Introduction to Life Cycle Assessment

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LIST OF CONTENTS

1 The context: sustainable development

2 How to measure sustainability?

3 Life Cycle Assessment methodology

4 Additional key concept

5 Take home message

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SUSTAINABLE DEVELOPMENT

«Development that meets the needs of the present without compromising the ability of future generations to meet their own needs»

Brundtland Conference, 1987

1 Sustainability in R&D phases

2 Sustainable products / processes

3 Sustainable development

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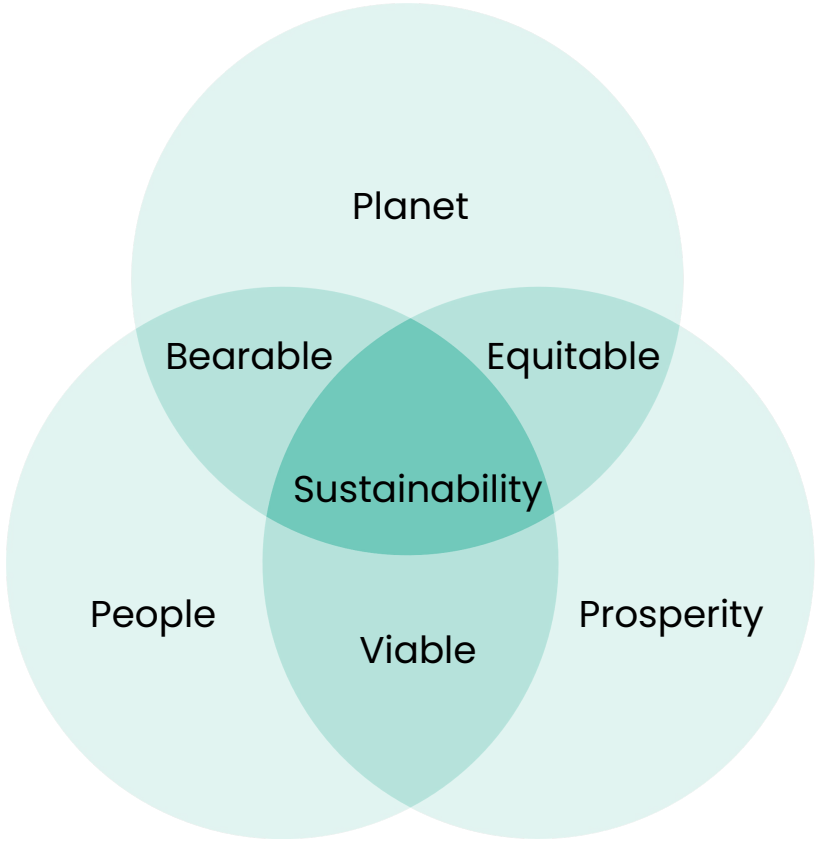
SUSTAINABLE DEVELOPMENT



The concept of sustainability is therefore extended not only to the **environmental** dimension, but also to the **economic and social** one, that define the **3 pillars** of sustainability.

This implies a **holistic approach** in the sustainability assessment challenge

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SUSTAINABLE DEVELOPMENT

On September 25, 2015, 193 ONU member countries adopted the **Agenda 2030** for Sustainable Development, which serves as a global strategy for a transition to a better and more equitable future for all.

Source: https://www.un.org/sustainabledevelopment/
The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States.

The Agenda 2030 recognizes the close link between human well-being, the health of natural systems and the presence of common challenges for all countries.

From these challenges are defined the **17 Sustainable Development Goals (SDGs)** declined into 169 targets.

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SUSTAINABLE DEVELOPMENT

The Sustainable Development Goals aim to address a wide range of economic and social development issues, which include **poverty, hunger, the right to health and education, access to water and energy, jobs, inclusive and sustainable economic growth, climate change and environmental protection, urbanization, production and consumption patterns, social and gender equality, justice and peace.**

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Sustainability: Can we measure it?

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HOW TO MEASURE SUSTAINABILITY?

To **measure** are necessary:

1
Unit of measurement

2
Measuring tool

3
Procedure
(measurement method)

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HOW TO MEASURE SUSTAINABILITY?

To **measure** are necessary:

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Unit of measurement

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Measuring tool

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Procedure
(measurement method)

Life Cycle Thinking

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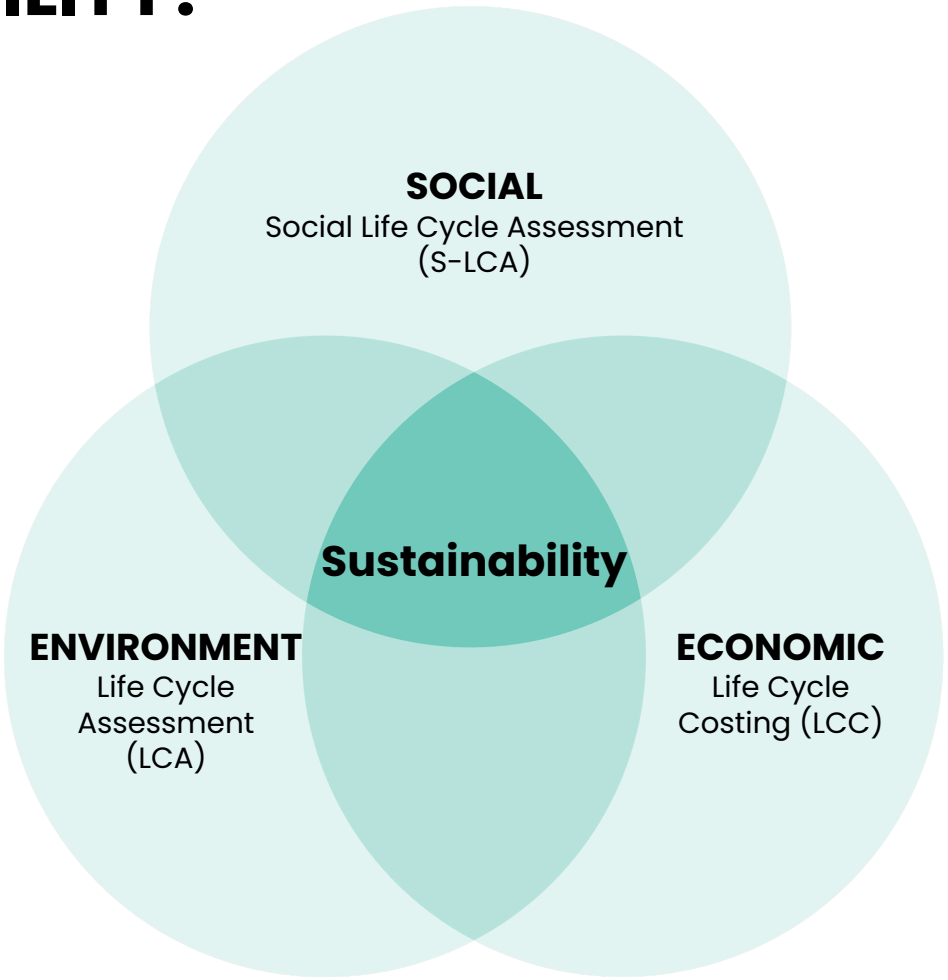
HOW TO MEASURE SUSTAINABILITY?

