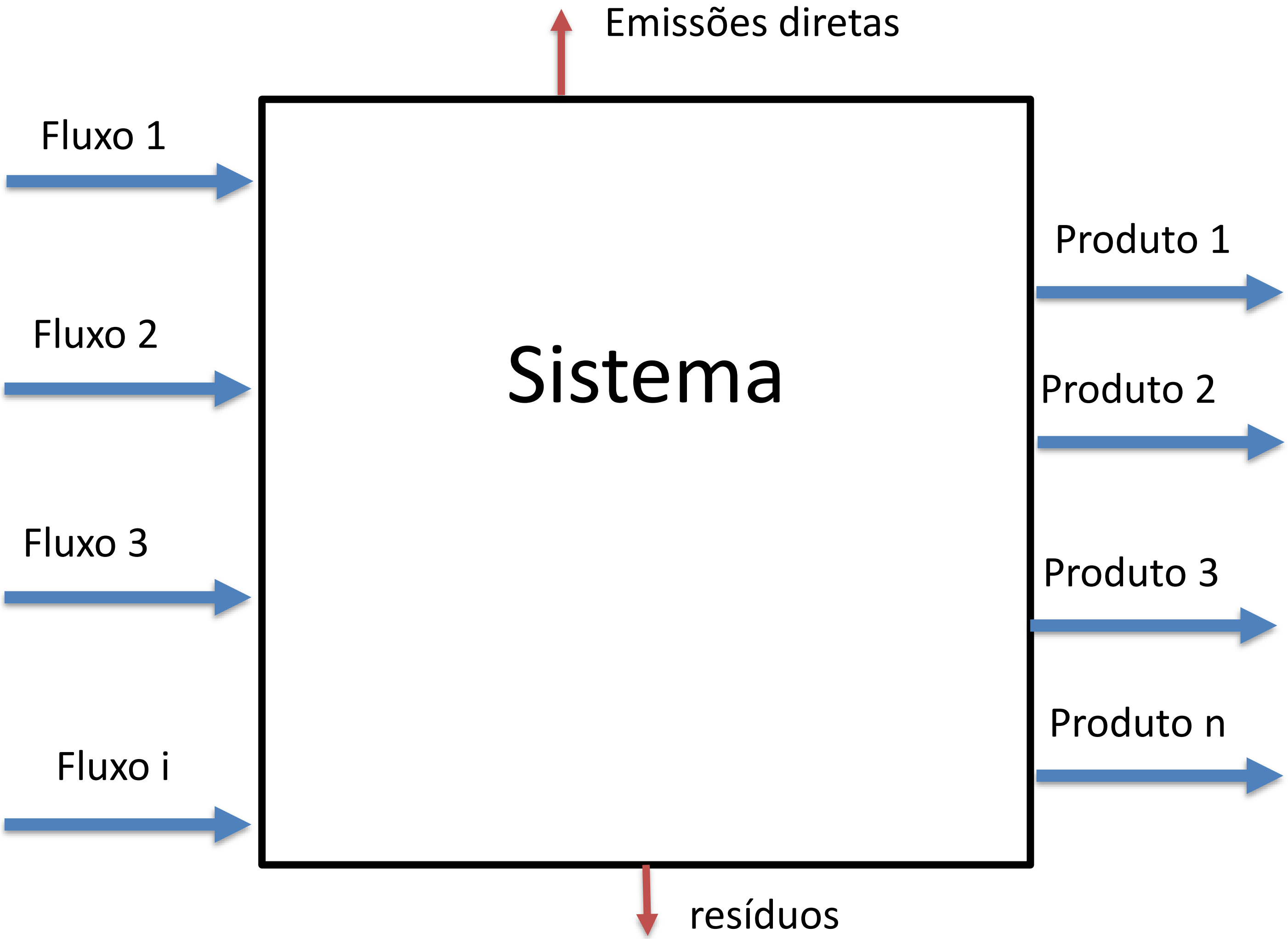
- European Union Waste Framework Directive 5 July 2023 revision **Directive 2008_98_EC on waste**

LCA- Life Cycle Assessment

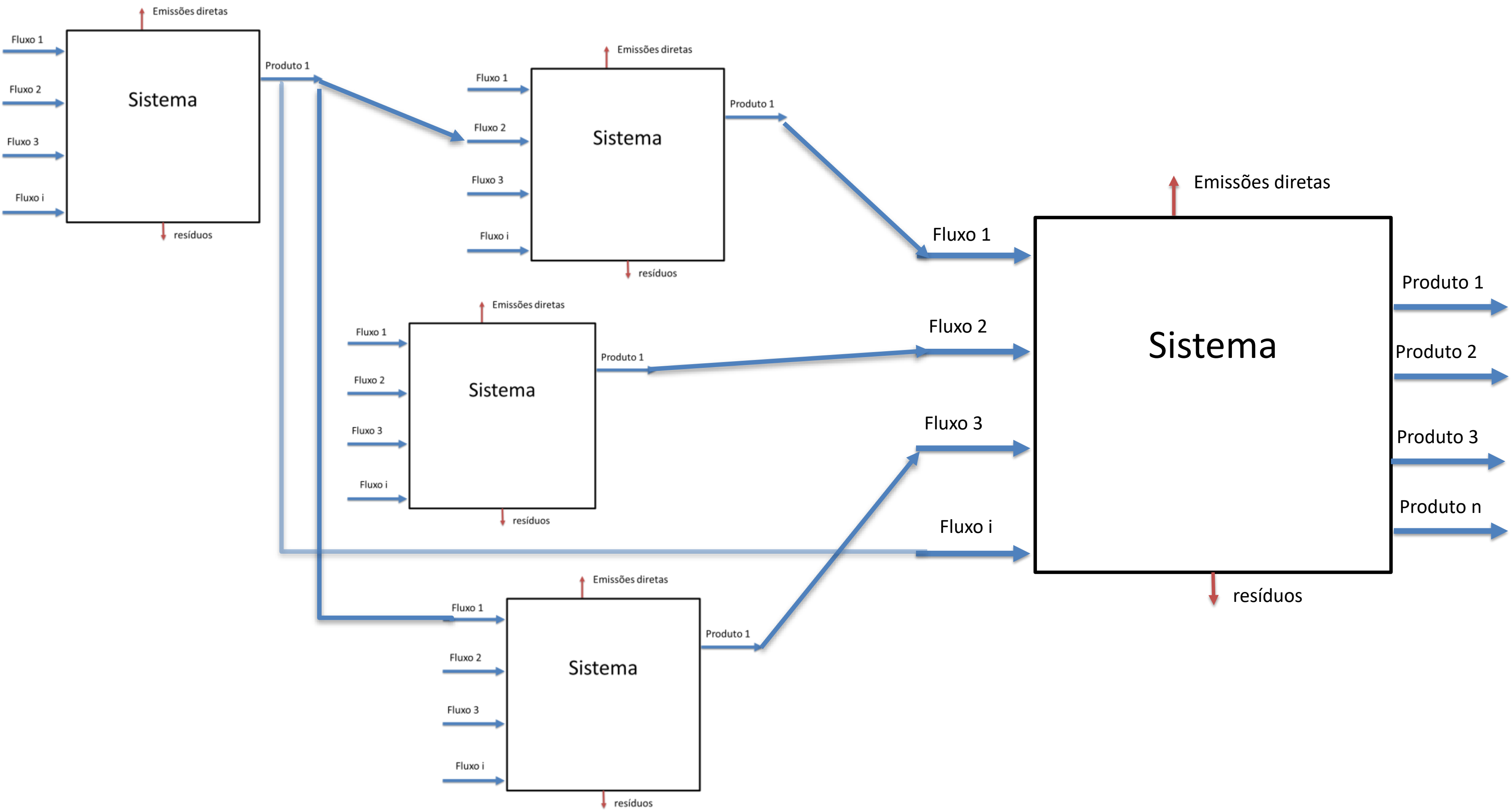


Do ponto de vista de uma empresa gestora de resíduos as emissões diretas são da queima da parte fossil e da libertação de CH_4 em aterro – âmbito 1/ Scope 1

System input/output

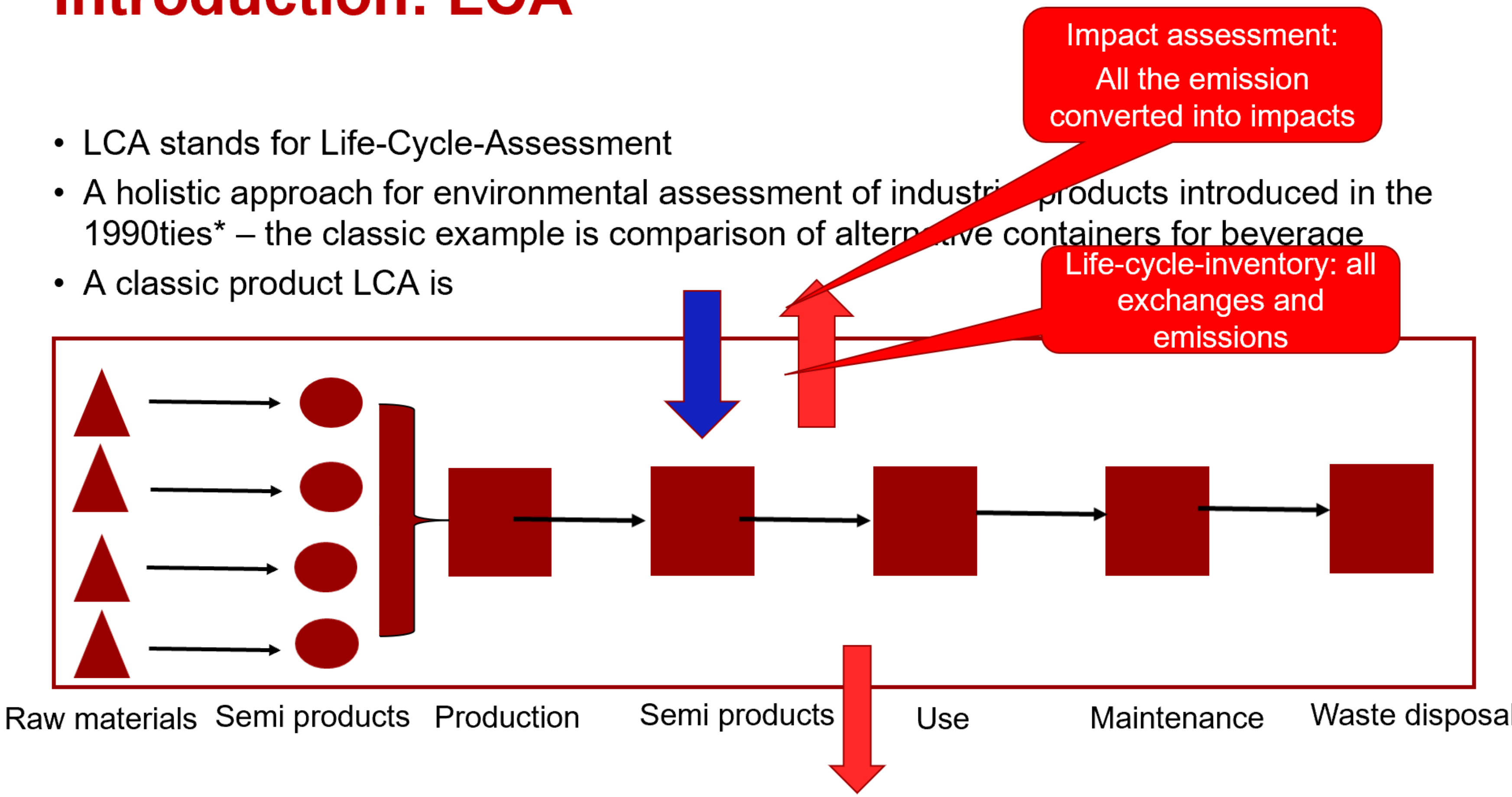


Supply chain/ Product pathway



Introduction: LCA

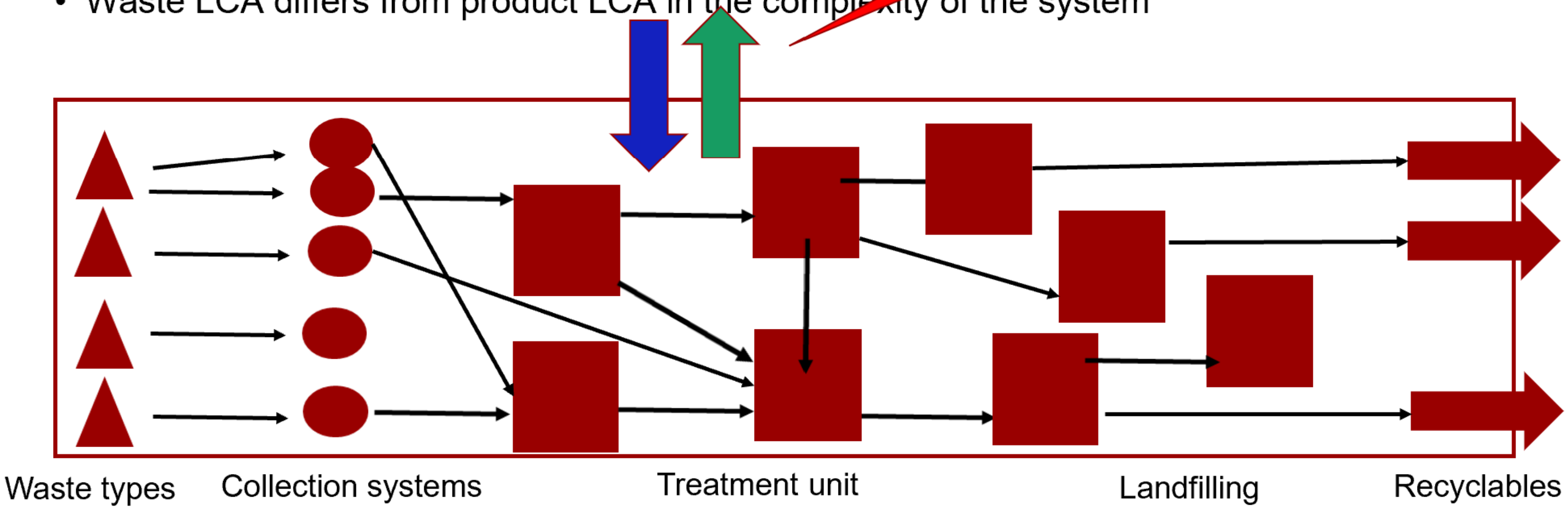
- LCA stands for Life-Cycle-Assessment
- A holistic approach for environmental assessment of industrial products introduced in the 1990ties* – the classic example is comparison of alternative containers for beverage
- A classic product LCA is



Introduction: LCA in waste management

All the emission converted into impacts as for other LCAs

- LCA came into waste management late 1990ties*, starting in S
- By 2020 more than 400 scientific papers have been publi ed from around the worlds
- Waste LCA differs from product LCA in the complexity of the system

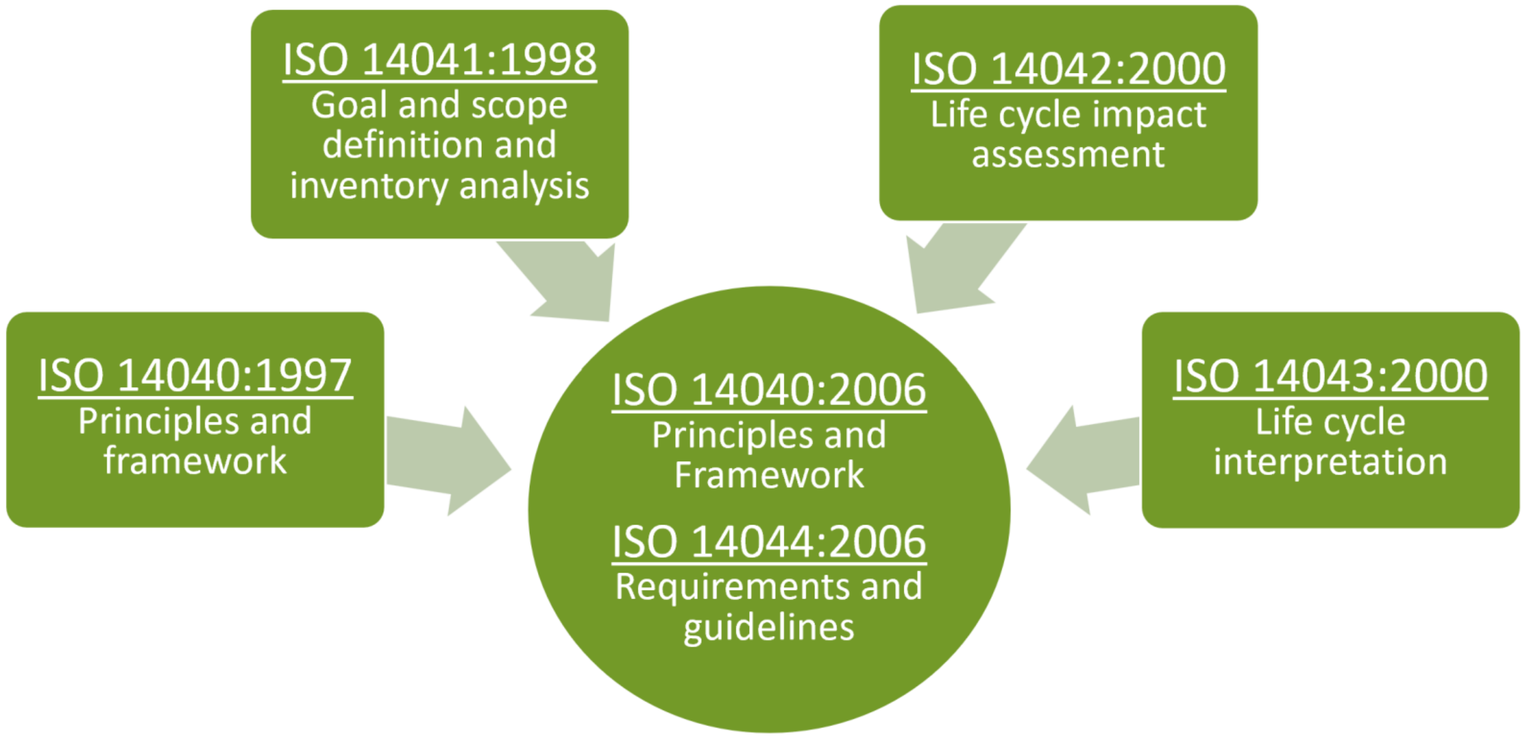


*Clift, R., Doig, A., Finnveden, G. (2000): The application of life cycle assessment to integrated waste management. Part 1. Methodology. Trans. IchemE 78/B, 279-287.

LCA- Life Cycle Assessment

- Enables to ascertain and manage emissions along the supply chain;
- Enables to compare different systems with the same function;
- Enables to evaluate future scenarios e.g variable electricity generation mix; variable heating generation origin; new technologies.