Life Cycle Thinking

is a **holistic methodological approach to define the sustainability of a product/service** that requires moving beyond the traditional focus on the production phase and related manufacturing processes with the intent to **include all environmental, social and economic impacts generated throughout the entire life cycle**.



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HOW TO MEASURE SUSTAINABILITY?

Environmental impacts:

- Life Cycle Assessment – **LCA**, ISO 14040-44
- Carbon footprint – **CFP**, ISO 14067

Economic:

- Life Cycle Costing - **LCC**

Social:

- Social Life Cycle Assessment – **S-LCA,** ISO 14075

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LCA METHODOLOGY

LCA allows to evaluate the **environmental impacts** of a product, process or service through every single stage of their life cycle.

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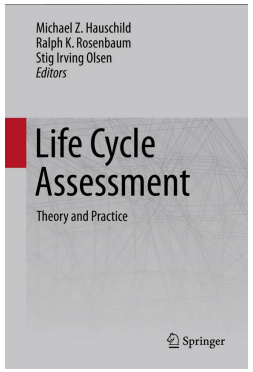
LCA METHODOLOGY

LCA allows to evaluate the **environmental impacts** of a product, process or service through every single stage of their life cycle.

ISO STANDARDS

LCA analysis is performed in accordance to specific ISO standards:

- **ISO 14040:2006** - Principles and framework
- **ISO 14044:2006** - Requirements and guidelines



Hauschild, M.Z., Rosenbaum, R.K., Olsen, S.I. (Eds.), 2018. Life Cycle Assessment: Theory and Practice. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-56475-3

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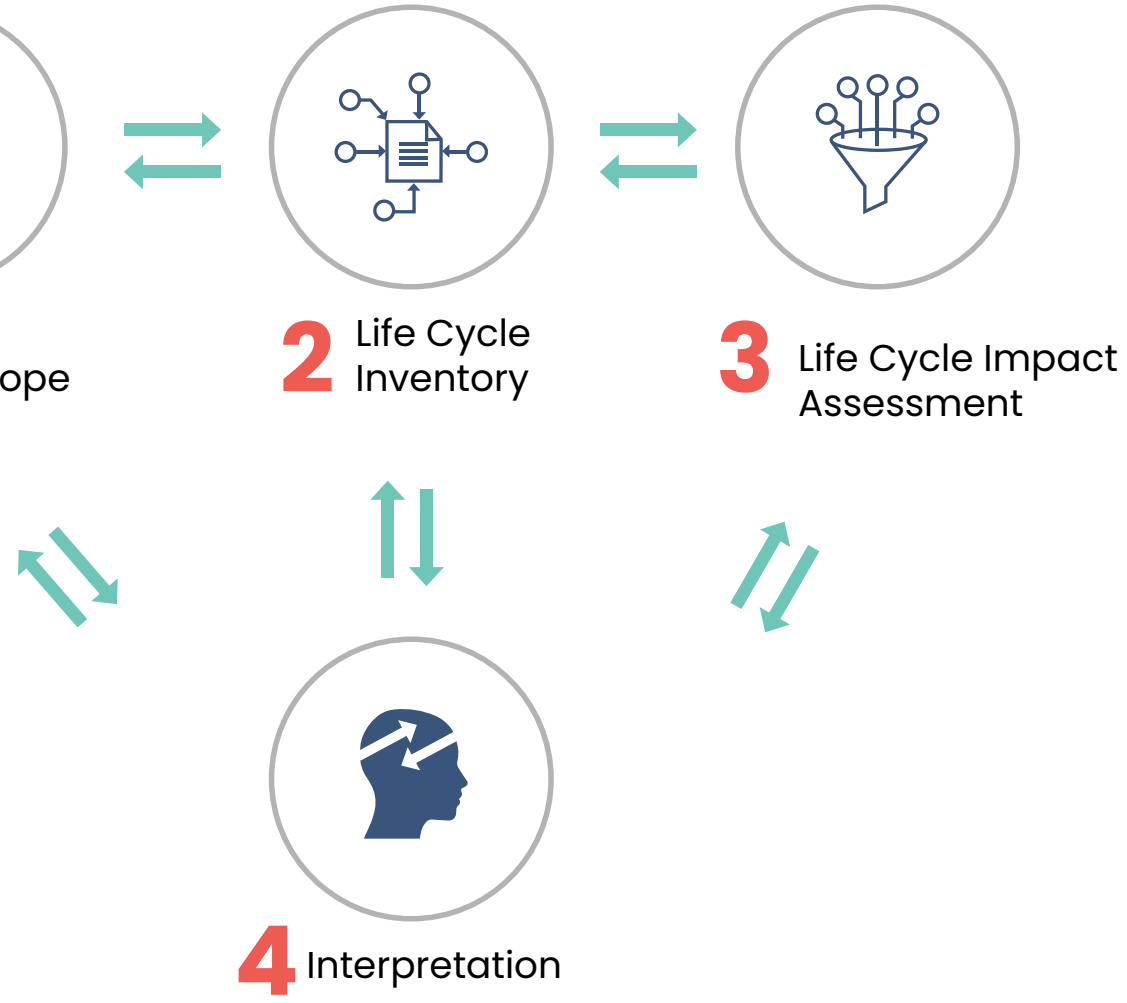
LCA METHODOLOGY

THE METHODOLOGY
LCA analysis must be conducted in **4 phases**:



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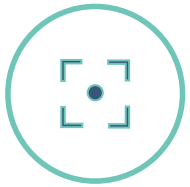
LCA METHODOLOGY



GOAL AND SCOPE

To be defined:

- The **reason** why we are performing LCA
- Intended audience
- The reference unit that we analyse called **FUNCTIONAL UNIT**
- The **system boundary** of the analysis
- Assumptions, exclusions and justification

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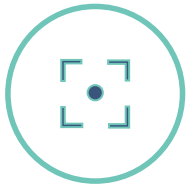
LCA METHODOLOGY



GOAL AND SCOPE

FUNCTIONAL UNIT:
is a quantified description of the performance requirements that the **“product system”** fulfils.

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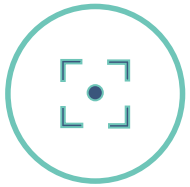
LCA METHODOLOGY



GOAL AND SCOPE

FUNCTIONAL UNIT:
is a quantified description of the performance requirements that the **“product system”** fulfils.