LCA- Life Cycle Assessment



ISO 14044:2006 Background

LCA Requirements and Guidelines

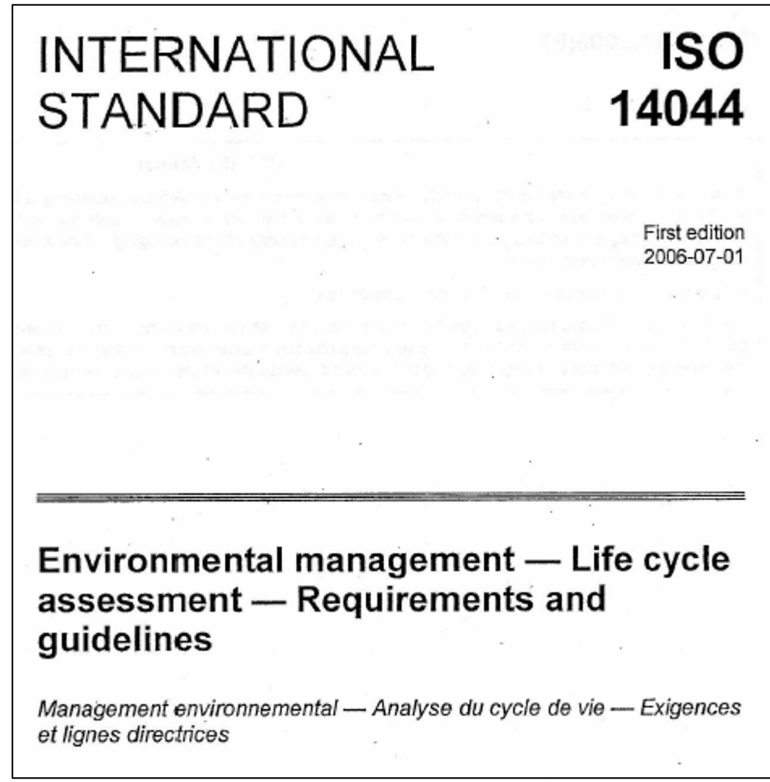
Similar to ISO 14040 in:

- Introduction
- Terminology definitions
- Phases and overview of process

Describes in more detail the required process for completing a life cycle assessment

First and only edition published in 2006

Replaces a host of previous ISO LCA standards



INTERNATIONAL STANDARD

ISO 14044

First edition 2006-07-01

Environmental management — Life cycle assessment — Requirements and guidelines

Management environnemental — Analyse du cycle de vie — Exigences et lignes directrices

LCA- Life Cycle Assessment

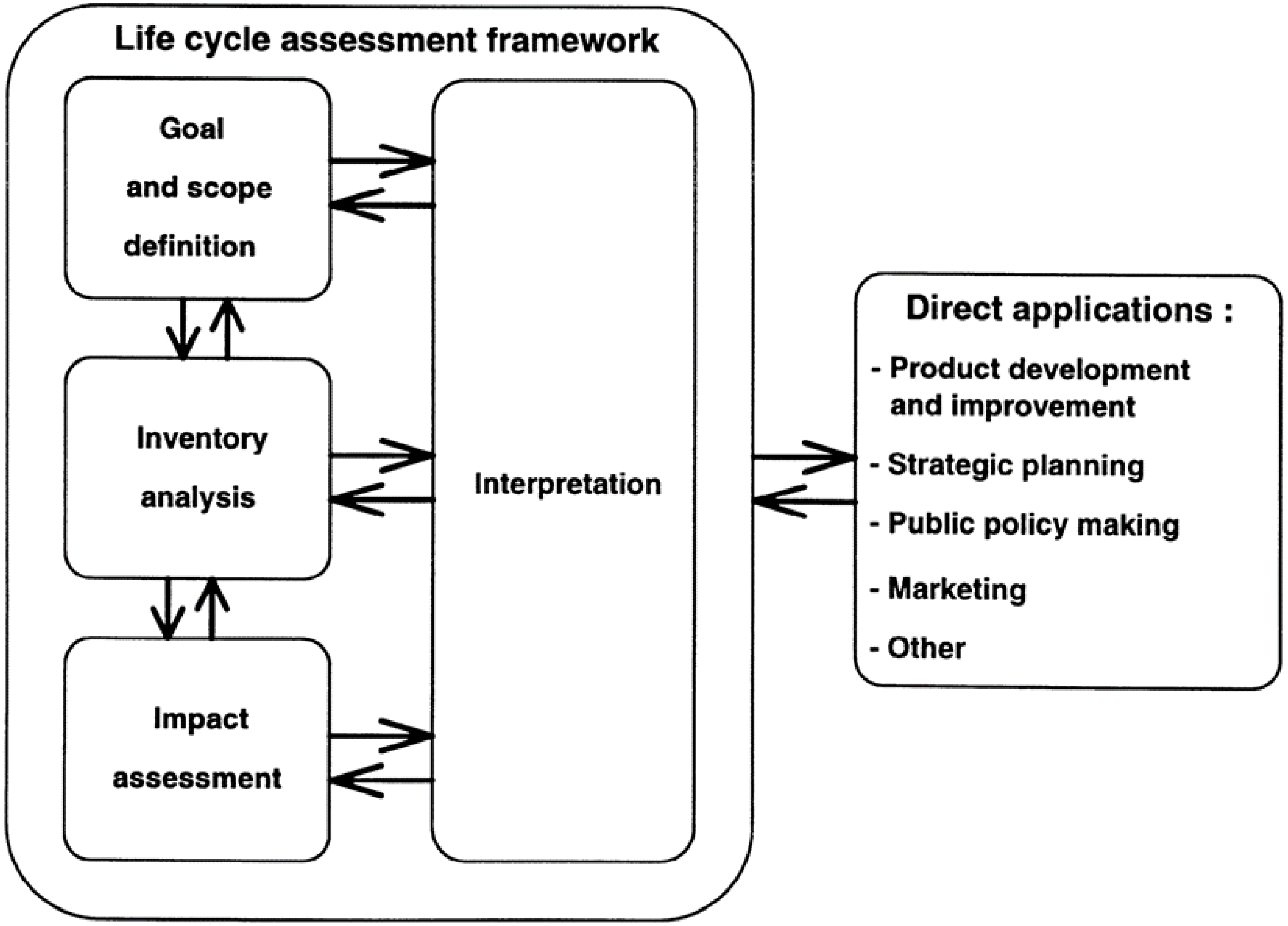


Figure 1 : Phases of an LCA

LCA- Life Cycle Assessment

DEFINE GOALS & SCOPE

- functional parameters
- system boundaries
- assumptions and limitations
- allocation/load sharing
- range of impacts assessed

INVENTORY ANALYSIS

flows of materials and energy

- cradle-to-grave
- cradle-to-gate
- cradle-to-cradle

IMPACT ASSESSMENT

- selection of impact categories, indicators, models
- classification into impact categories and parameters
- measurement of indicators, inventory flow, normalizations

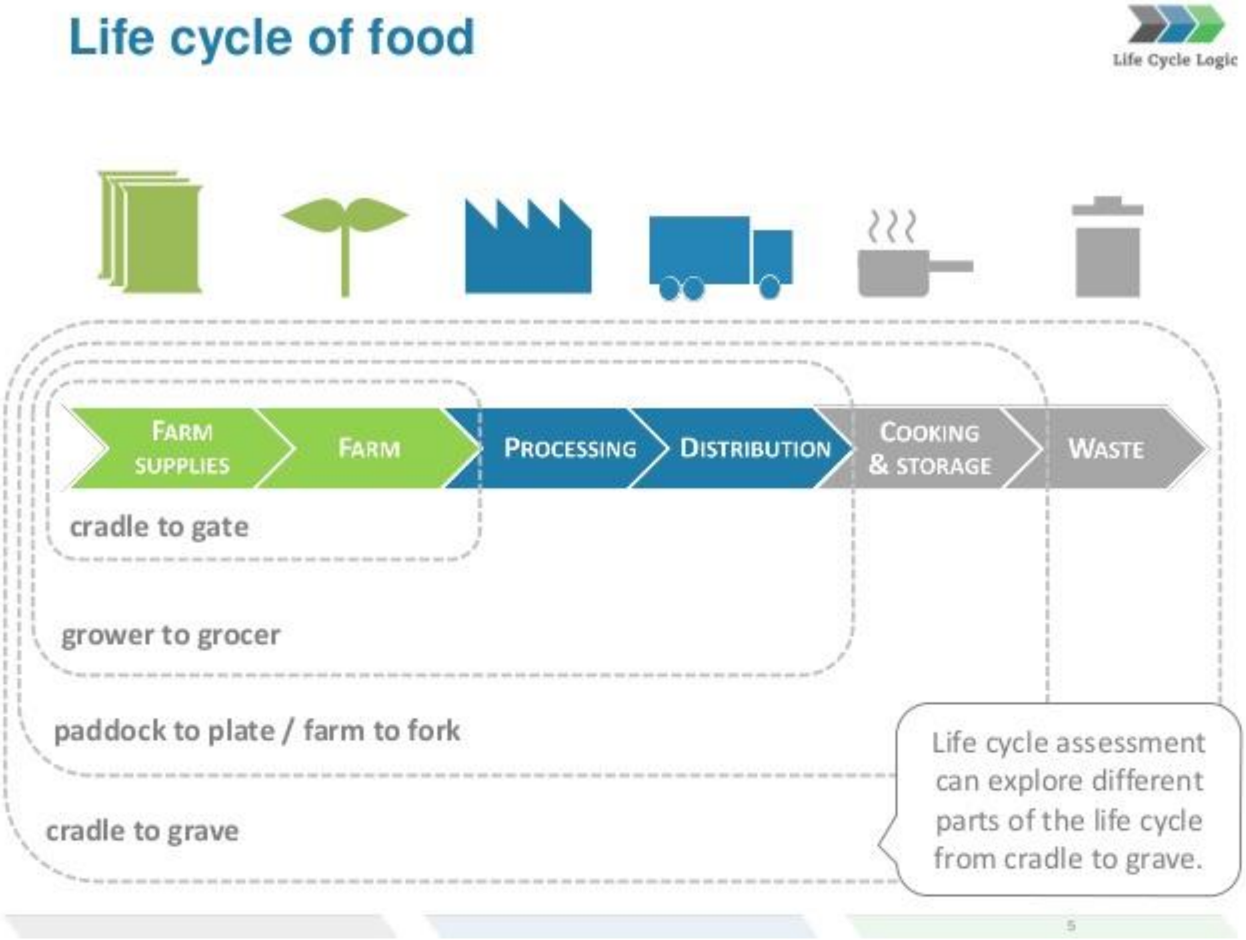
INTERPRETATIONS

Follow a systematic method for evaluating, checking, quanitifying, and identifying data/information collected from the Goals & Scope, Inventory Analysis, and Impact Assessments.

Occur at multiple stages throughout the scope of the project, such as at the collection of new information.

- *Identification of issues based on results.*
- *Evaluation of the study.*
- *Conclusions and recommended courses of action.*

Examples- different boundaries



LCA- Life Cycle Assessment

Só fim de vida....

Disposal-to-Management

Disposal-to-Cradle

Disposal-to-Recovery

Disposal-to-Landfill

LCA- Life Cycle Assessment

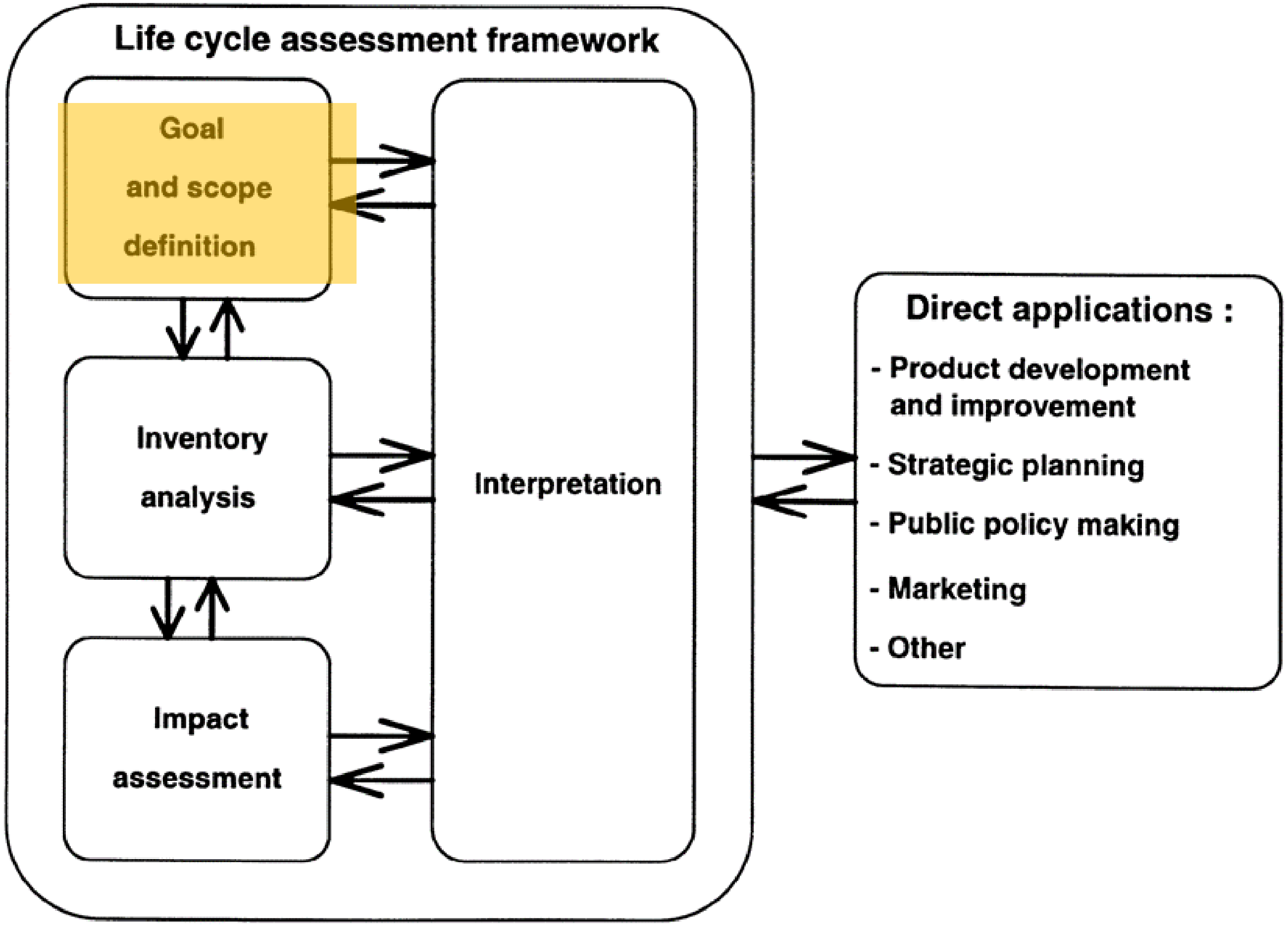


Figure 1 : Phases of an LCA

Goal Statement

- Goal statement is the first component of an LCA and guides much of the subsequent analysis
- Goal must state:
  - ➢Intended use
  - ➢Reasons for study
  - ➢Audience
  - ➢Whether comparative and disclosed to public

Scope Elements

- Function and functional unit
  - Define the functional characteristics of the product system
  - Functional unit for amount of function achieved, useful as a reference measure
- System boundary
  - Define which processes are included in the study
  - Helpful to include a process flow diagram
- LCIA methodology
  - State which impact categories and category indicators are used
  - State which impact characterization methodology is used
- Inventory Data
  - Obtain either from direct measurement of processes or from secondary sources (or a mix of the two)
  - Include inputs and outputs to air, water, and soil

Scope Elements

- Data quality
  - Address age, geographic coverage, technology coverage, precision, completeness, representativeness, consistency, reproducibility, sources, minimum length of time to collect, and uncertainty.
  - For missing data a zero value, non-zero value, or a calculated value from similar technology should be used and explained.
- Comparisons between systems
  - Use the same functional unit, system boundaries, data quality, allocation, and impact assessment procedures (if not possible, identify differences)
  - For publicly disclosed studies must include a critical review and the LCIA phase
- Critical Review
  - State whether or not a critical review will be conducted
  - Define how, and by whom, the critical review will be carried out

LCA- Life Cycle Assessment

VS

LCA- Life Cycle Assessment

Âmbito/Scope: comparar lavar o cabelo com shampô líquido ou sólido considerando

FU-Functional unit/ unidade funcional: 1 lavagem

Materiais da embalagem (extração, produção, fim de vida)

Água da lavagem (uso)

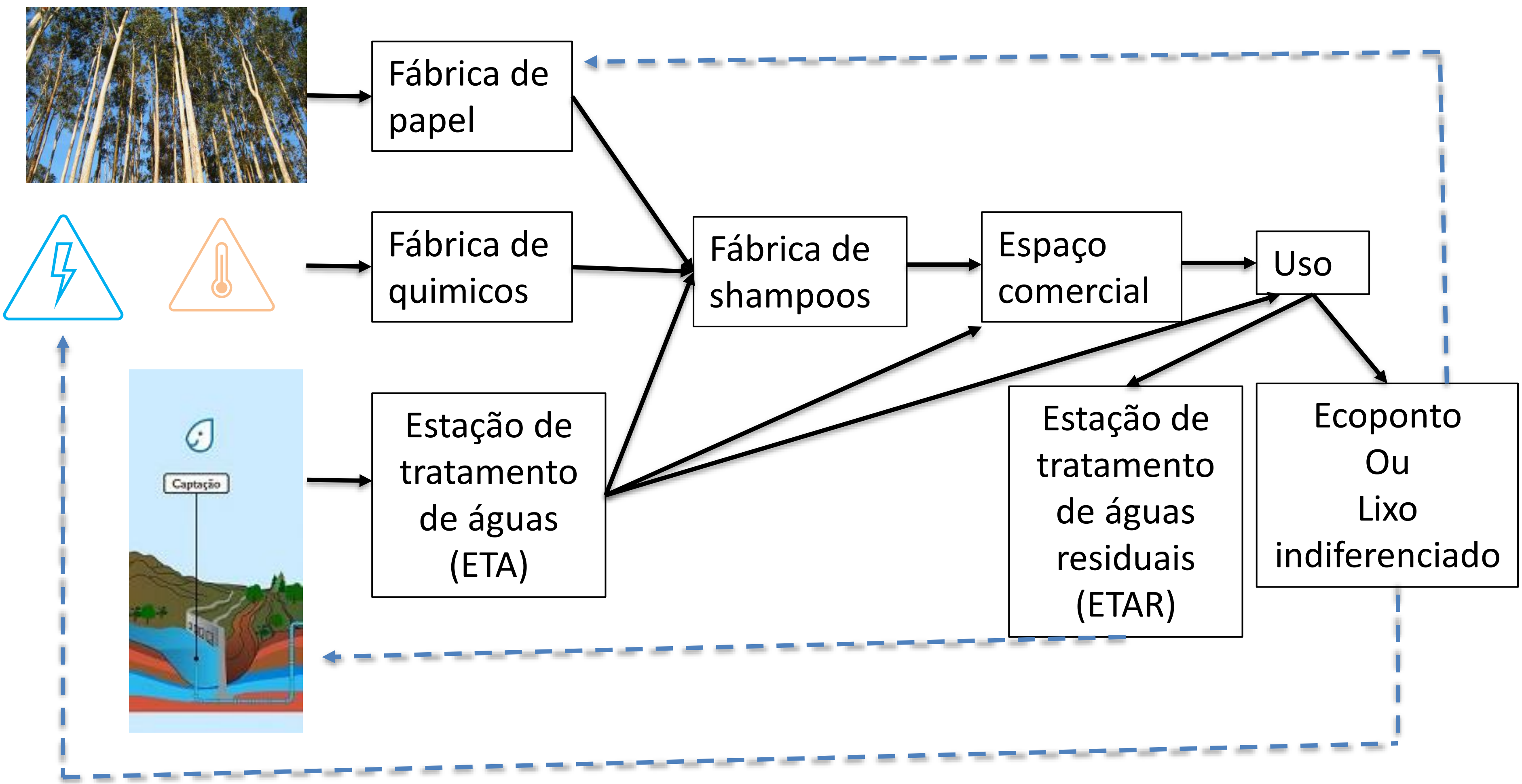
Gás natural e eletricidade (uso)

Químicos constituintes (extração, produção)

Fronteira do estudo: O que considerar??

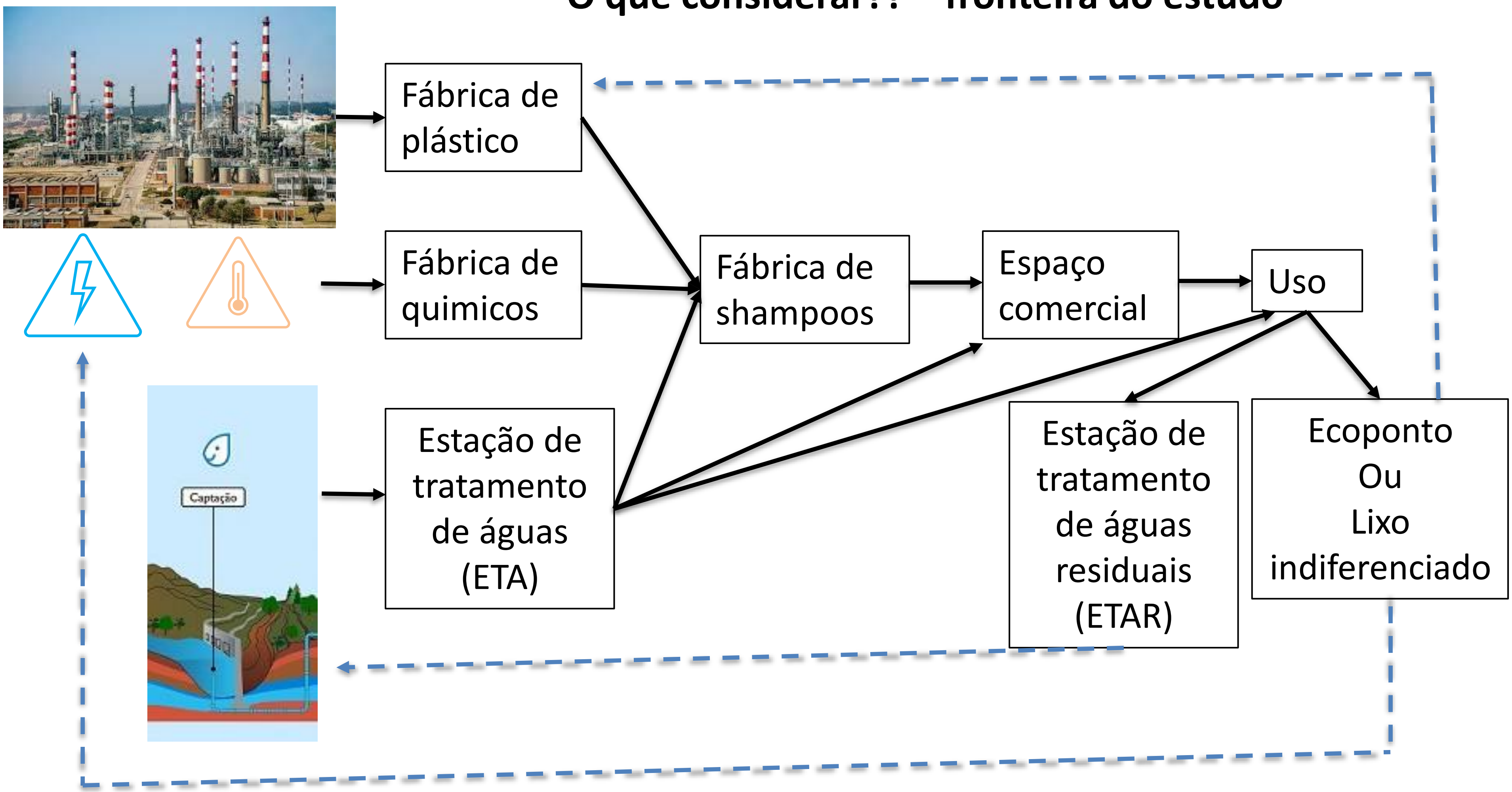
LCA- Life Cycle Assessment

O que considerar?? – fronteira do estudo



LCA- Life Cycle Assessment

O que considerar?? – fronteira do estudo



Examples Functional unit (FU) and reference flow/ unidade functional e fluxo de referência

Funciton produce 1 kWh electricity low voltage

FU =1 kWh result expressed per FU **250 g CO_2e/kWh**

Reference flow **1000 kWh** for the inventory

But final result expressed per FU

Function treat 1 kg solid urban waste

FU = 1 kg result expressed per FU **1000 g CO_2e/kg**

Reference flow **100 ton** for the inventory

But final result expressed per FU

LCA- Life Cycle Assessment

Âmbito/Scope: comparar lavar o cabelo com shampô líquido ou sólido considerando

FU-Functional unit/ unidade funcional: 1 lavagem

Materiais da embalagem (extração, produção, fim de vida)

Água da lavagem (uso)

Gás natural e eletricidade (uso)

Químicos constituintes (extração, produção)

Fronteira do estudo: O que considerar??

LCA- Life Cycle Assessment

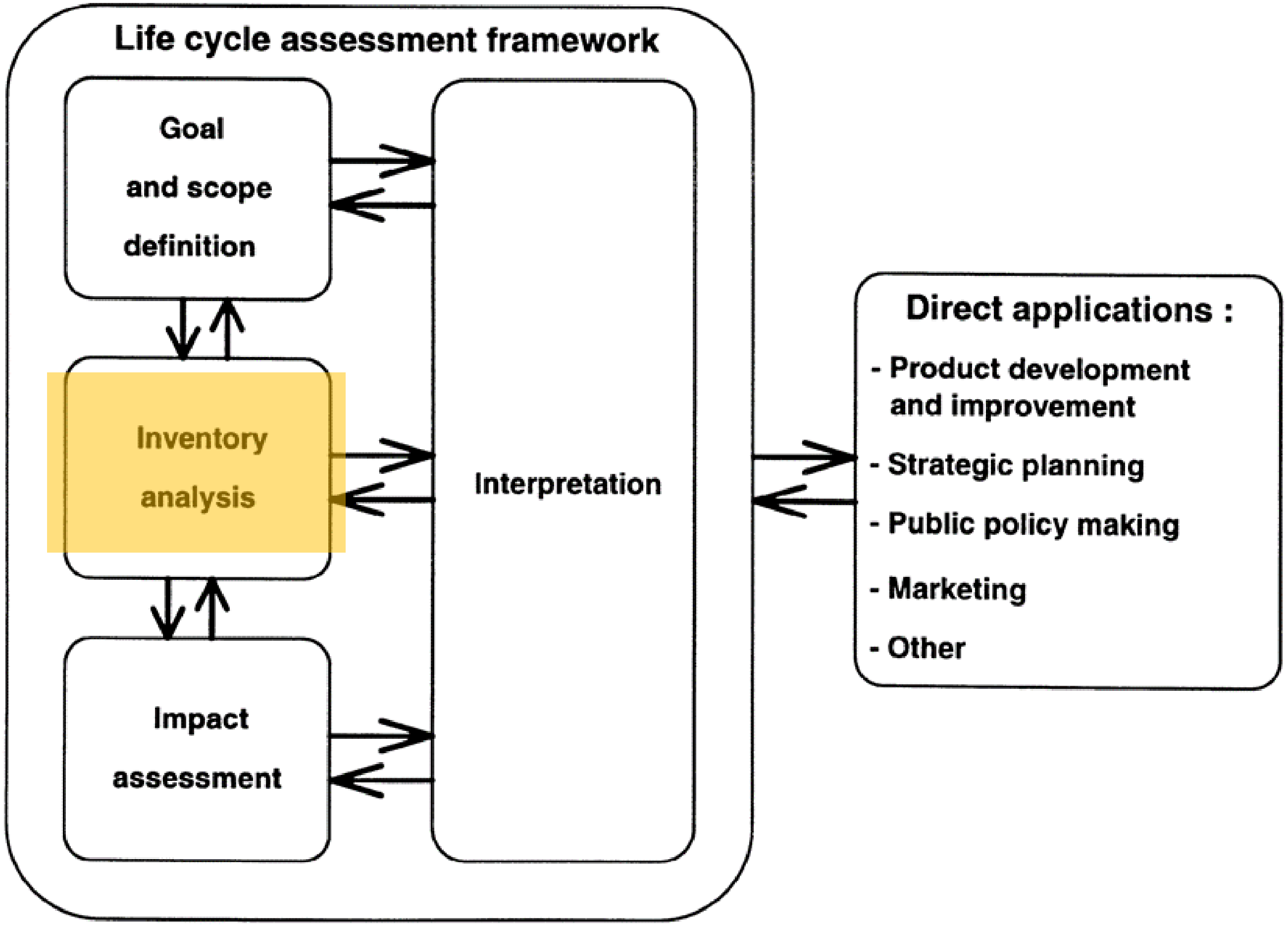
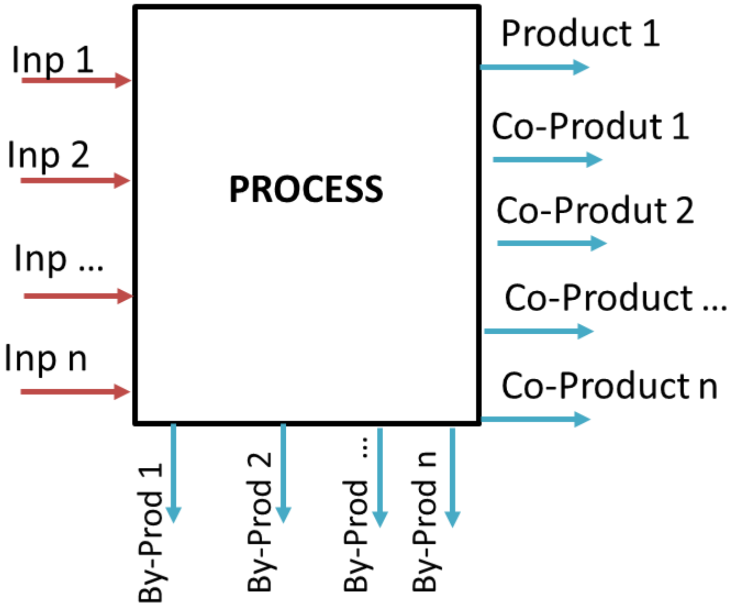


Figure 1 : Phases of an LCA

Carla Silva camsilva@fc.ul.pt

Case study

Inputs and outputs

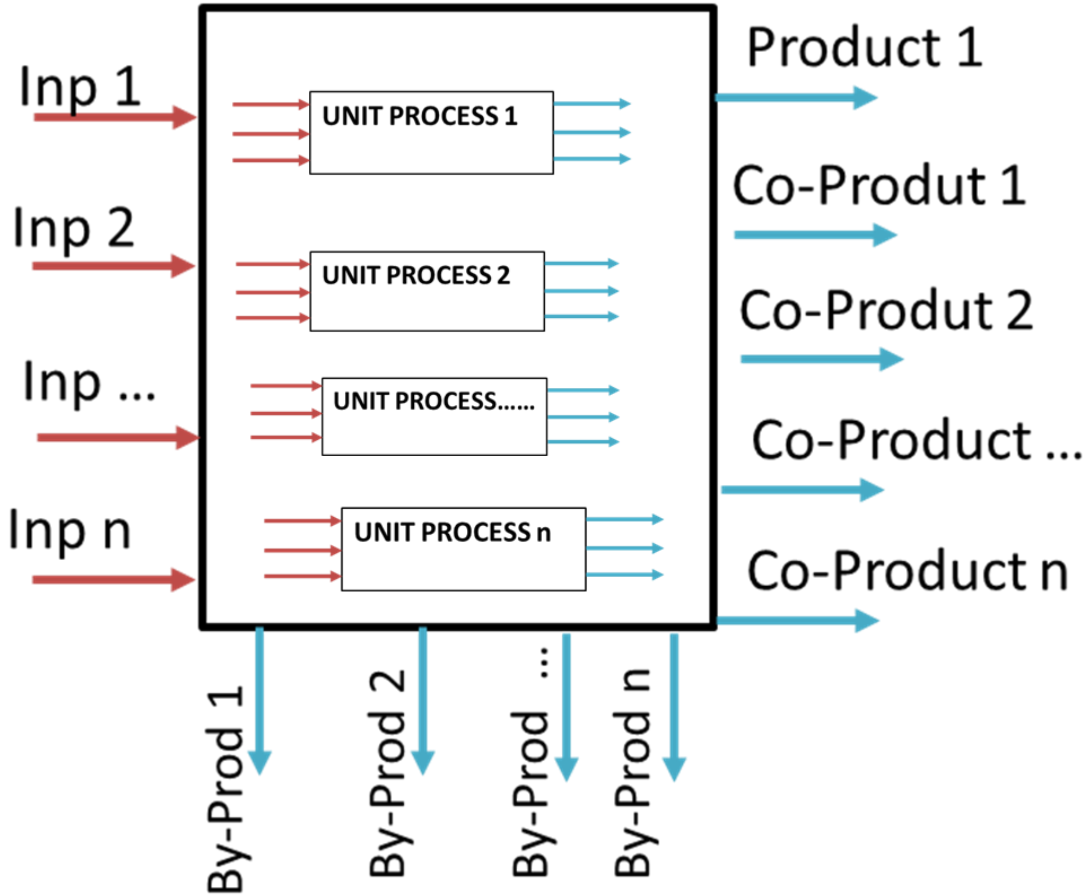


higher value and most desirable (e.g. refinery fuels)

lower value and less desirable
(e.g. wastewater, CO_2 emissions, ash, tar...)

Case study

Inputs and outputs



Data Collection

Collect for each unit process and reference sources, time taken, quality, etc.

Clearly define each unit process to prevent overlap in data collection

Provide the following details:

- Overall process flow diagrams
- Description of each unit process with inputs and outputs
- Flows and operating conditions of each unit process
- Units used
- Description of data collection techniques
- Instructions to document irregularities and all details

Example data collection sheet provided in the standard

Data Collection

Collect data and classify under the following major headings

Energy inputs, raw material inputs, ancillary inputs, and other physical inputs	Releases to air, water, and soil
Products, co-products and waste	Other environmental aspects

Data Collection

1. Consider goal and scope
2. Prepare for data collection
3. Collect data
4. Validate data
5. Relate data to unit process and allocations (reuse, etc.)
6. Relate data to functional unit
7. Aggregate data
8. Refine system boundary
9. Revise, repeat as needed

Already done if data from literature (step 3)

Already done if using database (steps 3–5)

LCA- Life Cycle Assessment

VS

LCA- Life Cycle Assessment

LCI – Life cycle inventory

Peso embalagem: 6 g

Contéudo: 60g

1.67 g/lavagem

$$\frac{60\ g}{1.67\ g/lavagem} = 36 \text{ lavagens}$$

6 g de material de embalagem → 0.17 g de material de embalagem por lavagem

LCA- Life Cycle Assessment

LCI – Life cycle inventory

200 ml por embalagem

29 g de embalagem está para 200 ml

X g está para 15 ml, ou seja,

g por lavagem (2.175 g/lavagem)

60 g por embalagem

6 g de embalagem está para 60 g

Y g está para 1.67 g, ou seja, 0.167 g/lavagem)

LCA- Life Cycle Assessment

Quimicos

Function	Ingredient	CAS	DID-list N°	Concentration (wt%)
Anionic surfactant	Sodium laureth sulfate	68891-38-3	8	13.00
Amphoteric surfactant	Cocamidopropyl betaine	61789-40-0	61	8.00
Non-ionic surfactants	Cocamide MEA	68140-00-1	50	1.25
Viscosity controlling agent	Propylene glycol	57-55-6	174	1.00
Preservative	Sodium benzoate	532-32-1	95	0.30
pH-adjustor	Chlorhydric acid	7647-01-0		0.80
Fragrance	alpha-hexyl cinnamaldehyde beta-pinene Dihydromyrcenol Hexyl salicylate Patchouli oil	101-86-0 127-91-3 2436-90-0 115-95-7 84238-39-1	142	0.50
Additional ingredients for additional functions (e.g. hair conditioning agent, hypo-irritancy agent)	Dimethicone	63148-62-9	110	1.00
Additional ingredients for additional functions (e.g. hair conditioning agent, hypo-irritancy agent)	Polyquaternium-10	68610-92-4		0.40
Additional ingredient for aspect (pearlescent / opacifying agent)	Glycol distearate	627-83-8	185	0.50
Solvent	Water			73.25

LCA- Life Cycle Assessment

Quimicos

Function	Ingredients for base case	Ingredients for worst case	Percentage (%)	Amount (g) in 100 g of product
Saponified oils (92%)	Tallow	Tallow		57
	Coconut oil fatty acids	Coconut oil fatty acids	92%	14
	Stearic acid	Stearic acid		14
Emulsifying / humectant	Glycerine	Propylene glycol	6%	5.52
Perfuming	Perfume	Benzyl alcohol	1%	1.38
Colorant	Colorants	Colorants	0,1%	0.092
Chelating agent	EDTA	EDTA	0,2%	0.184
Bleaching agent	Titanium dioxide	Titanium dioxide	0,1%	0.092
Water	Water	Water	8%	8