- Product
- Process
- Service

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LCA METHODOLOGY

GOAL AND SCOPE

FUNCTIONAL UNIT: example for **shopping bags**

Aspect	Example
"**What**" (function(s) or service(s) provided)	Carrying of shopping from supermarket to home
"**How much**" (extent of the function or service provided)	An average volume of 22 litres and an average weight of 12kg of purchased goods
"**How well**" (expected level of quality of the function or service)	Without tearing, puncturing and excessively deforming during the shopping trips
"**How long**" (duration of the function or service/product lifetime)	A minimum of 10 times/trips
"**Where**" (location/geography of the function or service)	In the entire EU-28 market
"**For whom**" (beneficiary of the function or service)	By the entirety of consumers

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LCA METHODOLOGY

GOAL AND SCOPE

TECHNICAL (or declared) UNIT:

- a glass bottle of 1l volume
- 100 g of CuO NPs
- 1 h of membrane filtration process at speed of 1 m^3 / min

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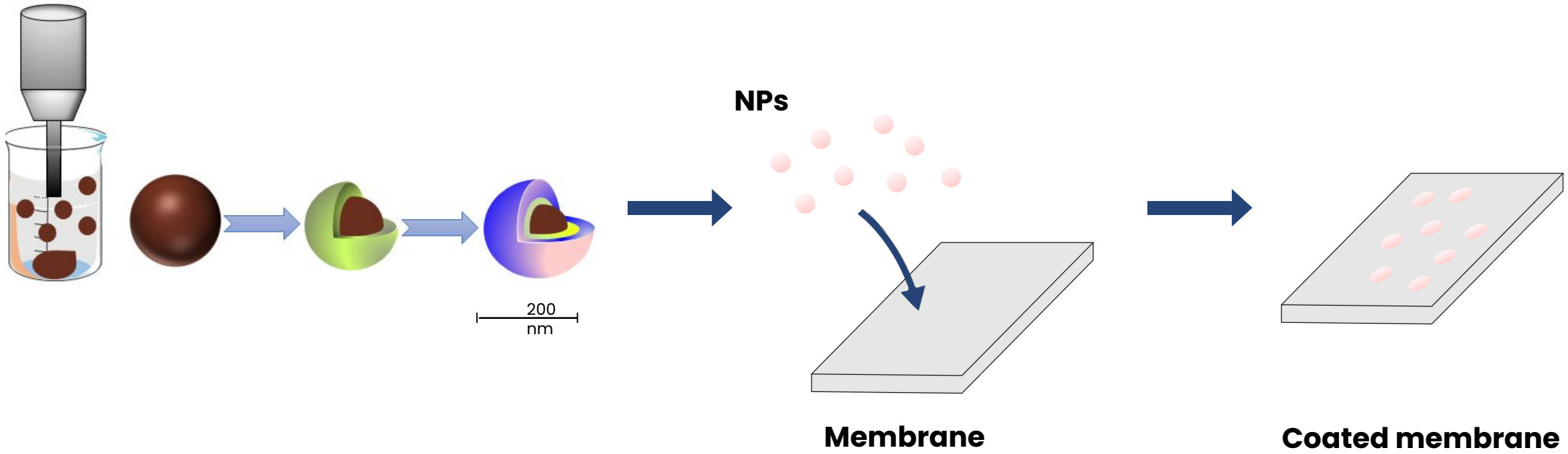
LCA METHODOLOGY

GOAL AND SCOPE

Process scheme - Flow charts
(example: production of a water filtration membrane coated with NPs)



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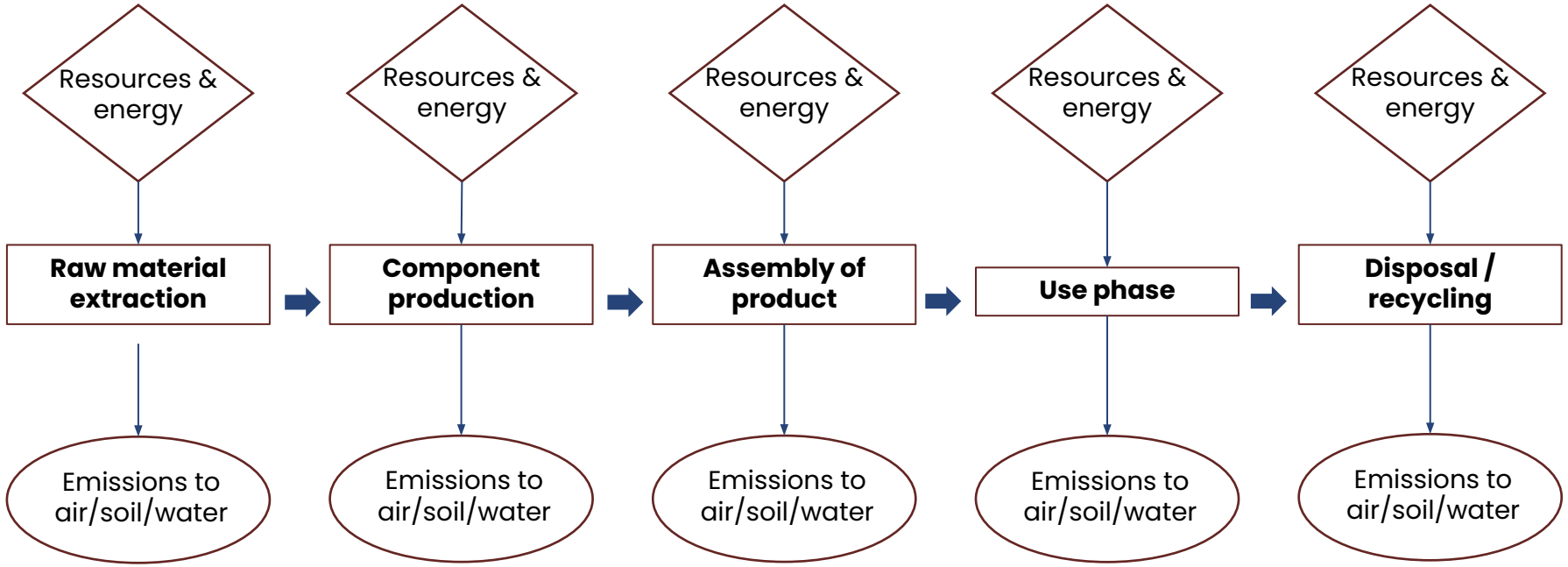
LCA METHODOLOGY

GOAL AND SCOPE

System boundary



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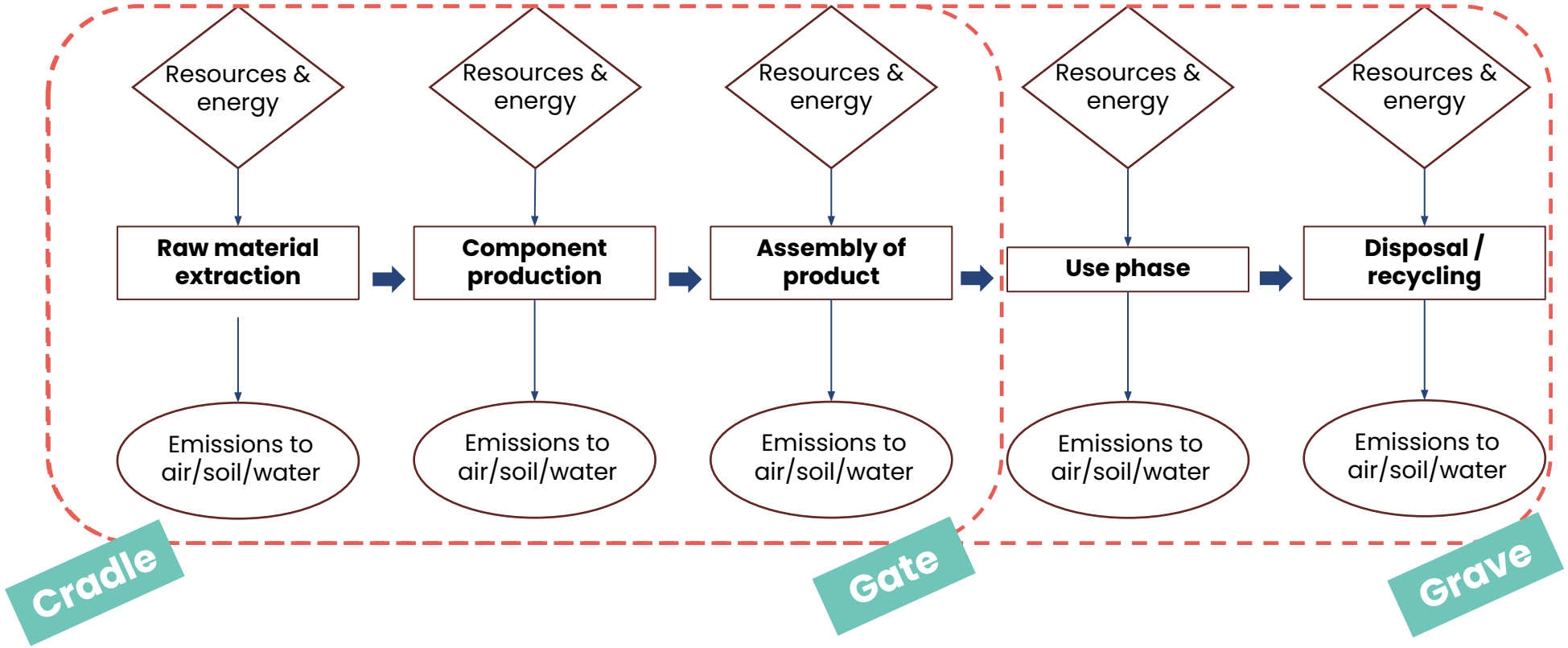
LCA METHODOLOGY

GOAL AND SCOPE

System boundary



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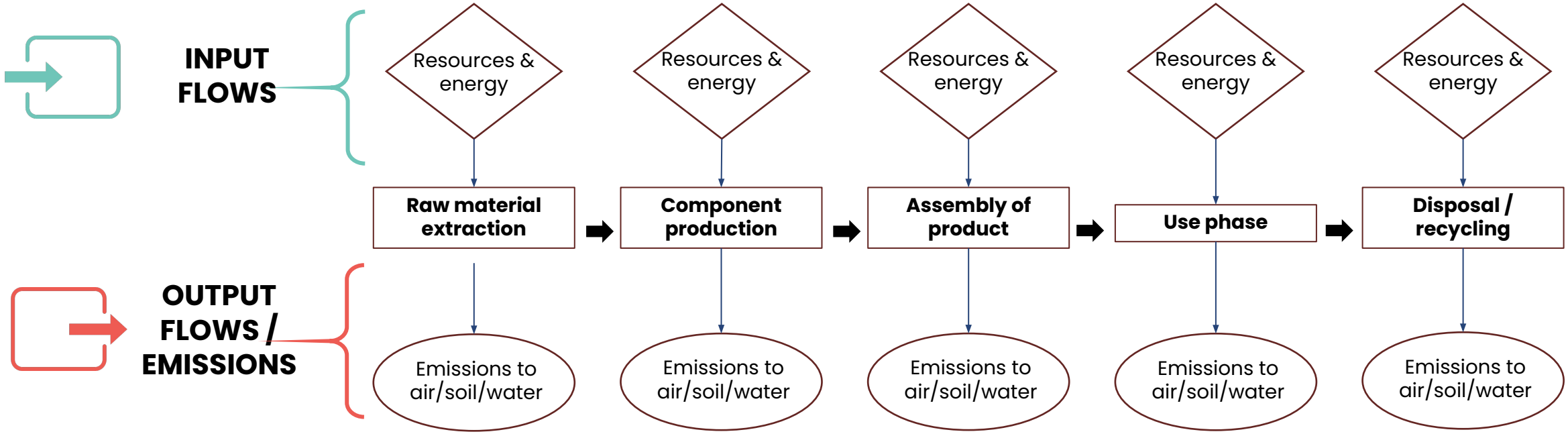
LCA METHODOLOGY

GOAL AND SCOPE

System boundary



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LCA METHODOLOGY

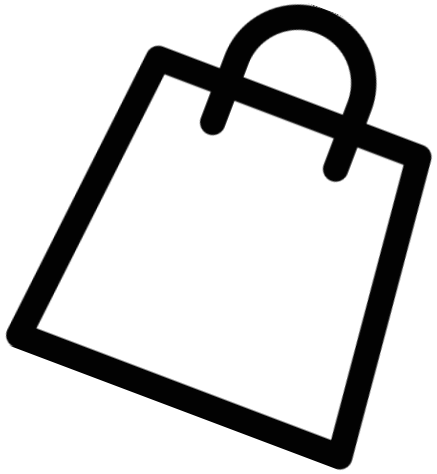
INVENTORY ANALYSIS PHASE

Input and output flows to obtain at the end of the process the quantity of the product defined in the Functional Unit.

INPUT FLOWS

OUTPUT FLOWS /

Quantification and data renormalisation



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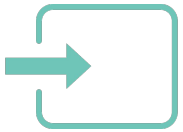
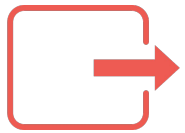
LCA METHODOLOGY

INVENTORY ANALYSIS PHASE

DATA COLLECTION: Through detailed **questionnaires**.



INPUT FLOWS



OUTPUT FLOWS /

For each phase of the process it is necessary to collect and weigh data:

- type / quantity of incoming materials
- energy consumed
- waste produced
- etc.