Examples-Inventory

WWTP LCI tool v.1.0_1 Oct 2015.xlsx

E99 {=TRANSPOSE('Sludge calc'!BX11:CC41)}

		LCI for WWTP+sludge disposal+environmental degradation		DTPMP	Sodium carbonate	Ethanol	TAED	Zeolite A	STPP
Input	From technosphere	Wastewater treatment	Product in wastewater (kg)	1	1	1	1	1	1
			Methanol (kg)	0	0	0	0.094473229	0	0
			FeCl3 (kg)	0	0	0	0	0	1.5896739
			Electricity (kWh)	0.419688889	0.038888889	1.015412328	0.578145351	0.442088889	0.6363845
			Heat (MJ)	6.1963	0.1375	0.456227973	0.513847686	6.5527	9.6440826
			WWTP infrastructure (unit)	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-
			Sewer infrastructure (km)	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-
		Sludge transport	transport, lorry (kgkm)	56.66666667	0	16.04638551	18.94471658	60	88.913043
		Sludge landfilling	process-specific burdens, municipal waste incineration (kg)	0	0	0	0	0	0
			process-specific burdens, slag compartment (kg)	0	0	0	0	0	0
			process-specific burdens, residual material landfill (kg)	0	0	0	0	0	0
			electricity from waste, at municipal waste incineration plant (kWh)	0	0	0	0	0	0
			heat from waste, at municipal waste incineration plant (MJ)	0	0	0	0	0	0
			iron (III) chloride, 40% in H2O, at plant (kg)	0	0	0	0	0	0
			cement, unspecified, at plant (kg)	0	0	0	0	0	0
			disposal, cement, hydrated, 0% water, to residual material landfill (	0	0	0	0	0	0
			transport, freight, rail (tkm)	0	0	0	0	0	0
			transport, lorry 28t (tkm)	0	0	0	0	0	0
			natural gas, burned in industrial furnace low-NOx >100kW (MJ)	0	0	0	0	0	0
			electricity, low voltage, at grid (kWh)	0	0	0	0	0	0
			light fuel oil, burned in boiler 100kW, non-modulating (MJ)	0	0	0	0	0	0
			natural gas, burned in boiler modulating >100kW (MJ)	0	0	0	0	0	0
			iron sulphate, at plant (kg)	0	0	0	0	0	0
			aluminium sulphate, powder, at plant (kg)	0	0	0	0	0	0
			process-specific burdens, sanitary landfill (kg)	0	0	0	0	0	0
		Sludge incineration	municipal waste incineration plant (unit)	4.10833E-10	0	1.16336E-10	1.37349E-10	4.35E-10	6.4462E-1
			process-specific burdens, municipal waste incineration (kg)	1.643333333	0	0.46534518	0.549396781	1.74	2.5784782
			slag compartment (unit)	2.52723E-09	0	5.82536E-10	6.87755E-10	2.16533E-09	4.35559E-
			process-specific burdens, slag compartment (kg)	1.421565745	0	0.327676312	0.386862265	1.218	2.4500196
			residual material landfill facility (unit)	7.64319E-11	0	4.16598E-13	4.91848E-13	0	1.61406E-
			process-specific burdens, residual material landfill (kg)	0.036687316	0	0.000199967	0.000236087	0	0.0774750
			electricity from waste, at municipal waste incineration plant (kWh)	0.99155231	0	0.245335611	0.28965067	1.039848779	1.759374
			heat from waste, at municipal waste incineration plant (MJ)	6.513955639	0	1.59353423	1.881376086	6.826090477	11.662580
			sodium hydroxide, 50% in H2O, production mix, at plant (kg)	0.000421342	0	9.09621E-05	0.000107415	0	0.0002849
			quicklime, milled, packed, at plant (kg)	7.46588E-05	0	1.61179E-05	1.90332E-05	0	5.04972E-
			hydrochloric acid, 30% in H2O, at plant (kg)	5.50918E-07	0	1.13195E-07	1.33648E-07	5.08202E-07	4.79599E-

WWTP input | USESLCA input | Env deg calc | WWTP calc | Sludge calc | Sludge landfill LCI calc | Sludge incineration LCI calc | Sludge landfarming calc | LCI output | Ready to CSV output | Paramete

Normal View Ready Sum=0

Examples-Inventory

Life cycle phase	Process/Product flow (I_j)	Unit	Quantity	LCI data (from Ecoinvent v. 2.2) $(E_{i,j})$
Corn production	Calcium ammonium nitrate	g N	26.74	Calcium ammonium nitrate, as N/RER
	Mono ammonium phosphate	g P_2O_5	128.34	Monoammonium phosphate, as P2O5/RER
	Potassium chloride fertilizer	g K_2O	85.56	Potassium chloride, as K2O/RER
	Urea	g N	245.99	Urea, as N/RER
	Herbicide (nikosulfuron)	g	0.11	[sulfonyl]urea-compounds, at regional storehouse/CH
	Herbicide (dicamba)	g	0.51	Dicamba, at regional storehouse/RER
	Sowing seeds	kg	0.39	Maize seed IP, at storehouse/CH
	Fuel in agricultural machinery	MJ	6.93	Energy, from diesel burned in machinery/RER
	Transport to dryer	tkm	0.73	Transport, lorry >16t, fleet average/RER
Corn drying	Light fuel oil for process heating	MJ	4.60	Light fuel oil, burned in industrial furnace 1MW/CH
	Electricity	kWh	0.046	Electricity, low voltage, at grid/CS
Other processes (corn to PLA)	Production of PLA granules	kg	11.54	Polylactide, granulate, at plant/GLO*
Transport	Transport to bottle producer	tkm	2.31	Transport, lorry >16t, fleet average/RER
Blow moulding	Bottle production and packaging	kg	11.54	Blow moulding/RER
	Waste treatment	kg	0.26	Disposal, plastics, mixture, 15.3% water, to municipal incineration/CH

**modified Ecoinvent v. 2.2 process. See related text above.*

LCA- Life Cycle Assessment

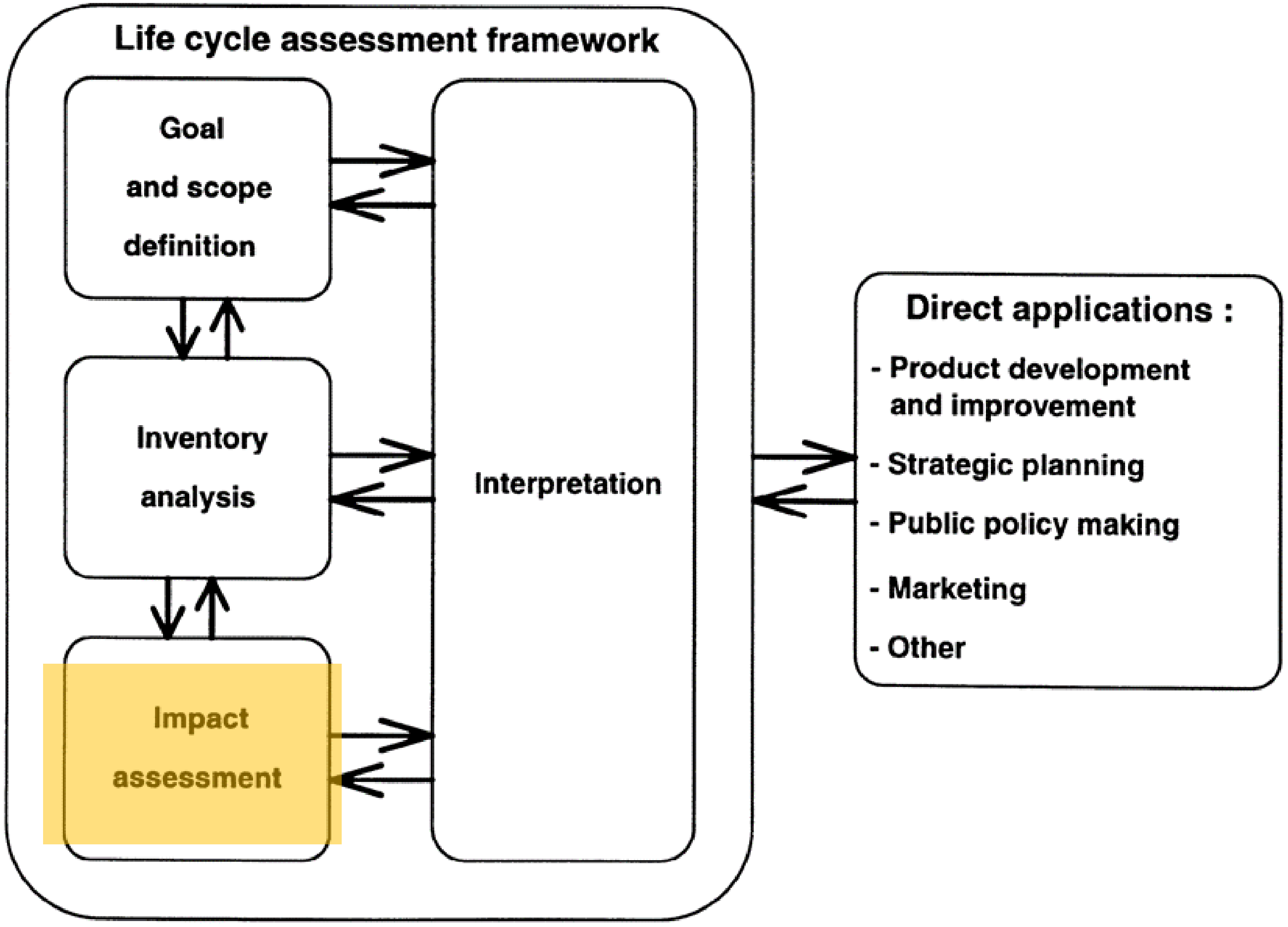


Figure 1 : Phases of an LCA

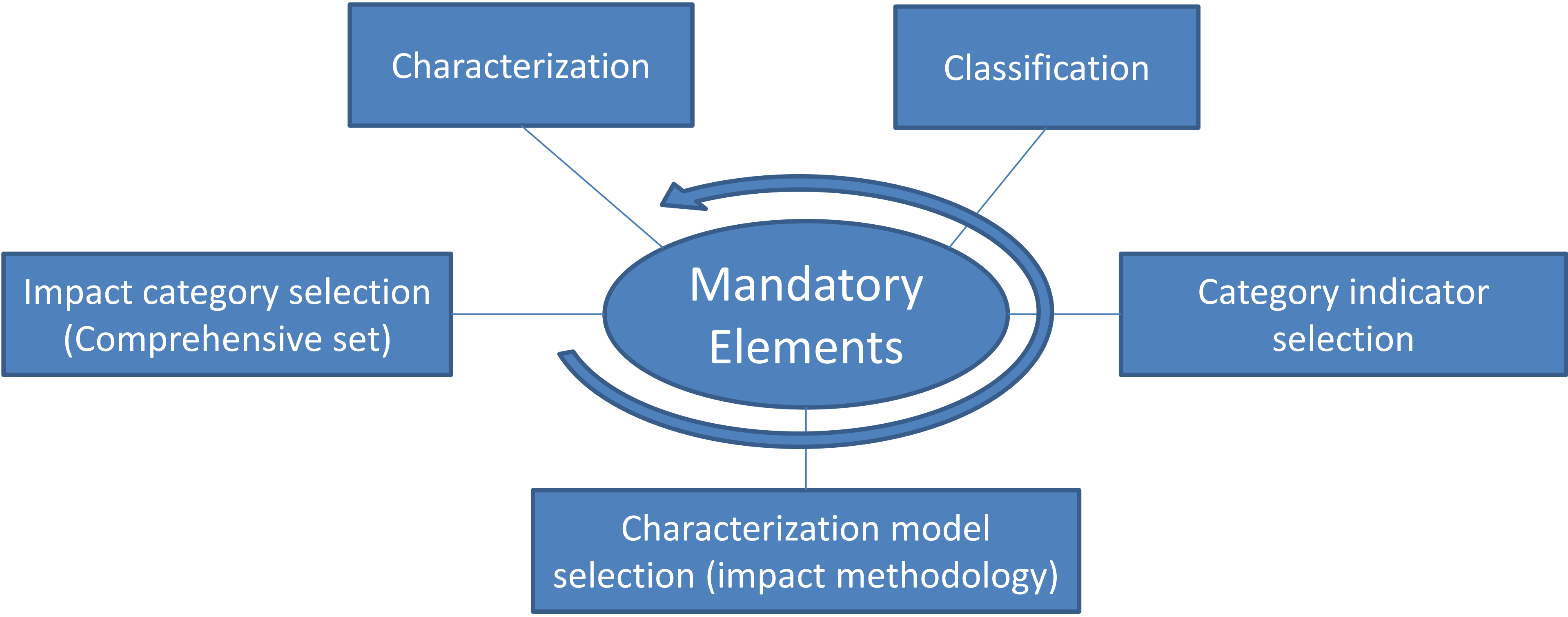
Life Cycle Impact Assessment

Data are converted into potential environmental impacts

During LCIA determine if:

- Quality of data sufficient to conduct the LCIA
- System boundaries and cut-offs (magnitude of input or output flow that is small enough to be negligible) appropriate to calculate indicator results
- Other methodological choices, like the choice of functional unit or averaging used, decreased the direct linkage between the data collected and environmental impact results obtained, potentially biasing the results

Mandatory Elements



Mandatory Elements Example

- Impact category selection:
  - GWP, AP, EP, ETP, HHNCP, HHCP HHCAP, ODP, SCP
- Category indicator selection:
  - kg CO_2eq for GWP, kg SO_2eq for AP, kg Neq for EP, etc…
- Characterization model selection:
  - RECIPE 2016 (other options include IMPACT 2002+, eco-indicator 99, CML 2001…)
- Classification:
  - Midpoint climate change
- Characterization:

  GWP100

Repeat for each flow, sum results in each impact category

Characterization factor

$$\text{Emissões } (tCO_2e) = \Sigma \, (\text{Fluxo}_i \times \text{Emissão/unidade de fluxo i})$$

FATOR DE EMISSÃO

EMISSION FACTOR

The activity data (that is, litres) is multiplied by the appropriate conversion factor to produce company A's fuel emissions.
Organisations should determine whether to use the net or gross calorific value of fuels according to their data. For example, the majority of energy billing is provided on a gros

Since company A is reporting a type of fuel that has biofuel content, it should also account for the 'biogenic' part of this fuel. To calculate this, it must also multiply the total lit a separate line item within its report called 'outside of scopes'. This will not be included in the organisation's emissions total, but displayed separately within the emissions rep activities.

For more information refer to the 'Outside of scopes' tab for guidance.

Activity	Fuel	Unit	kg CO_2e	kg CO_2e of CO_2 per unit	kg CO_2e of CH_4 per unit	kg CO_2e of N_2O per unit
Gaseous fuels	Butane	tonnes	3033.38	3029.26	2.52	1.60
		litres	1.75	1.74	0.00	0.00
		kWh (Net CV)	0.24	0.24	0.00	0.00
		kWh (Gross CV)	0.22	0.22	0.00	0.00
	CNG	tonnes	2562.57	2557.53	3.85	1.19
		litres	0.45	0.44757	0.00067	0.00020
		kWh (Net CV)	0.20	0.20226	0.00031	0.00010
		kWh (Gross CV)	0.18	0.18256	0.00028	0.00009
	LNG	tonnes	2581.98	2576.94	3.85	1.19
		litres	1.17	1.16604	0.00175	0.00054
		kWh (Net CV)	0.20	0.20379	0.00031	0.00010
		kWh (Gross CV)	0.18	0.18395	0.00028	0.00009
	LPG	tonnes	2939.36	2935.18	2.55	1.63
		litres	1.56	1.55491	0.00136	0.00086
		kWh (Net CV)	0.23	0.22999	0.00020	0.00012
		kWh (Gross CV)	0.21	0.21419	0.00019	0.00012
	Natural gas	tonnes	2562.57	2557.53	3.85	1.19
		cubic metres	2.04	2.03437	0.00307	0.00095
		kWh (Net CV)	0.20	0.20226	0.00031	0.00010
		kWh (Gross CV)	0.18	0.18256	0.00028	0.00009
	Natural gas (100% mineral blend)	tonnes	2581.98	2576.94	3.85	1.19
		cubic metres	2.05	2.04981	0.00307	0.00095
		kWh (Net CV)	0.20	0.20379	0.00031	0.00010
		kWh (Gross CV)	0.18	0.18395	0.00028	0.00009
	Other petroleum gas	tonnes	2578.25	2575.70	1.31	1.24
		litres	0.94	0.94348	0.00048	0.00045

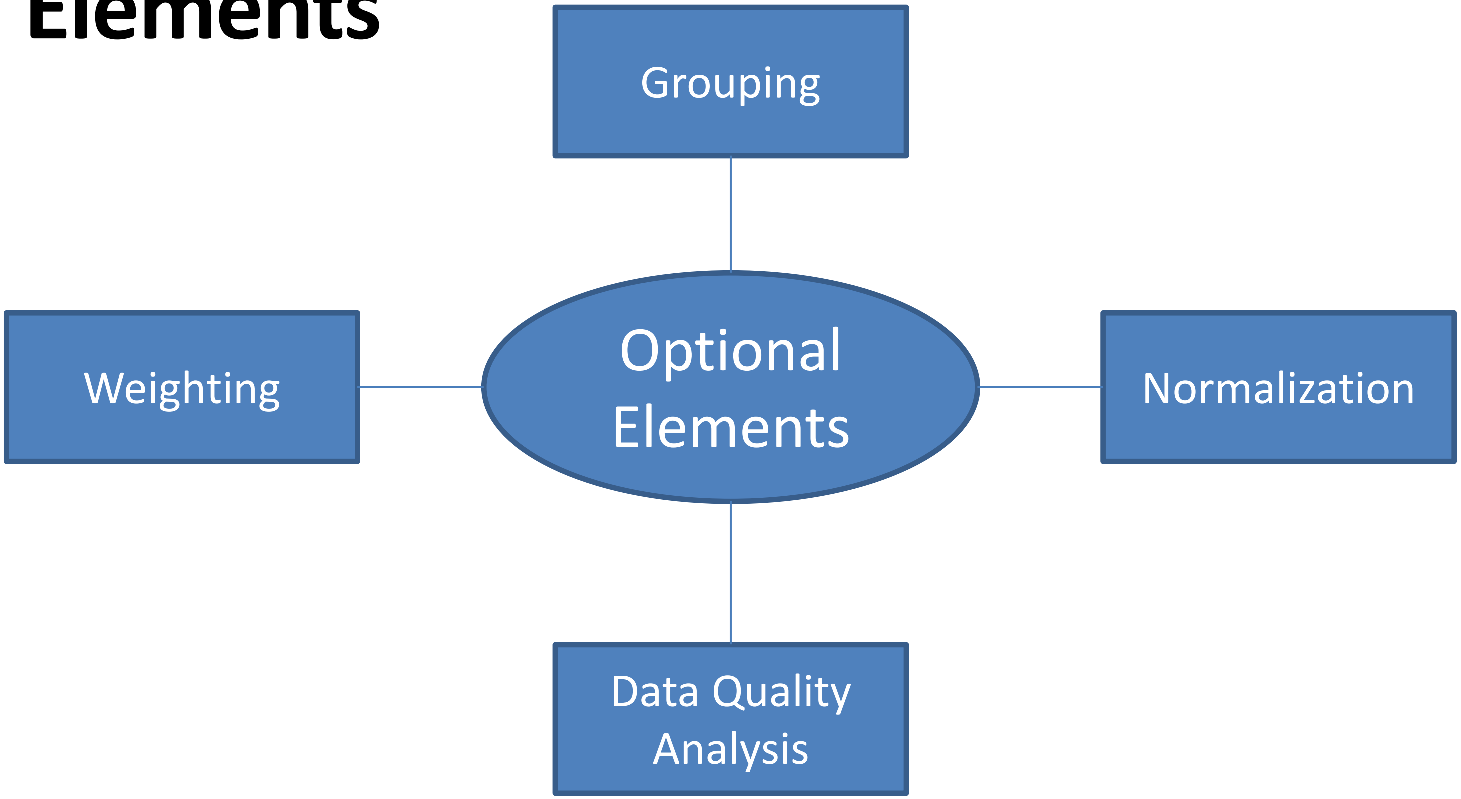
Introduction | What's new | Index | Fuels | Bioenergy | Re