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LCA METHODOLOGY

LIFE CYCLE STAGES to consider

1) Raw materials extraction
To produce products, machines, devices.



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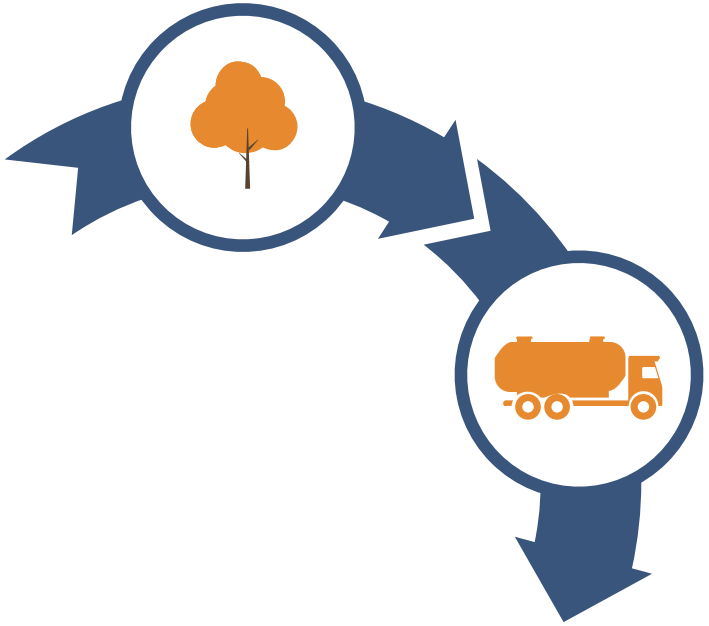
LCA METHODOLOGY



LIFE CYCLE STAGES to consider

2) Transportation*
Ex. transport of raw materials, product distribution, final disposal.

- Distance - km
- Transported weight - kg
- Means of transport:

**Transportation may occur several times during the life cycle of a product!*

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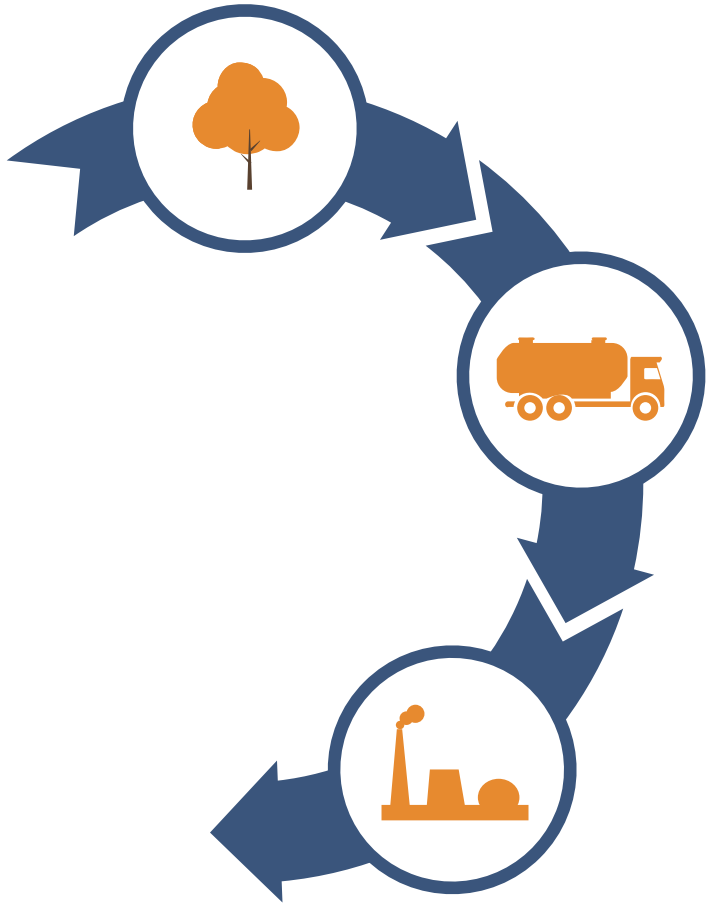
LCA METHODOLOGY



LIFE CYCLE STAGES to consider

3) Production
It considers energy, water, packaging, emissions, waste.

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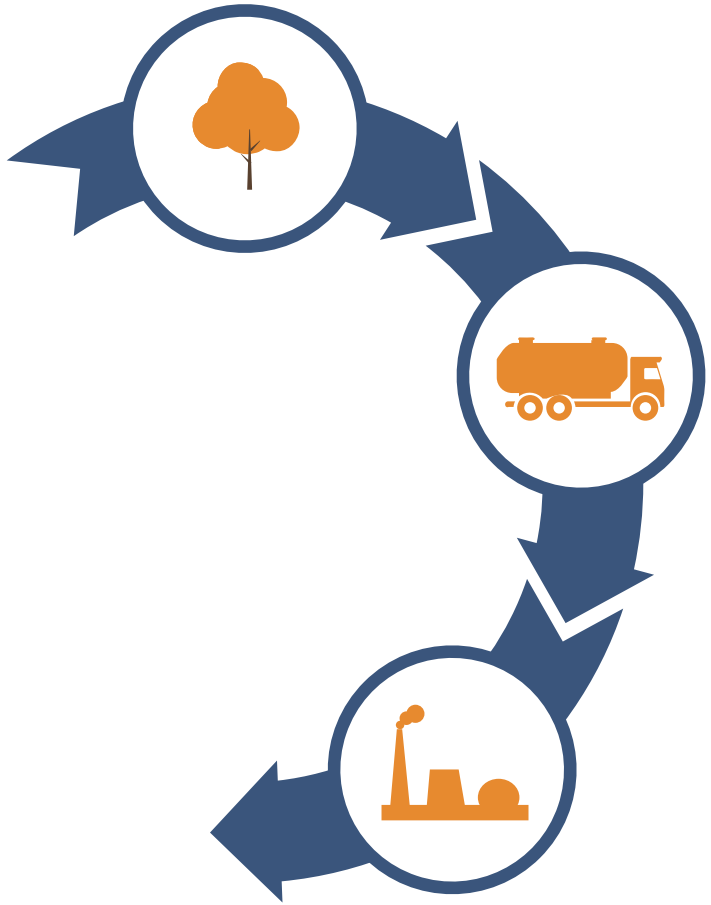
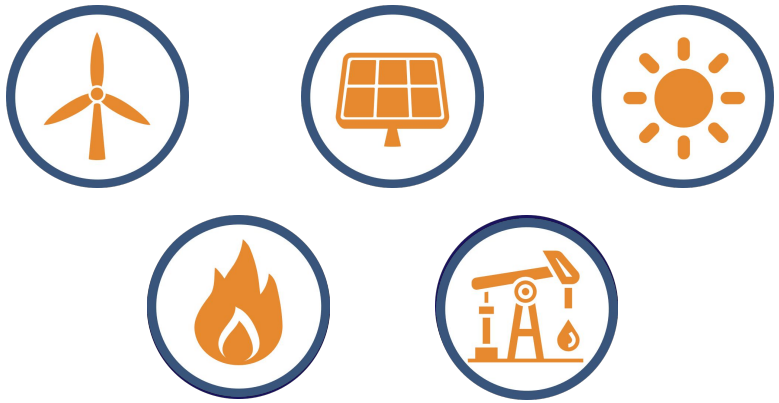
LCA METHODOLOGY



LIFE CYCLE STAGES to consider

3) Energy sources:

- Renewable
- Non-renewable



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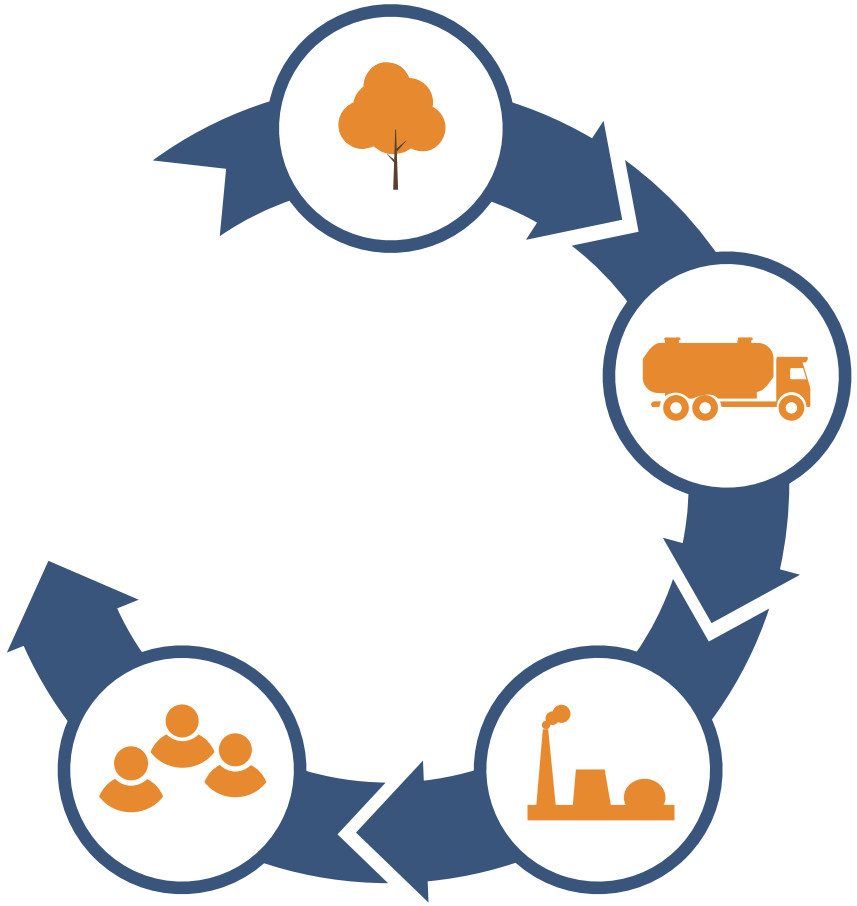
LCA METHODOLOGY



LIFE CYCLE STAGES to consider

4) Use phase
Impact associated with the quantity of energy, water, fuel used.

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LCA METHODOLOGY

LIFE CYCLE STAGES to consider

5) End of life
What happens to the product when its useful life ends.

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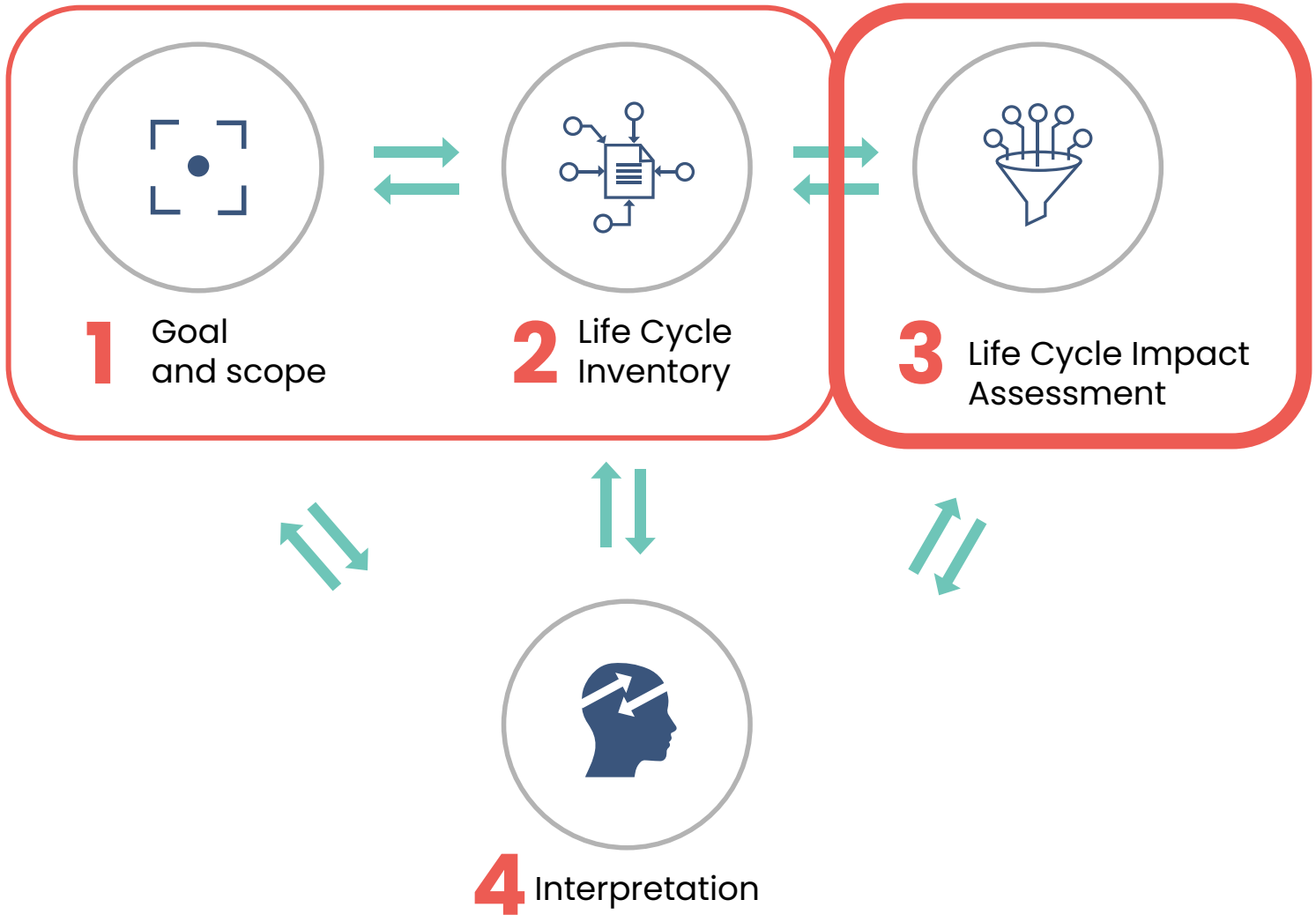
LCA METHODOLOGY