CO2-equivalent per un

Label						Default value	
Title					Unit	[illegible]ission [illegible]tor (kg CO2eq per unit)	Uncertainty
[illegible]					kg	25.00	0%
[illegible]					kg	298.00	0%
[illegible]					kWh	0.19	10%
[illegible]					kWh	0.32	
[illegible]					kWh	0.40	10%
[illegible]					kWh	0.40	10%
[illegible]					kWh	0.50	10%
[illegible]					kWh	0.18	
[illegible]					kWh	0.39	10%
[illegible]					kWh	0.27	5%
[illegible]					kWh	0.30	5%
[illegible]					liter	2.79	5%
[illegible]					kWh	0.20	
[illegible]					kWh	0.29	5%
[illegible]					liter	3.19	5%
[illegible]					kg	3.53	
[illegible]					kWh	0.27	5%
[illegible]					kWh	0.21	5%
[illegible]					liter	1.69	10%
[illegible]					kWh	0.21	5%
Energy	Heat	Combustible	Petroleum coke		kWh	0.35	10%
Energy	Heat	Combustible	UNG		kWh	0.18	
Energy	Heat	Organic combustible	Biodiesel (kWh)		kWh	0.01	
Energy	Heat	Organic combustible	Biodiesel (liter)		liter	0.81	
Energy	Heat	Organic combustible	Bioethanol		kg	1.21	10%
Energy	Heat	Organic combustible	Biogas (kg)		kg	1.61	
Energy	Heat	Organic combustible	Biogas (kWh)		kWh	0.02	
Energy	Heat	Organic combustible	Biogas (m3)		m3	0.12	

DATABASE

Optional Elements



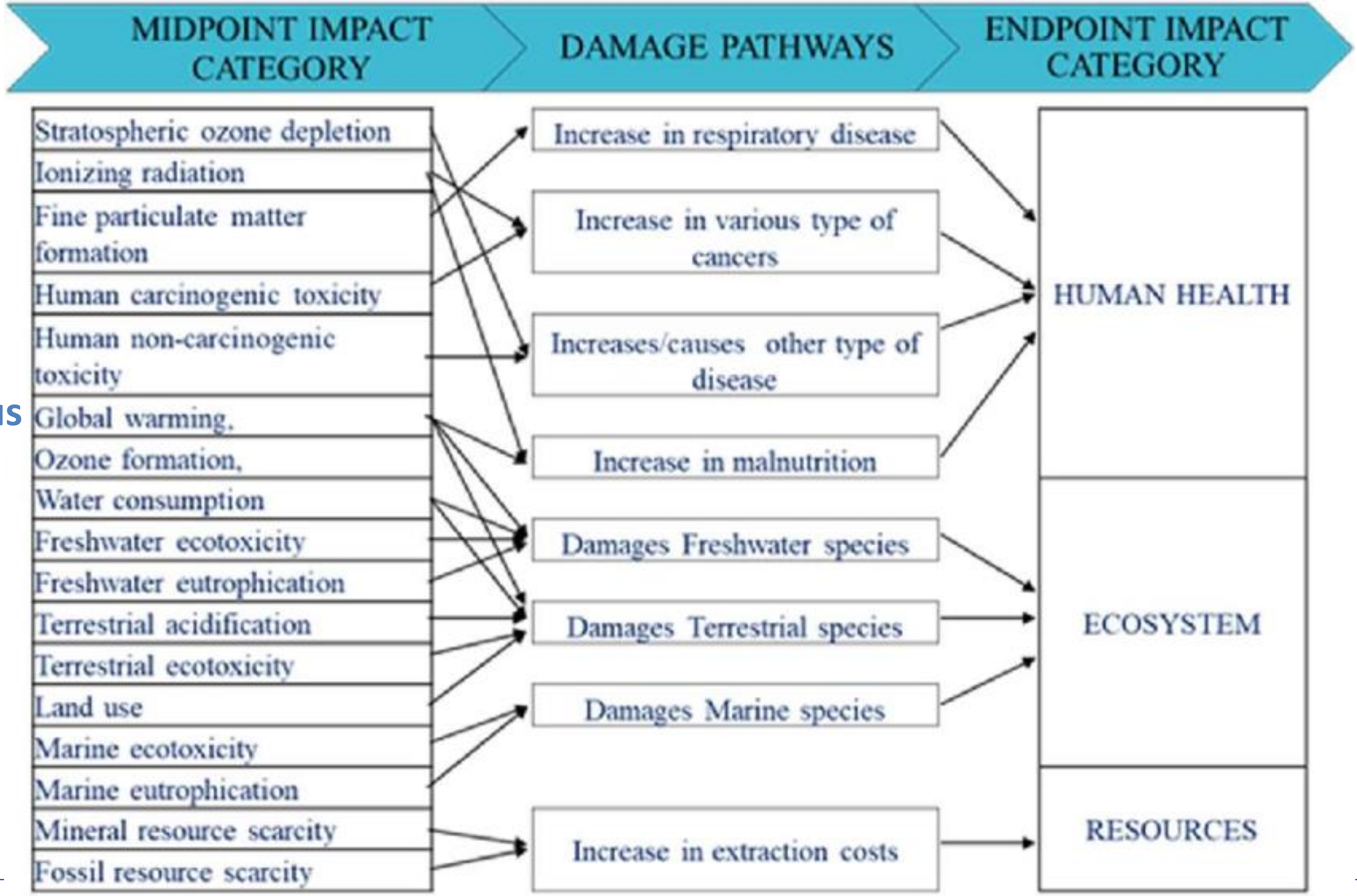
These elements can be useful to help decision makers interpret results, but also may introduce additional subjectivity. Inclusion of these elements should be consistent with goal and scope.

Example of terminology for acidification

Impact Category	• Acidification potential (AP)
LCI result	• 500 kg SO_2, 100 kg NO_x , 10 kg HNO_3 per functional unit
Characterization Model	• TRACI 2.1*
Category Indicator	• Increase in acidity in the environment (moles H^+)
Characterization Factor	• Potential of each compound to cause acid deposition (such as acid rain) in relation to that of SO_2
Category Indicator Result	• Kilograms of SO_2-equivalent
Category Endpoints	• Ecosystem effects such as acidic lakes, corrosion to buildings, damage to plants
Environmental Relevance	• Increased emissions of species such as nitric oxides and sulfur oxides directly contribute to increases in environmental acidity, depending on transport and chemistry models, such as in the form of acid rain.

*TRACI is the Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts

Impact assessment, e.g. Recipe 2016



Our Focus

Impact assessment, e.g. Recipe 2016

No	Midpoint Impact Category Name	Unit
1	Global warming	kg CO_2 eq
2	Stratospheric ozone depletion	kg CFC11 eq
3	Ionizing radiation	kBq Co-60 eq
4	Ozone formation, human health	kg NO_x eq
5	Fine particulate matter formation	kg $PM_{2.5}$ eq
6	Ozone formation, terrestrial ecosystems	kg NO_x eq
7	Terrestrial acidification	kg SO_2 eq
8	Freshwater eutrophication	kg P eq
9	Marine eutrophication	kg N eq
10	Terrestrial ecotoxicity	kg 1,4-DCB
11	Freshwater ecotoxicity	kg 1,4-DCB
12	Marine ecotoxicity	kg 1,4-DCB
13	Human carcinogenic toxicity	kg 1,4-DCB
14	Human non-carcinogenic toxicity	kg 1,4-DCB
15	Land use	m^2a crop eq
16	Mineral resource scarcity	kg Cu eq
17	Fossil resource scarcity	kg oil eq
18	Water consumption	m^3

Our Focus

Table 1.2. Overview of the endpoint categories, indicators and characterization factors.

Area of protection	Endpoint	Abbr.	Name	Unit
human health	damage to human health	HH	disability-adjusted loss of life years	year
natural environment	damage to ecosystem quality	ED	time-integrated species loss	species ×yr
resource scarcity	damage to resource availability	RA	surplus cost	Dollar

Comparative Assessment LCIA

No weighting allowed

Sufficiently comprehensive set of category indicators

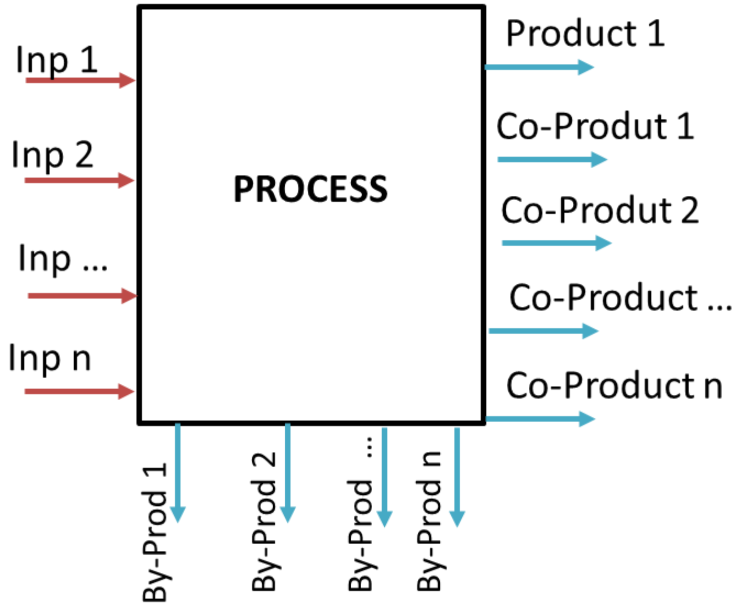
Category indicators should be scientifically valid, environmentally relevant, and internationally accepted

Not sole basis for decisions

Must include sensitivity and uncertainty analyses

Case study

Inputs and outputs

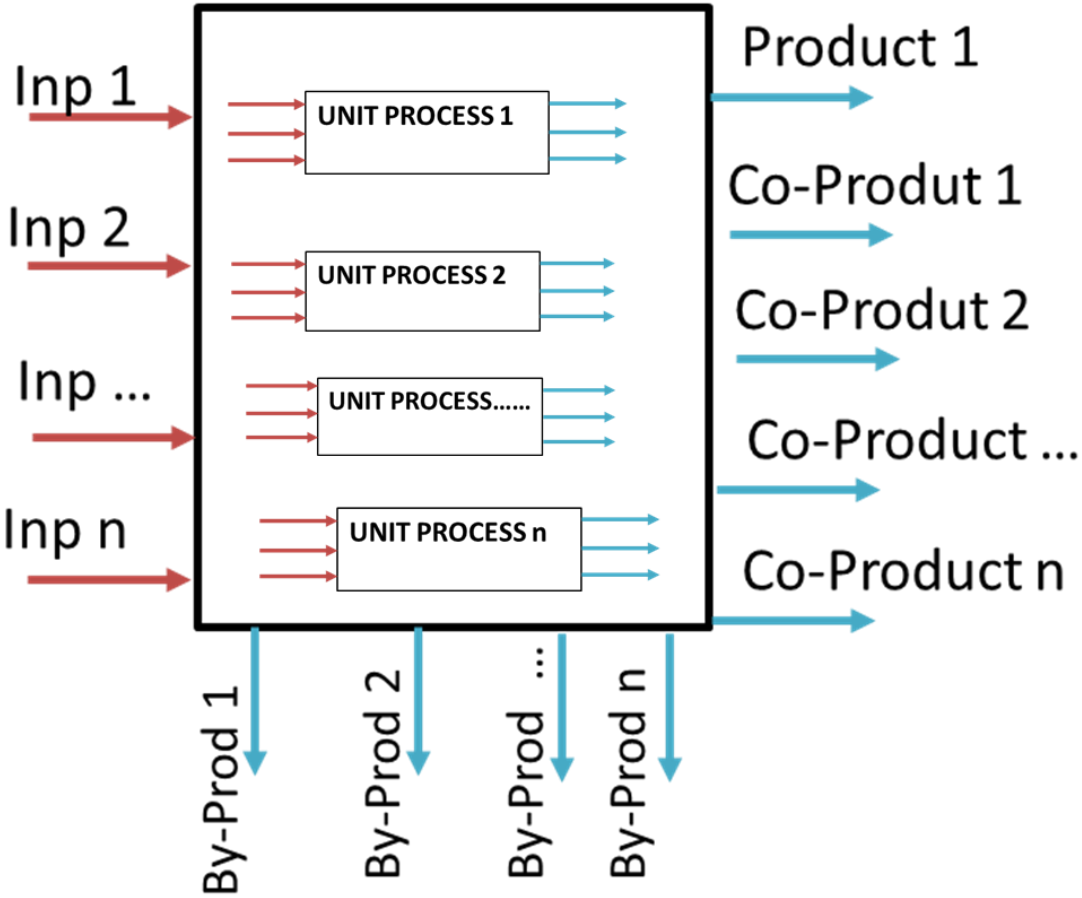


higher value and most desirable (e.g. refinery fuels)

lower value and less desirable (e.g. wastewater, CO_2 emissions, ash, tar...)

Case study

Inputs and outputs



Case study

Emission factor database gCO_{2eq}/ unit

Construction materials "grey materials"

Chemicals

Fuels

Heat/vapour

Electricity

2006 IPCC Guidelines for National Greenhouse Gas Inventories

39

Scientific literature DOI:.....

Case study

Material embalagem: e.g. mistura papel e cartão

Fator de emissão:

881.19 kg CO_{2eq}/Ton (0%reciclado) + 1041.804 kgCO_{2eq}/Ton (aterro) = 1923 kg CO_{2eq}/Ton

731.28 kg CO_{2eq}/Ton (100% reciclado) + 21.294 kg CO_{2eq}/Ton (reciclagem) = 753 kg CO_{2eq}/Ton

UK Government GHG Conversion Factors for Company Reporting

Material use

Index

Activity	Material	Unit	Primary material production kg CO_2e	Re-used kg CO_2e	Open-loop source kg CO_2e	Closed-loop source kg CO_2e
Paper	Paper and board: board	tonnes	821.23			718.54
	Paper and board: mixed	tonnes	881.19			731.28
	Paper and board: paper	tonnes	919.4			739.4

GREENHOUSE GAS PROTOCOL

Department for Environment Food & Rural Affairs

UK Government GHG Conversion Factors for Company Reporting

Waste disposal

Index

Activity	Waste type	Unit	Re-use kg CO_2e	Open-loop kg CO_2e	Closed-loop kg CO_2e	Combustion kg CO_2e	Composting kg CO_2e	Landfill kg CO_2e	Anaerobic digestion kg CO_2e
Paper	Paper and board: board	tonnes			21.294	21.294	8.951	1,041.804	
	Paper and board: mixed	tonnes			21.294	21.294	8.951	1,041.804	
	Paper and board: paper	tonnes			21.294	21.294	8.951	1,041.804	

LCA- Life Cycle Assessment

LCIA– Life cycle impact assessment

Materiais da embalagem (extração, produção, fim de vida)

Água da lavagem (uso)

Químicos constituintes

GREENHOUSE GAS PROTOCOL

Department for Environment Food & Rural Affairs

Base de dados??

LCA- Life Cycle Assessment

Químicos

Químico	Valor Cradle-to-Gate	Referência da base de dados
Sodium Lauryl Sulfate (SLS)	1.63 Ton CO2eq/ton	Environmental Fact Sheet (#5) C12-14 and C12-15 Sodium Alkyl Sulphate (C12-14 mix AS) oleo/petrochemical anionic surfactant https://www.erasm.org/
Cocamidopropyl betaine	1.63 Ton CO2eq/ton	Environmental Fact Sheet (#28) C8-18 Alkyl Amidopropyl Betaine (CAPB) oleo/petrochemical amphoteric surfactant https://www.erasm.org/
Cocamide Diethanolamine	-0.88 Ton CO2eq/ton	Environmental Fact Sheet (#16) Cocamide Diethanolamine (CDEA) oleochemical non-ionic surfactant https://www.erasm.org/
Propylene glycol	4.67 Ton CO2eq/ton	OpenLCA Energies 2020, 13, 5653; doi:10.3390/en13215653
Titanium dioxide	1.43 Ton CO2eq/ton	2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 3, Chapter 3, Table 3.9) https://www.ipcc-nggip.iges.or.jp/EFDB/find_ef.php?ipcc_code=2.B.6&ipcc_level=2
HCL	0.89 Ton CO2eq/ton	Winipeg -canada
Water	0.149 kg CO2eq/m3	UK DEFRA
Tallow Oil	3.05 kg CO2eq/kg	Life Cycle Analysis of Greenhouse Gas Emissions from Biosynthetic Base Oil (BBO) compared to Poly-Alpha Olefin (PAO) Base Oil Prepared for Biosynthetic Technologies Prepared by Dustin Mulvaney, Ph.D., EcoShift Consulting February 3, 2014

Ciências ULisboa

LCA- Life Cycle Assessment

Emission factors in kg CO2-equivalent per unit

Categories			Label		Default value	
Category 1	Category 2	Category 3	Title	Unit	Emission factor (kg CO2eq per unit)	Uncertainty
Reagent	Chemical	Al(OH)3	Aluminium hydroxide, Al(OH)3	kg	0.66	
Reagent	Chemical	Al2(SO4)3	Aluminium sulphate, powder, Al2(SO4)3	kg	0.50	
Reagent	Chemical	Al2O3	Aluminium oxide, Al2O3	kg	1.23	
Reagent	Chemical	AlCl3	Aluminium chloride, AlCl3	kg	0.60	0%
Reagent	Chemical	Alcool	Alcohol	kg	1.47	25%
Reagent	Chemical	C2Cl4	Tetrachloroethylene, C2Cl4	kg	3.90	
Reagent	Chemical	C2H3ClO2	Chloroacetic acid, C2H3ClO2	kg	2.20	
Reagent	Chemical	C2H6O	Ethanol from ethylene, C2H6O	kg	1.24	
Reagent	Chemical	C2HCl3	Trichloroethylene, C2HCl3	kg	0.45	
Reagent	Chemical	C3H6O	Acetone, liquid, C3H6O	kg	2.19	
Reagent	Chemical	C3H6O	Propanal, C3H6O	kg	3.32	
Reagent	Chemical	C3H7OH	Isopropanol, C3H7OH	kg	1.85	
Reagent	Chemical	C3H8O	1-propanol, C3H8O	kg	3.84	
Reagent	Chemical	C3H8O2	Propylene glycol, C3H8O2	kg	4.14	
Reagent	Chemical	C4H10O	Isobutanol, C4H10O	kg	2.27	
Reagent	Chemical	C4H8O	Tetrahydrofuran, C4H8O	kg	5.78	
Reagent	Chemical	C5H12	Pentane, C5H12	kg	1.09	
Reagent	Chemical	C5H12O	1-pentanol, C5H12O	kg	4.52	
Reagent	Chemical	C6H14	Hexane, C6H14	kg	0.62	50%
Reagent	Chemical	C6H14O4	Triethylene glycol, C6H14O4	kg	3.09	
Reagent	Chemical	C6H4Cl2	o-dichlorobenzene, C6H4Cl2	kg	12.20	
Reagent	Chemical	C6H4Cl2	p-dichlorobenzene, C6H4Cl2	kg	12.20	
Reagent	Chemical	C6H5Cl	Monochlorobenzene, C6H5Cl	kg	12.20	
Reagent	Chemical	C6H5OH	Phenol, C6H5OH	kg	3.87	
Reagent	Chemical	C6H6	Benzene, C6H6	kg	1.76	
Reagent	Chemical	C7H16	Heptane, C7H16	kg	0.92	
Reagent	Chemical	C7H8 (C6H5CH3)	Toluene, C7H8 (C6H5CH3)	kg	1.47	
Reagent	Chemical	CaC2	Calcium carbide, technical grade, CaC2	kg	3.68	
Reagent	Chemical	CaCl2	Calcium chloride, CaCl2, CaCl2	kg	0.89	
Reagent	Chemical	CH2O2	Formic acid, CH2O2	kg	2.51	
Reagent	Chemical	CH3OH	Methyl alcohol, CH3OH	kg	0.66	50%