THE METHODOLOGY
LCA analysis must be conducted in **4 phases**:



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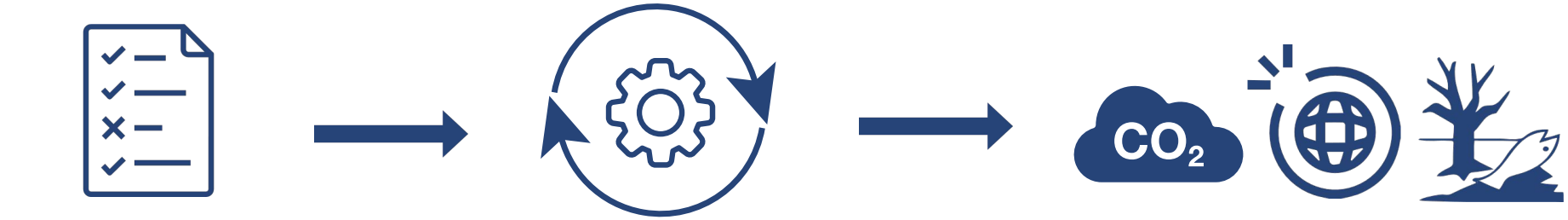
LCA METHODOLOGY

IMPACT ASSESSMENT

Here data are modeled with specific software and databases, that allow to convert these input/output flows into **environmental impacts**



input/output flows → conversion → environmental impacts

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LCA METHODOLOGY

IMPACT ASSESSMENT

In order to evaluate the ENVIRONMENTAL IMPACTS, we need to use ENVIRONMENTAL INDICATORS:

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LCA METHODOLOGY

IMPACT ASSESSMENT

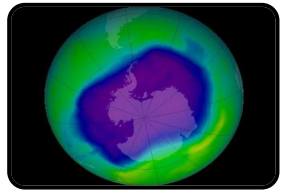
In order to evaluate the ENVIRONMENTAL IMPACTS, we need to use ENVIRONMENTAL INDICATORS:

GWP
Global Warming Potential

AP
Acidification Potential

ADP
Abiotic Depletion Potential

ADP (fossil)
Abiotic Depletion Potential Fossil Fuels



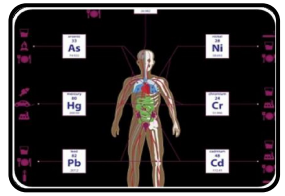
ODP
Ozone Depletion Potential

POCP
Photochemical Oxidation Potential

EP
Eutrophication Potential

TETP
Terrestrial Ecotoxicity Potential

FAETP
Freshwater Aquatic Ecotoxicity Potential



HTTP
Human Toxicity Potential Cancerogenic Pollutants

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LCA METHODOLOGY

IMPACT ASSESSMENT

In order to evaluate the ENVIRONMENTAL IMPACTS, we need to use ENVIRONMENTAL INDICATORS:

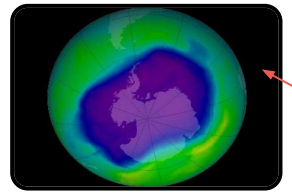
kg CO_2 eq.

GWP
Global Warming Potential

AP
Acidification Potential

ADP
Abiotic Depletion Potential

ADP (fossil)
Abiotic Depletion Potential Fossil Fuels



ODP
Ozone Depletion Potential

kg 1,4-DCB

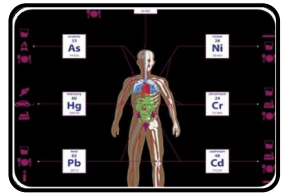
kg SO_2 eq.

POCP
Photochemical Oxidation Potential

EP
Eutrophication Potential

TETP
Terrestrial Ecotoxicity Potential

FAETP
Freshwater Aquatic Ecotoxicity Potential



HTTP
Human Toxicity Potential Cancerogenic Pollutants

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LCA METHODOLOGY

IMPACT ASSESSMENT

INVENTORY ANALYSIS

- Input flows
- Output flows
- Emissions

MID-POINT:

- Global Warming Potential
- Acidification Potential
- Abiotic Depletion Potential
- Abiotic Depletion Potential fossil fuels
- Ozone Depletion Potential
- Photochemical Oxidation Potential
- Eutrophication Potential
- Terrestrial Ecotoxicity Potential
- Freshwater Aquatic Ecotoxicity Potential
- Human Toxicity Potential
- Marine Aquatic Ecotoxicity Potential

END-POINT:

- Health
- Resources
- Ecosystem quality

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LCA METHODOLOGY

IMPACT ASSESSMENT

INVENTORY ANALYSIS

- Input flows
- Output flows
- Emissions

Characterisation Factors
e.g. kg CO_2 eq./kg flow

MID-POINT:

- Global Warming Potential
- Acidification Potential
- Abiotic Depletion Potential
- Abiotic Depletion Potential fossil fuels
- Ozone Depletion Potential
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END-POINT:

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LCA METHODOLOGY

IMPACT ASSESSMENT

Input data flows are converted into impact category values by means of **Characterisation Factors (CF)**

Flow	CF in EF3.0	CF in EF3.1
Emission of “Carbon dioxide (biogenic)” to air	0	0
Emission of “Carbon dioxide (fossil)” to air	1	1
Emission of “Carbon dioxide (land use change) ” to air	1	1
Emission of “Methane (biogenic)” to air	34	27
Emission of “Methane (fossil)” to air	36.8	29.8
Emission of “Methane (land use change)” to air	36.8	29.8
Resource “Carbon dioxide (biogenic)” from air	0	0
Resource “Carbon dioxide (fossil)” from air	0	0
Resource “Carbon dioxide (land use change)” from air	-1	-1

Source: JRC analysis.