LCA- Life Cycle Assessment

t

Category 1 | Cat | nit | Default value: Emission factor (kg CO2eq per unit) | Uncertainty

Reagent	Chemical	CHCl3	Trichloromethane, CHCl3	kg	4.13	
Reagent	Chemical	Cl	Chlorine, liquid, Cl	kg	1.08	
Reagent	Chemical	ClO2	Chlorine dioxide, ClO2	kg	6.33	
Reagent	Chemical	CO	Carbon monoxide, CO	kg	1.57	
Reagent	Chemical	CO2	Carbon dioxide liquid, CO2	kg	0.82	
Reagent	Chemical	Cu2O	Copper oxide, Cu2O	kg	2.07	
Reagent	Chemical	CuCO3	Copper carbonate, CuCO3	kg	2.00	
Reagent	Chemical	F	Fluorine, liquid, F	kg	11.40	
Reagent	Chemical	FeCl3	Iron (II) chloride, 40% in H2O, FeCl3	kg	0.18	
Reagent	Chemical	H	Hydrogen, liquid, H	kg	1.63	
Reagent	Chemical	H2O2	Hydrogen peroxide, 50% in H2O, H2O2	kg	1.14	
Reagent	Chemical	H2SiF6	Fluosilisic acid, 22% in H2O, H2SiF6	kg	0.97	
Reagent	Chemical	H2SO4	Sulphuric acid, H2SO4	kg	0.14	50%
Reagent	Chemical	H3BO3	Boric acid, anhydrous, powder, H3BO3	kg	0.72	
Reagent	Chemical	H3PO4	Phosphoric acid, industrial grade, 85% in H20, H3PO4	kg	1.45	50%
Reagent	Chemical	HCl	Hydrochloric acid, 30% in H2O, HCl	kg	1.20	50%
Reagent	Chemical	HCl	Hydrochloric acid, HCl	kg	0.89	
Reagent	Chemical	HCN	Hydrogen cyanide, HCN	kg	7.06	
Reagent	Chemical	HF	Hydrogen fluoride, HF	kg	2.82	
Reagent	Chemical	HNO3	Nitric acid production - Atmospheric pressure plants (low pressure), HNO3	kg	1.55	
Reagent	Chemical	HNO3	Nitric acid production - High pressure plant, HNO3	kg	2.79	
Reagent	Chemical	HNO3	Nitric acid production - Medium pressure combustion plant, HNO3	kg	2.17	
Reagent	Chemical	HNO3	Nitric acid, 50 % in H2O, HNO3	kg	3.18	
Reagent	Chemical	Inorganic	Carbon black	kg	2.38	
Reagent	Chemical	Inorganic	Silicone product	kg	2.67	
Reagent	Chemical	K2CO3	Potassium carbonate, K2CO3	kg	2.38	
Reagent	Chemical	K2O	Potassium carbonate, by ton of K2O	kg	0.69	30%
Reagent	Chemical	KClO4	Potassium perchlorate, KClO4	kg	5.09	
Reagent	Chemical	KOH	Potassium hydroxide, KOH	kg	1.94	
Reagent	Chemical	MgO	Magnesium oxide, MgO	kg	1.06	
Reagent	Chemical	MgSO4	Magnesium sulphate, MgSO4	kg	0.30	
Reagent	Chemical	N	Nitrogen, liquid	kg	0.43	
Reagent	Chemical	Na2B4O7·10H2O	Borax, anhydrous, powder	kg	1.65	
Reagent	Chemical	Na2CO3	Sodium carbonate (caustic soda), 50%, Na2CO3	kg	0.59	50%
Reagent	Chemical	Na2Si3O7	Sodium silicate at 48%, Na2Si3O7	kg	0.71	0%
Reagent	Chemical	Na2SiO3	Sodium silicate, spray powder 80%, Na2SiO3	kg	1.64	
Reagent	Chemical	Na2SO4	Sodium sulphate, powder, Na2SO4	kg	0.47	
Reagent	Chemical	NaCl	Sodium chloride, powder, NaCl	kg	0.20	
Reagent	Chemical	NaClO	Sodium hypochlorite, 15% in H2O, NaClO	kg	0.92	
Reagent	Chemical	NaClO3	Sodium chlorate, powder, NaClO3	kg	3.23	
Reagent	Chemical	NaHCO3	Bicarbonate of soda, NaHCO3	kg	1.17	0%
Reagent	Chemical	NaHSO3	Sodium bisulfite, NaHSO3	kg	0.44	0%
Reagent	Chemical	NaOH	Soda, powder, NaOH	kg	0.46	
Reagent	Chemical	NaOH	Sodium hydroxide, 50% in H2O, production mix, NaOH	kg	1.12	
Reagent	Chemical	NH3	Ammonia, liquid, NH3	kg	2.11	
Reagent	Chemical	NH4Cl	Ammonium chloride, NH4Cl	kg	1.18	
Reagent	Chemical	NH4HCO3	Ammonium bicarbonate, NH4HCO3	kg	1.20	
Reagent	Chemical	NH4NO3	Ammonium nitrate (NH4NO3), by ton of nitrogen	kg	4.09	30%
Reagent	Chemical	O2	Oxygen, liquid	kg	0.41	
Reagent	Chemical	O3	Ozone, liquid	kg	8.01	
Reagent	Chemical	Organic	Lubricating oil	kg	1.07	
Reagent	Chemical	Organic	Palm oil	kg	2.93	
Reagent	Chemical	Organic	Soya oil	kg	1.70	
Reagent	Chemical	Other	Other chemical	kg	3.00	50%
Reagent	Chemical	Other	Soap	kg	1.75	
Reagent	Chemical	PCl3	Phosphorous chloride, PCl3	kg	3.39	
Reagent	Chemical	SF6	Sulphur hexafluoride, liquid, SF6	kg	120.00	
Reagent	Chemical	SO2	Sulphur dioxide, liquid, SO2	kg	0.44	
Reagent	Chemical	Solvent	White spirit	kg	0.95	
Reagent	Chemical	ZnO	Zinc oxide, ZnO	kg	2.91	
Reagent	Chemical	ZnS	Zinc sulphide, ZnS	kg	4.18	
Reagent	Chemical	ZrO2	Zirconium oxide, ZrO2	kg	4.05	

LCA- Life Cycle Assessment

$$mCO_{2eq} = m_{CO2} * 1 + m_{CH4} * EQ_{CH4} + m_{N2O} * EQ_{N2O} + \ldots$$

$GWP_{100years}$

AR = Assessment report IPCC
EQ = Equivalence

Substance	AR1 (1990)	AR2 (1995)	AR3 (2001)	AR4 (2007)	AR5 (2013)
Carbon dioxide, fossil (CO_2)	1	1	1	1	1
Methane, fossil (CH_4)	21	21	23	25	28
Methane, biogenic (CH_4)	18.25	18.25	20.25	22.25	25.25
Dinitrogen monoxide (N_2O)	290	310	296	298	265
HCFC-141b	440	-	700	725	782
HFC-134a	1200	1300	1300	1430	1300
HCFC-22	1500	-	1700	1810	1760
HCFC-142b	1600	-	2400	2310	1980
CFC-11	3500	-	4600	4750	4660
CFC-12	7300	-	10600	10900	10200
Sulfur hexafluoride	-	23900	22200	22800	23500

Landfill – direct emissions

Greenhouse Gas	100-Year Time Period				20-Year Time Period			
	AR4 2007	AR5 2014		AR6 2021	AR4 2007	AR5 2014		AR6 2021
	Feedback Not Included		*Feedback Included*		*Feedback Not Included*		*Feedback Included*	
CO_2	1	1	1	1	1	1	1	1
$CH_{4\ fossil\ origin}$	25	28	34	29.8	72	84	86	82.5
$CH_{4\ non\ fossil\ origin}$				27.2				80.8
N_2O	298	265	298	273	289	264	268	273

IPCC AR6

Landfill

Case study

Inputs and outputs

Chemicals, electricity, heat...

Wastewater, CO_2 emissions, CH_4 emissions, N_2O emissions.....

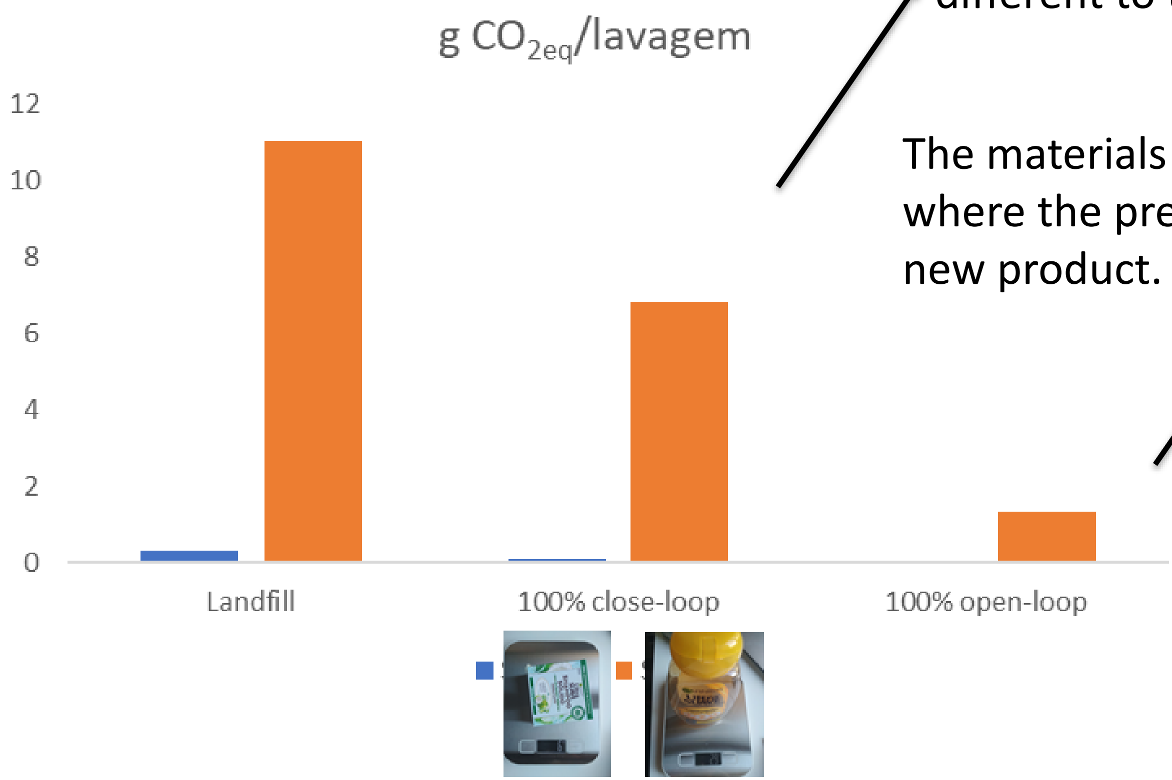
GHG emissions = Σ_i(input data$_i$ x emission factor$_i$)+Σ_i(by-products ouput data$_i$ x emission factor$_i$) - Σ_i(co-products ouput data$_i$ x emission factor$_i$)

If replace fossil based products

“avoid” its production

Global warming potential (GWP) = GHG emissions = CO_2e

Materiais embalagem (produção +fim de vida)



The materials are made from recycled content where the previous product was different to the current product.

The materials are made from recycled content where the previous product was the same as the new product.

LCA- Life Cycle Assessment

Materiais embalagem (produção +fim de vida)

+ uso de água na lavagem e tratamento de águas residuais

Não é um fator diferenciador…..é igual quer no shampoo sólido quer no liquido

Mas se o objetivo fôr responder à pergunta: Qual a pegada carbónica de lavar o cabelo?

Pode fazer sentido incluir

Case study

Uso de água: **por defeito 15 l agua/lavagem**

ETA

A | B | C | D | E | F | G | H | I | J | K

UK Government GHG Conversion Factors for Company Reporting

Water supply

Index

Company J multiplies the water used (cubic metres (m^3)) by the appropriate year's conversion factor called 'water supply' to produce its emissions.

Activity	Type	Unit	kg CO_2e
Water supply	Water supply	cubic metres	0.149
		million litres	149.0

For information about how the conversion factors have been derived, please refer to the Methodology paper' that accompanies the conversion factors.

ETAR

A | B | C | D | E | F | G

UK Government GHG Conversion Factors for Company Reporting

Water treatment

Index

Example of calculating emissions from water treatment

Company J report its emissions from mains water treatment, a Scope 3 emissions source. It gathers data from its utility bil

Company J multiplies the volume of water disposed of via the drains (in cubic metres (m^3)) by the appropriate year's conve

Activity	Type	Unit	kg CO_2e
Water treatment	Water treatment	cubic metres	0.272
		million litres	272.0

For information about how the conversion factors have been derived, please refer to the 'Methodology paper' that acco

... WTT- UK & overseas elec | WTT- heat and steam | Water supply | Water treatment | Material use

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Case study

Uso de água: **por defeito 15 l agua/lavagem**

ETA 15L*10^-6*149*10^3= 2.235 g CO_{2eq}

ETAR 15L*10^-6*272*10^3= 4.08 g CO_{2eq}

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+ 6.3 g CO_2eq

LCA- Life Cycle Assessment

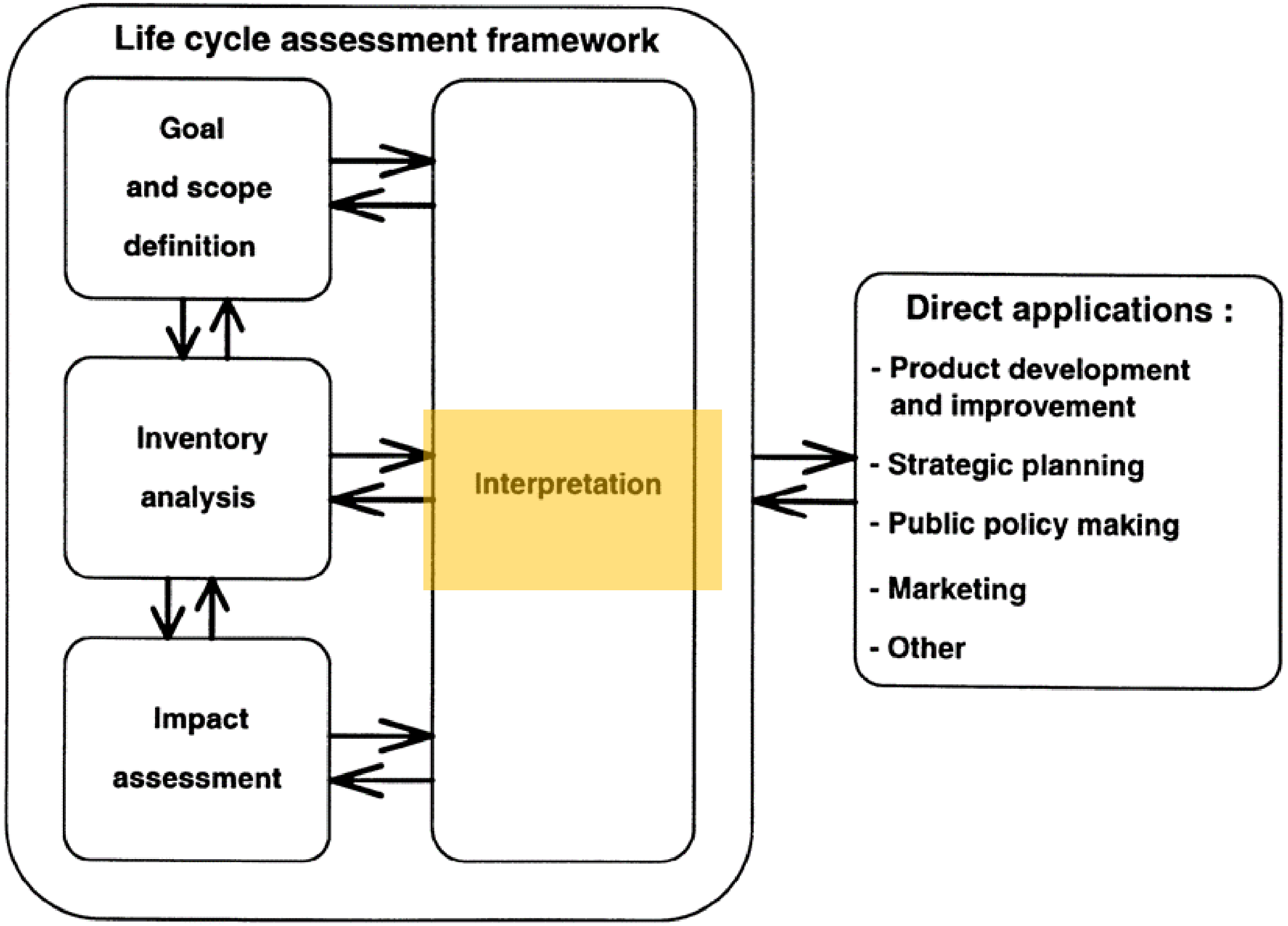


Figure 1 : Phases of an LCA

LCA- Life Cycle Assessment

Interpretation

Takes the form of conclusions and recommendations

Identify significant issues with:

- Inventory data
- Impact categories
- Significant contributions from life cycle stages

Include information on:

- Assembled findings from LCI and LCIA
- Methodologies used
- Value choices
- Limitations
- Roles of interested parties in compilation and review

Consider the following that may be critically reviewed:

- Completeness check
- Sensitivity check
- Consistency check

Interpretation

Critical Review

*Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment**

Done by an independent third party

Defined in the scope

Required if comparative and disclosed to the public

All LCA phases might be critically reviewed, with the exception of the goal

Answers the questions in the following slide

Interpretation

A embalagem de plástico é pior que a embalagem de cartão do ponto de vista de uma análise cradle-to-grave e cradle-to-cradle, categoria de impacte ambinetal GWP100 (potencial de aquecimento global a 100 anos). A reciclagem é preferível a aterro.

Limitações do estudo: transporte não incluido, uso não incluido, quimicos não incluidos, infraestrutura não incluida

LCA- Life Cycle Assessment

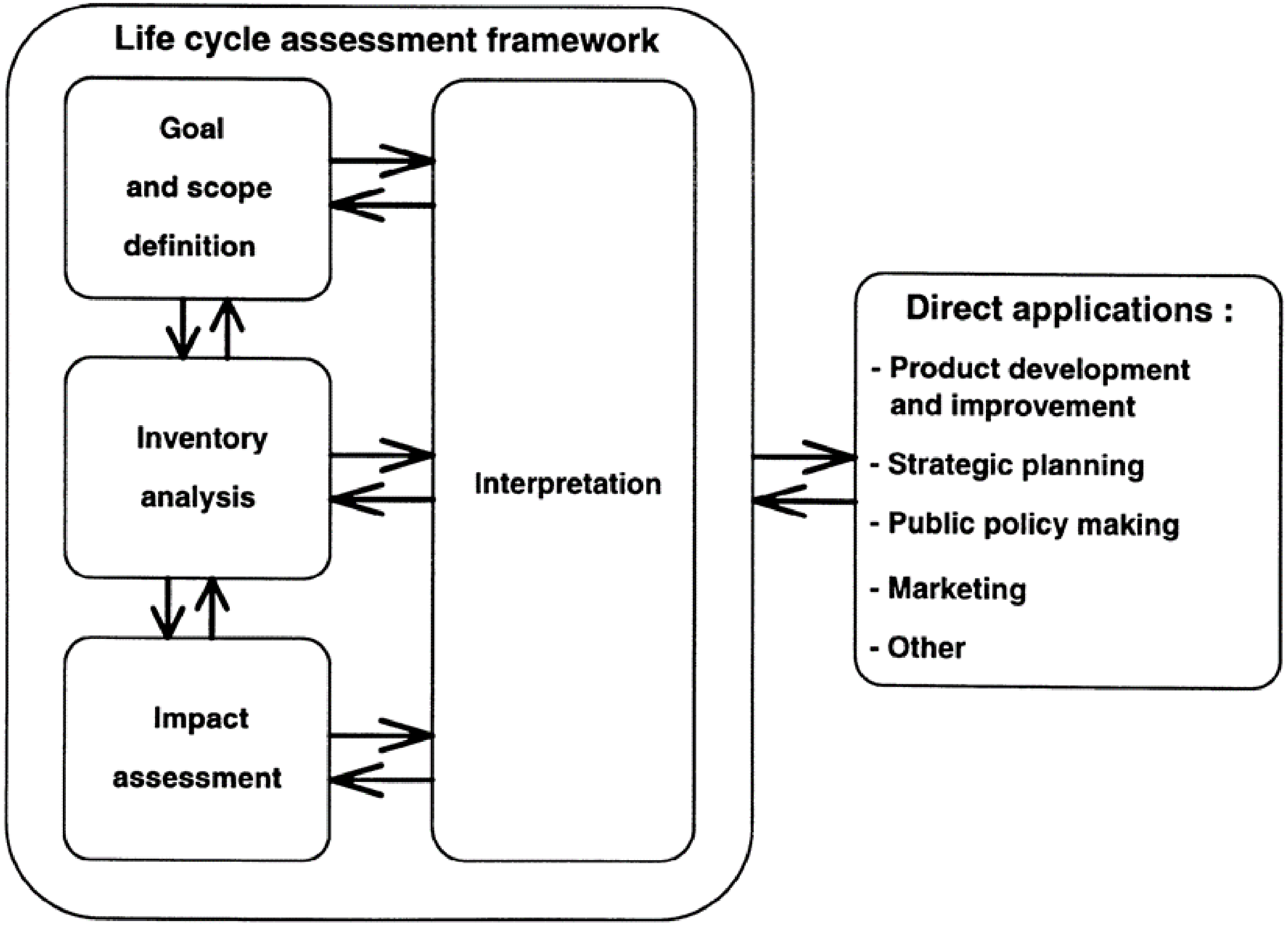
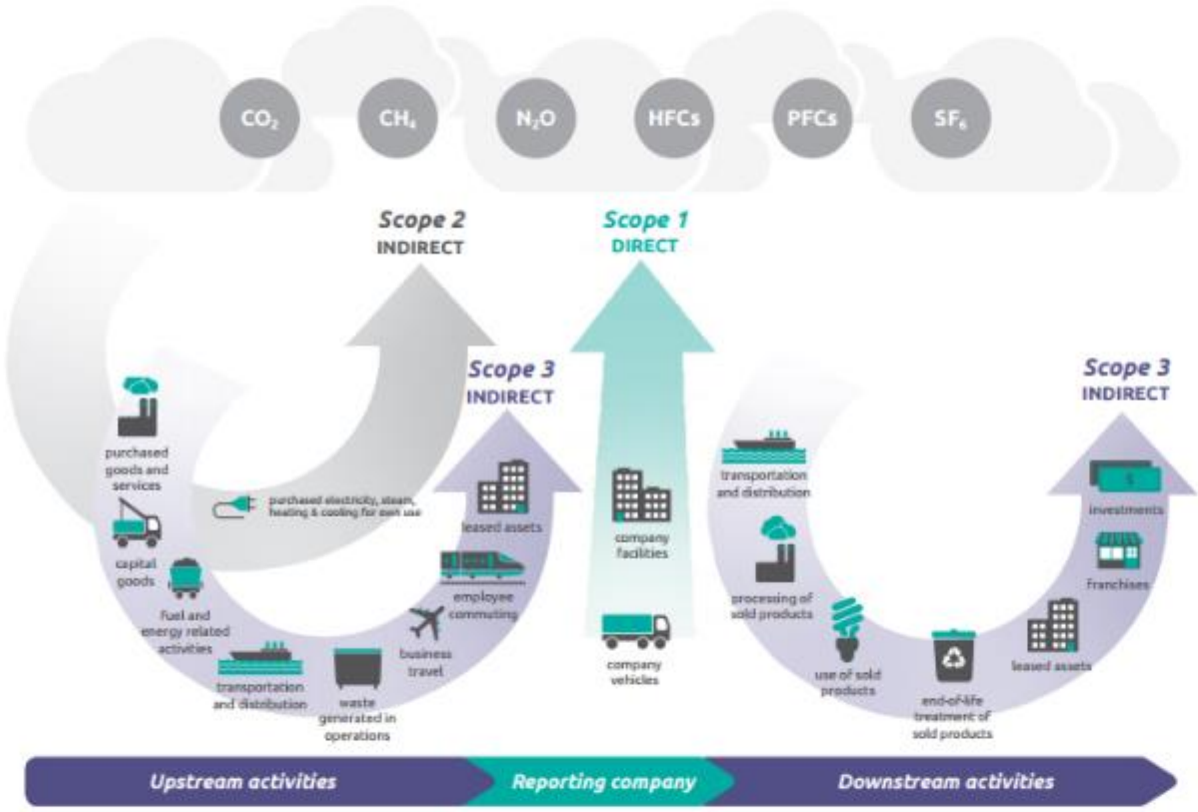


Figure 1 : Phases of an LCA

LCA- Life Cycle Assessment



Based on LCA but specific for one environmental impact that is **climate change – GWP 100 – CO_2e**

EXEMPLO ACV (análise do Ciclo de vida)

LCA- Life Cycle Assessment

Aluminium cap 1 g

The plastic of the bottles HDPE

The plastic sleeve covering the bottles 1 g PET

The weight of the bottle has been halved since its launch: from 11 g of HDPE in 1992 to 6 g in 2007 and 5.35 g in 2021

The cardboard around the 8 bottles pack weights 60 g

ECO-DESIGN

LC

MATREC
Sustainable Materials & Trends

ABOUT US CONSULTING PROJECTS MATREC LAB

MORE SUSTAINABLE PACKAGING FOR ACTIMEL

Reducing environmental impact, encouraging recycling and reducing CO2 emissions.
These are the goals achieved by the team of experts at Actimel, a Danone brand, which has been implementing **eco-design strategies** for years to **improve the environmental performance** of its packaging.
The latest innovation sees the elimination of the graphic label that used to cover the bottles, transferring all useful information onto the primary packaging.
This improvement, under optimal sorting and recycling conditions where the aluminium cap and bottle are disposed of separately, allows a **recycling rate** of 99% according to Cyclos – HTTP, Institute for Recycling and Product Stewardship.
The new Actimel bottle was first launched in 2022 in Germany and Belgium and will be marketed in all European countries from 2023, saving 857 tonnes of plastic.

Source and image: actimel.it

RECYCLING RATE 99% (OPTIMAL disposal and sorting)

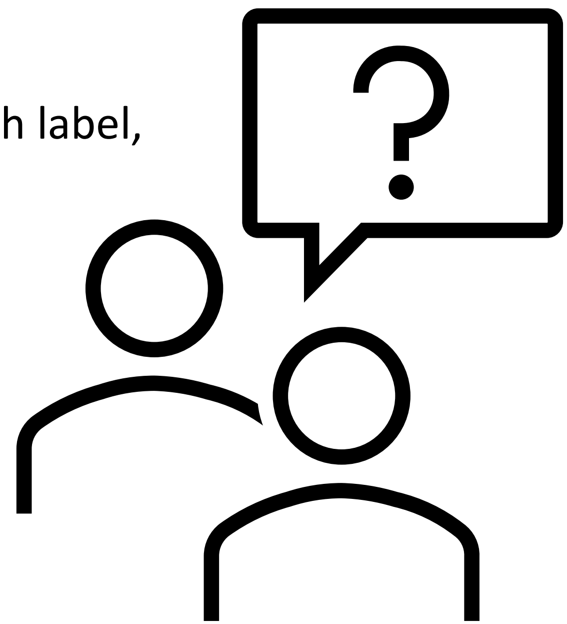
ECO-DESIGN STRATEGY (easing sorting)

Exercise 4 -LCA- Life Cycle Assessment

i) Estimate the **GWP 100** of the system of producing virgin 8 pack Danone Actimel original package in 1992;

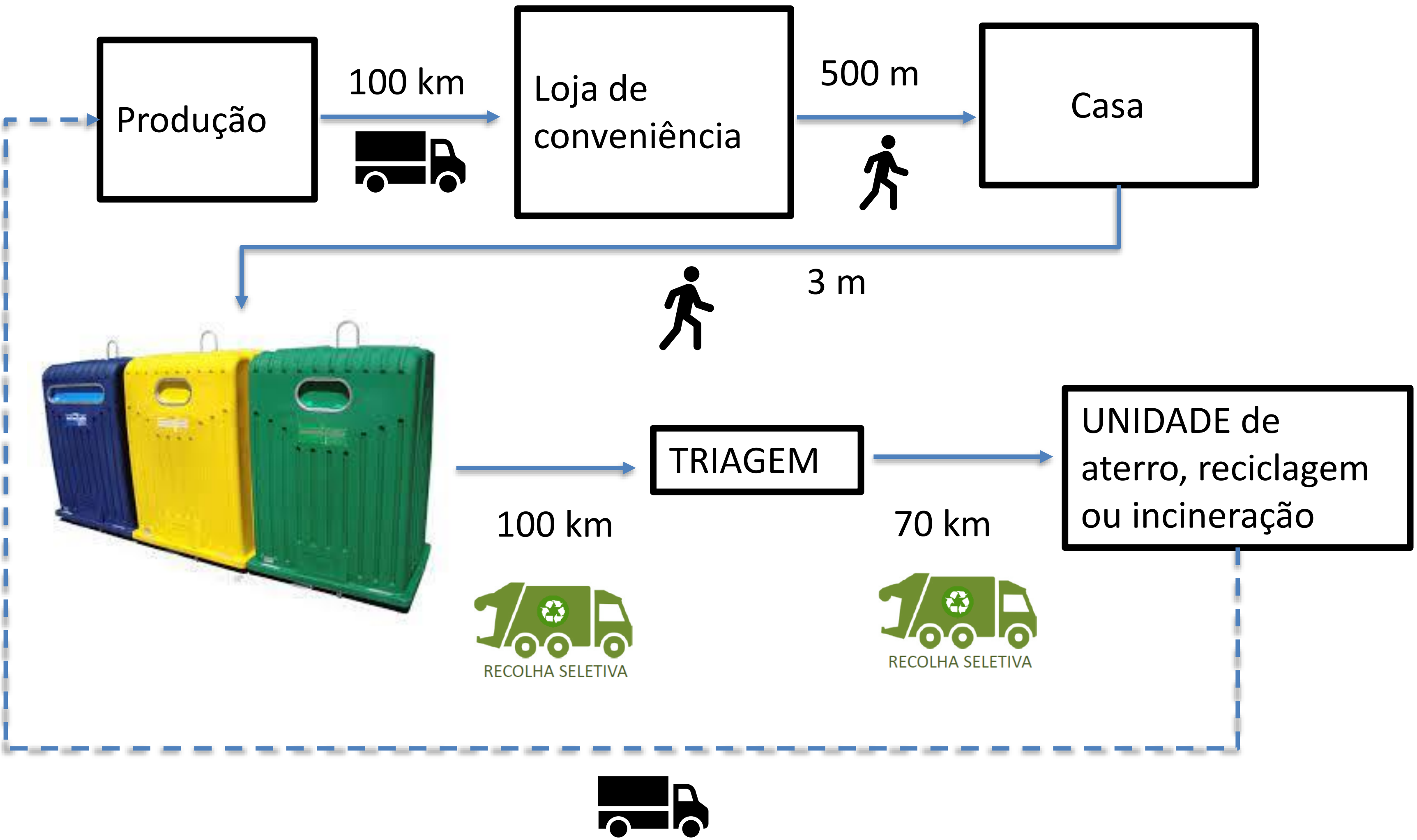
ii) Compare GWP of 8 pack Danone Actimel virgin with 8 pack Danone Actimel with recycled material included of 60% HDPE, 30% PET, 100% cap, 100% cardboard;

iii) Compare the GHG savings of 8 pack Danone Actimel,with label, against non-label (new bottles)



LCA- Life Cycle Assessment

Cradle-to-Cradle (reciclagem), Cradle-to- Grave (landfill, incineração)



WASTE MANAGEMENT

Goal and Scope:

Evaluate the global warming impact of a “8 pack dadone actimel” by impact category Climate change, using GWP100 years in CO_2eq/FU

Boundary: production (cradle-to-gate);

Boundary: production, distribution, storage, collection and use (cradle-to-use);
Boundary: production, distribution, storage, use, waste collection and sorting Cradle-to-Sorting
Boundary: production, distribution, use and end-of-life (cradle-to-grave).

Inventory: Boundary: production, distribution, use and end-of-life (cradle-to-grave). Para um 8-pack 100% material virgem, 1992

etapa	Input	Quantidade
Produção (embalamento)	Aluminio Cartão HDPE PET	8 g 60 g 88 g 8 g
Distribuição	Carga*km = (8+60+88+8)*10^-6*100	0.02 tkm
Loja	Eletricidade refrigeração	1 W/L
Casa	Eletricidade refrigeração	1 W/L
Recolha	Carga	0.02 tkm
Triagem	Yay, A.S.E. Application of life cycle assessment (LCA) for municipal solid waste management: A case study of Sakarya. J. Clean. Prod. 2015, 94, 284–293	0.059 kWh/ton
Aterro	8-pack	164 kg
Incineração	8-pack	164 kg
reciclagem	AL HDPE PET Cartão	MJ

WASTE MANAGEMENT

Inventory: fatores de emissão

	Fator	Referência
Aluminio virgem Cartão virgem HDPE virgem PET virgem	9.1 kg CO_2e /kg 0.87 kg CO_2e /kg 3.3 kg CO_2e /kg 4.0 kg CO_2e /kg	UK DEFRA
Aluminio reciclado Cartão reciclado HDPE reciclado PET reciclado	0.99 kg CO_2e /kg 0.72 kg CO_2e /kg 2.4 kg CO_2e /kg 3.1 kg CO_2e /kg	UK DEFRA
	0.12 kg CO_2/tkm	UK DEFRA
	0.241 kgCO_2e/tkm	UK DEFRA
Eletricidade	519 gCO_2/kWh(@1990)	https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-14/#tab-googlechartid_chart_41
Gás natural	56 g CO_2e/MJ	UK DEFRA
Gasóleo	2.7 kg CO_2/L ou 75 g CO_2e/MJ	UK DEFRA (mineral diesel)

LCA- Life Cycle Assessment

0.241 g CO_2e/tkm

0.12 kg CO_2/tkm

0 g CO_2e/tkm

LCA- Life Cycle Assessment

e.g. produção embalagem virgem:

Aluminio	**8 g**
Cartão	**60 g**
HDPE	**88 g**
PET	**8 g**

8*10^-3 kg* 9.1 kg CO_2e /kg = 0.0728 kg CO_2e
60*10^-3 kg* 0.87 kg CO_2e /kg =0.0522 kg CO_2e
88*10^-3 kg* 3.3 kg CO_2e /kg =0.2904 kg CO_2e
8*10^-3 * 4.0 kg CO_2e /kg = 0.032 kg CO_2e

447 g CO_2e

LCA- Life Cycle Assessment

e.g. transporte do 8-pack para a loja:

Carga*km = (8+60+88+8)*10^-6*100 = 0.02 t.km

0.02 t.km x 0.241 kgCO_2e/tkm = **4.8 g CO_2e**

e.g. conservação do 8-pack na loja durante 15 dias:

1 W/L * 8*94*10^-3 L* 24h * 15 = 270.72 Wh ,
270.72/1000 kWh * 519 gCO_2/kWh(@1990) = **140 g CO_2e**

LCA- Life Cycle Assessment

e.g. conservação do 8-pack em casa durante 3 dias:

1 W/L * 8*94*10^-3 L* 24h * 3 = 54 Wh ,
54/1000 kWh * 519 gCO_2/kWh(@1990) = **28 g CO_2e**

e.g. transporte do 8-pack para triagem:

Carga*km = (8+60+88+8)*10^-6*100 = 0.02 t.km

0.02 t.km x 0.12 $kgCO_2$e/tkm = **2.4 g CO_2e**

e.g. triagem:

0.059 kWh/ton * 519 gCO_2/kWh(@1990) * (8+60+88+8)*10^-6 ton = **0.005 g CO_2e**

LCA- Life Cycle Assessment

IDENTIFICAÇÃO DO QUE CONTRIBUI MAIS PARA A PEGADA CARBÓNICA….

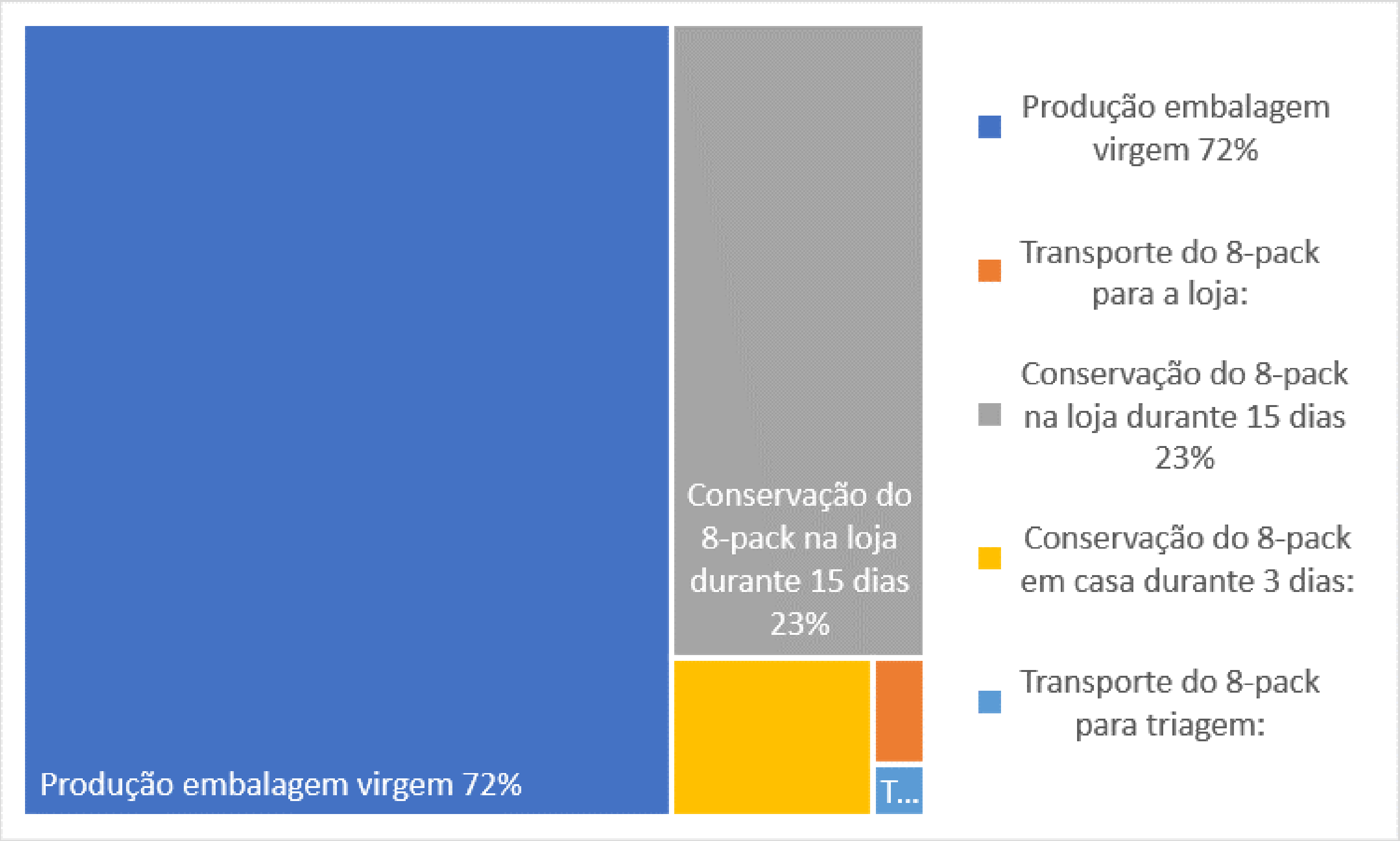
“HOTSPOT”,
QUAL O PROCESSO QUE CONTRIBUI MAIS,
QUAL O INPUT DESSE PROCESSO QUE CONTRIBUI MAIS??

ONDE SE PODE ATUAR PARA BAIXAR IMPACTO??

LCA- Life Cycle Assessment

IDENTIFICAÇÃO DO QUE CONTRIBUI MAIS PARA A PEGADA CARBÓNICA….

"HOTSPOT"



LCA- Life Cycle Assessment

IDENTIFICAÇÃO DO QUE CONTRIBUI MAIS PARA A PEGADA CARBÓNICA….

“HOTSPOT”,
QUAL O PROCESSO QUE CONTRIBUI MAIS,
QUAL O INPUT DESSE PROCESSO QUE CONTRIBUI MAIS??

ONDE SE PODE ATUAR PARA BAIXAR IMPACTO??

Nas etapas consideradas o hotspot seria a produção com materiais virgens e a refrigeração

Propor soluções:
Usar mais reciclagem incorporada e usar mais renováveis isto é diminuir o fator de emissão eletricidade e aumentar eficiencia do frigorifico

LCA- Life Cycle Assessment – GHG protocol

Conceitos LCA – ISO 14040, 14044, GHG protocol

LCA- Life Cycle Assessment – GHG protocol

Q1-What is the first step of the LCA data collection procedure?/ Qual deve ser o primeiro passo de uma ACV antes de iniciar o procedimento de recolha de dados?

a) Refine system boundary/ Refinar a fronteira do sistema

b) Consider the goal and scope/ Considerar o objetivo e o âmbito

c) Collect data/ Recolher dados

LCA- Life Cycle Assessment – GHG protocol

Q2-What is the difference between ISO 14040 and ISO 14044?/Qual a diferença entre a ISO 14040 e a ISO 14044?

a) ISO 14044 is the updated version of ISO 14040/ A ISO 14044 é uma versão atualizada da ISO14040

b) ISO 14040 describes life cycle assessment procedures, while ISO 14044 is an example of a life cycle assessment/ ISO 14040 descreve os procedimentos da ACV, enquanto que a ISO 14044 é um exemplo de uma ACV

c) ISO 14040 is the general introduction to life cycle assessment concepts and procedures, while ISO 14044 includes more details about the procedures/ A ISO é uma descrição introdutória geral de uma ACV e a ISO14044 inclui mais detalhes

LCA- Life Cycle Assessment – GHG protocol

Which of these is an optional element of the LCIA phase?/ Qual destes é um element opcional no cálculo dos impactes ambientais?

a) Grouping/ Agrupamento de impactes

b) Characterization/ caracterização de impactes

c) Classification/ Classificação de impactes

d) None of the above/ nada é opcional

LCA- Life Cycle Assessment – GHG protocol

Can the Goal and Scope be updated after completing the LCI stage?/ O Objetivo e âmbito podem ser alterados depois de reunir o inventário?

a) No, it must be left as originally written/ Não, tem de ser deixado como definido originalmente

b) Yes, but it should be avoided if possible / Sim, mas deve ser evitado

c) Yes, this type of iterative process is encouraged and can strengthen results/ Sim este tipo de processo iterative é encorajado e pode melhorar os resultados obtidos

LCA- Life Cycle Assessment – GHG protocol

What is the difference between LCA and GHG protocol?/Qual é a diferença entre uma ACV e o protocol de gases com efeito de estufa?

a) São a mesma coisa

b) O GHG protocol é uma ACV em que a categoria de impacte Ambiental são só as alterações climáticas agrupando emissões diretas e indiretas

c) O GHG protocol é uma ACV em que as emissões diretas e indiretas estão agrupadas por âmbito 1, 2 e 3 em que a categoria de impacte Ambiental são só as alterações climáticas, relativas ao potencial de aquecimento global a 100 anos (GWP100) em kg CO_2e

Challenge #3 – GHG protocol, LCA, Climate change

1- Given the following input/output from a Waste Management enterprise

Fig 1

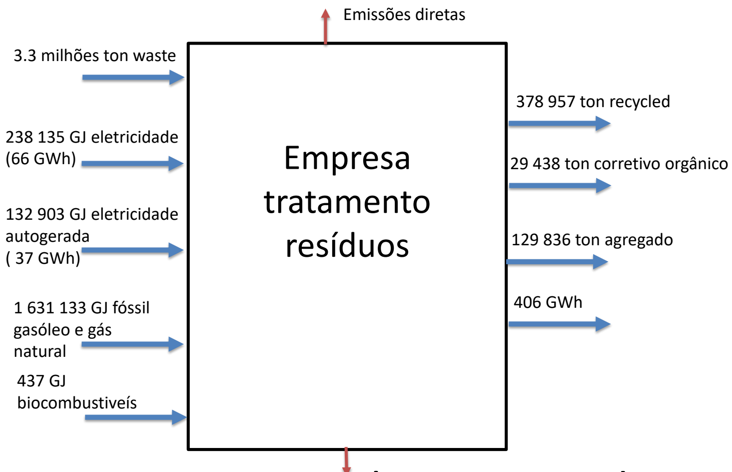
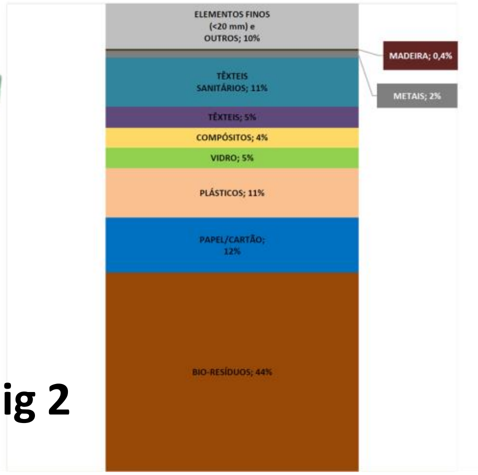


Fig 2



i) Compute GHG protocol Scope 1 and scope 2 emissions, method location based, year 2022.

ii) Compare with Mota Engil GRI/Greenhouse protocol scope 1 and scope 2 and discuss. https://www.mota-engil.com/wp-content/uploads/2023/07/TabGRI22_PT.pdf

iii) Compare direct emissions with total Portuguese emissions in 2022 and comment. (https://ourworldindata.org/greenhouse-gas-emissions or **NATIONAL INVENTORY REPORT 2021 PORTUGAL**).

iv) If the 2035 PERSU target was accomplished repeat ii).

Challenge #3 – GHG protocol, LCA, Climate change

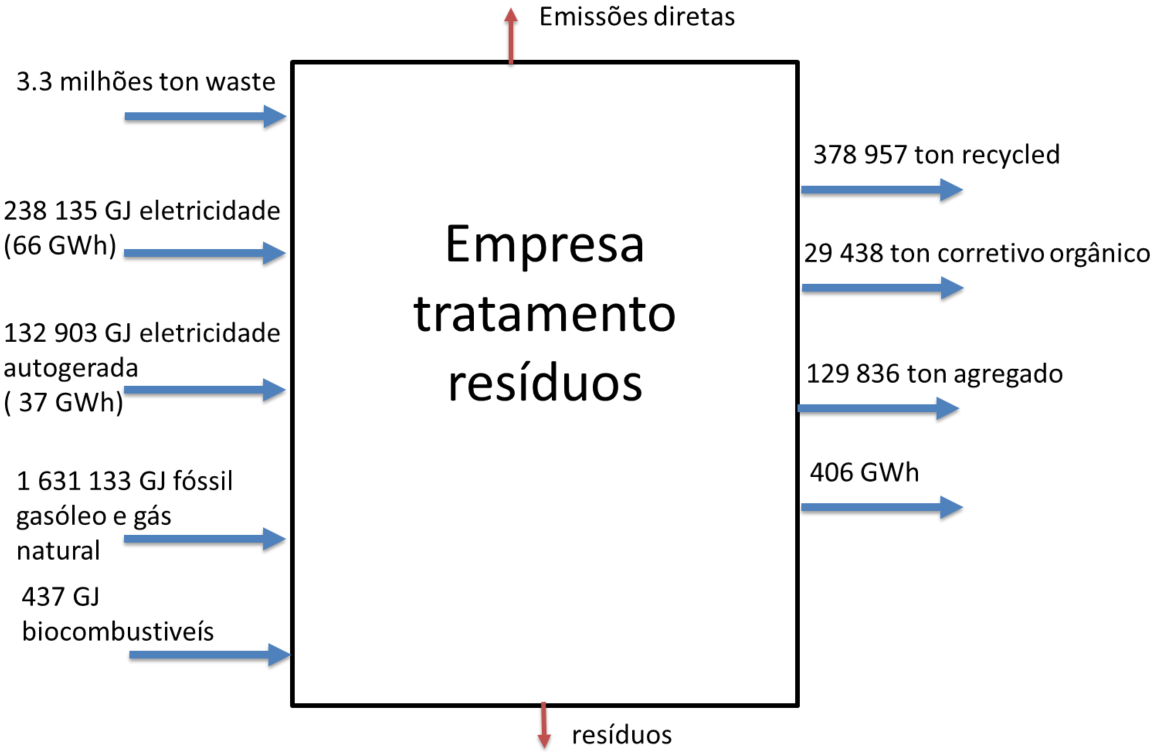


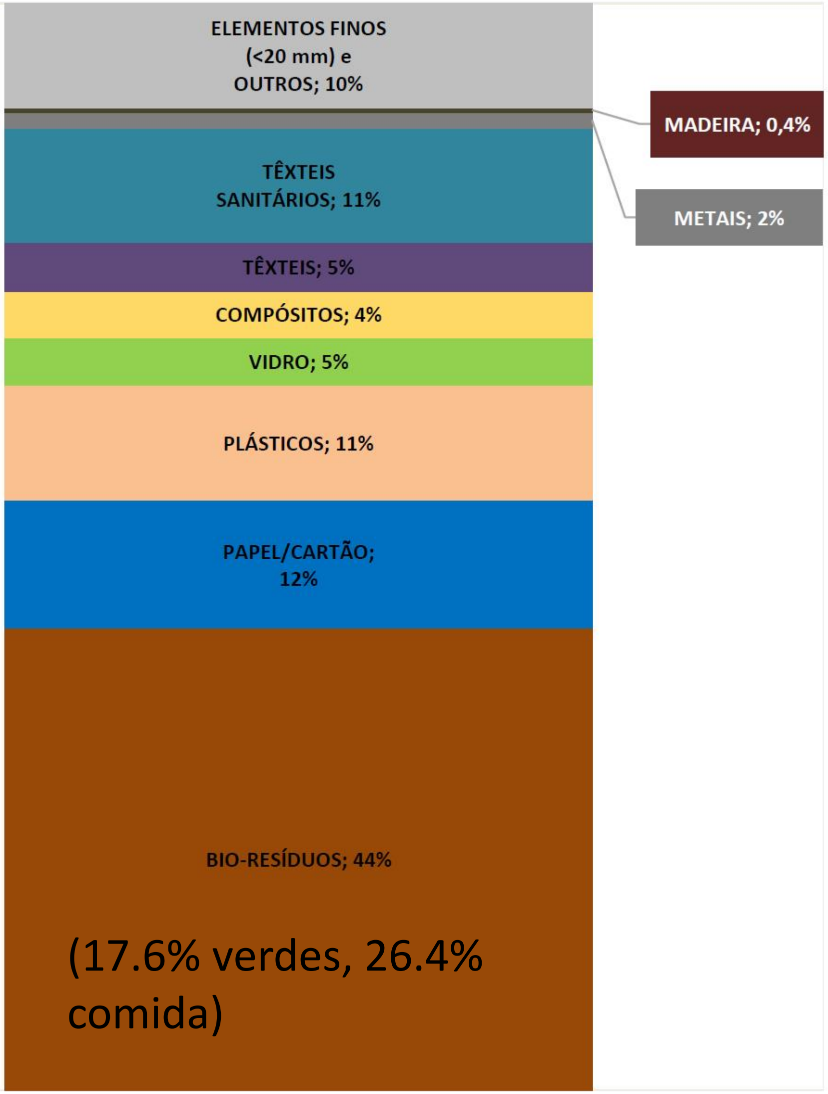
Fig 1

Assumir que a eletricidade consumida de fornecedor externo tem fator de emissão *location based*, o consumo de combustíveis fósseis tem um fator de emissão associado e está relacionado com queima, libertando maioritariamente CO_2

50% dos resíduos são lixo indifirenciado com a composição da figura seguinte e vão para aterro sem aproveitamento energético.

Challenge #3 – GHG protocol, LCA, Climate change

Fig 2



Gás natural	56 g CO_2e/MJ	UK DEFRA
Gasóleo	2.7 kg CO_2/L ou 75 g CO_2e/MJ	UK DEFRA (mineral diesel)

Challenge #3 – GHG protocol, LCA, climate change

2-

i) Estimate the GWP 100 of the system of producing virgin 8 pack Danone Actimel original package in 2021;

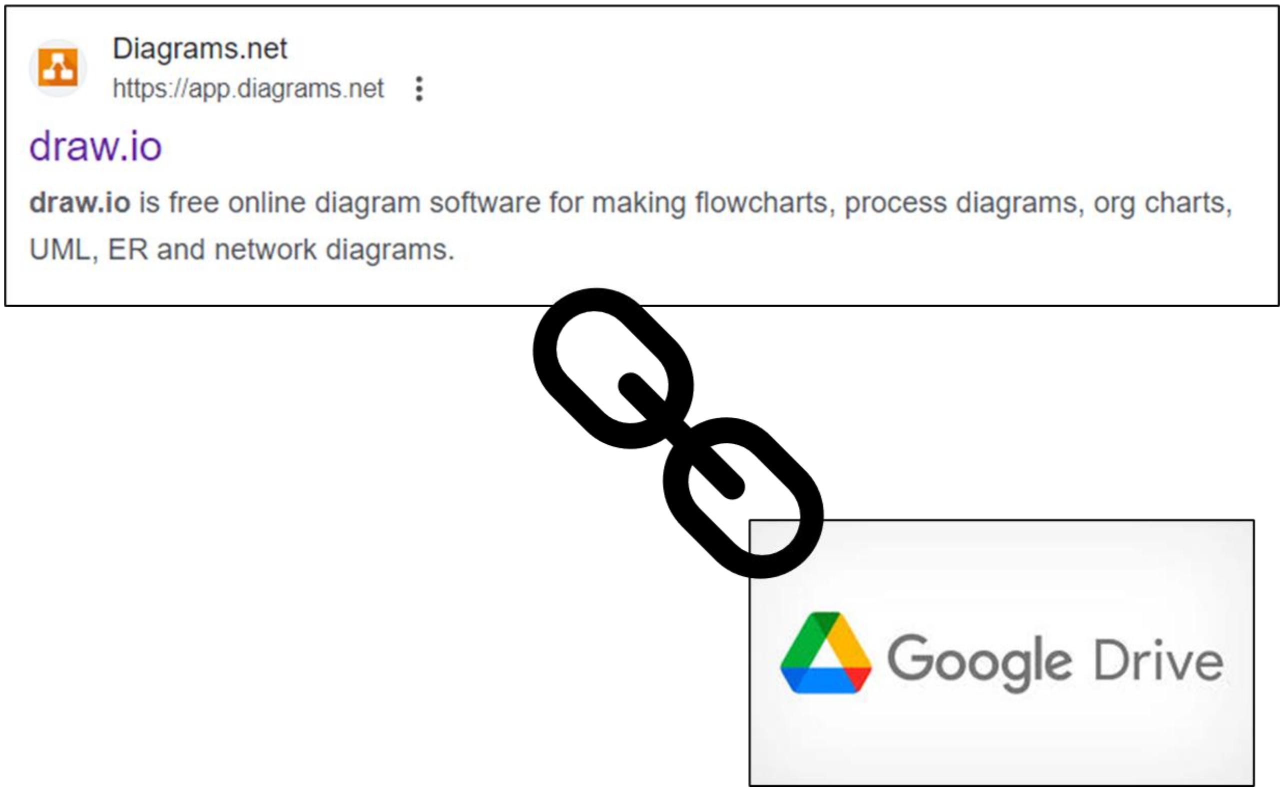
ii) Compare the GHG savings of 8 pack Danone Actimel in 2021,with label, against non-label (new bottles).

Don't forget to:

Define Goal & Scope with a process scheme (draw.io) and functional unit;
Build an inventory;
Calculate the impact assessment;
Interpret/conclude

Process input/output

Deliver: Deliver draw.io file with process scheme, pdf/excel until 15 december



Thanks

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