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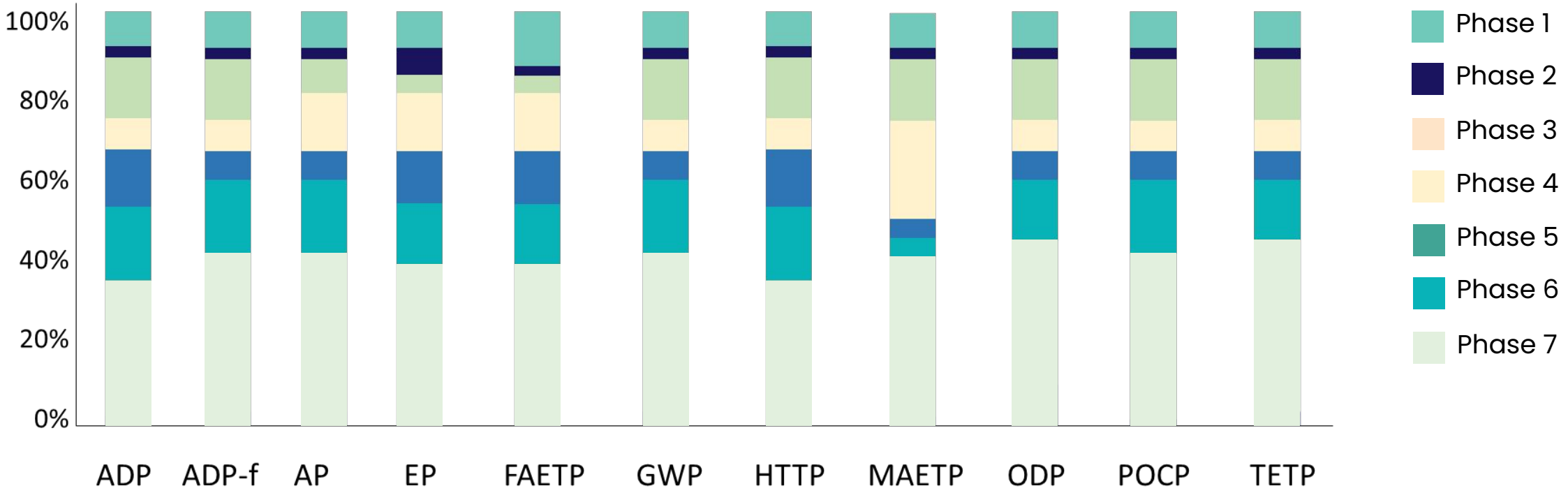
LCA METHODOLOGY

IMPACT ASSESSMENT

Breakdown of the impacts for each process Phase or life cycle phase.



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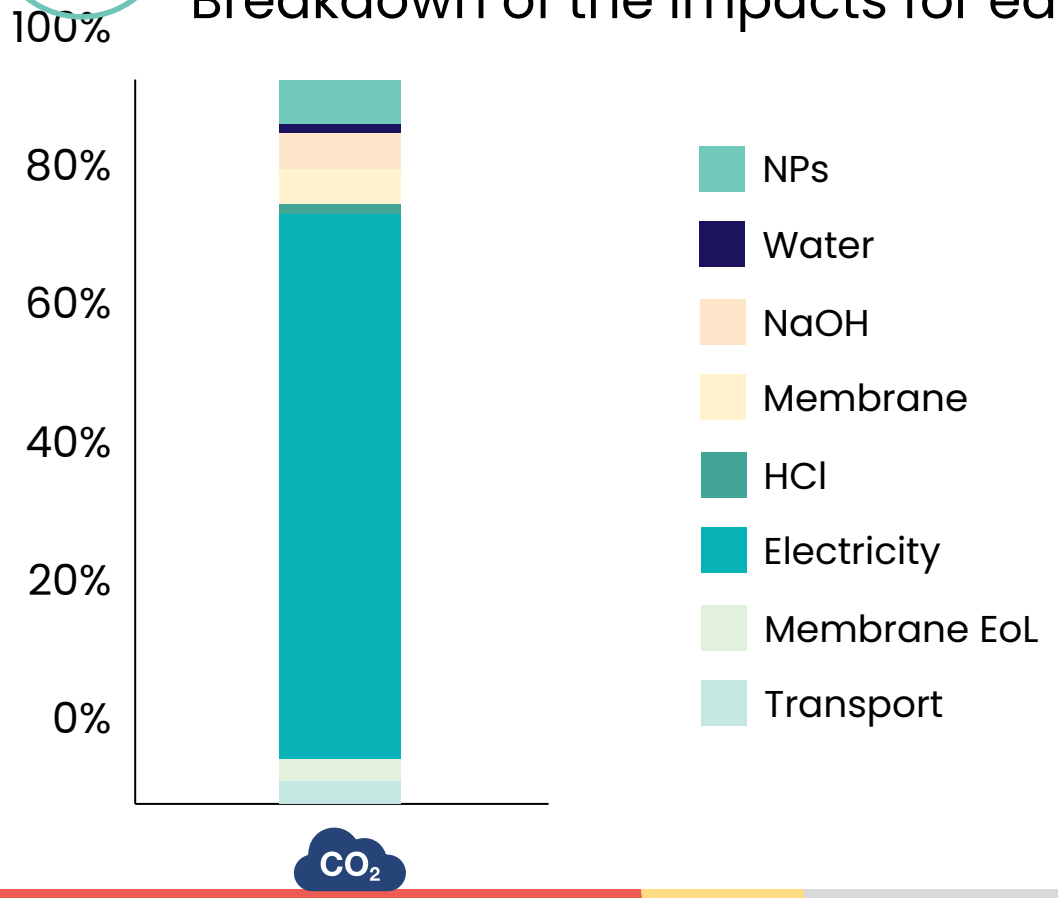
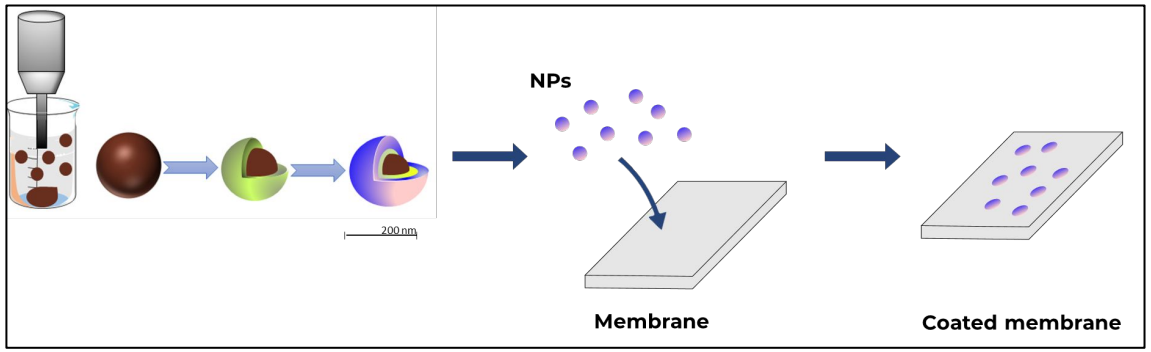
LCA METHODOLOGY

IMPACT ASSESSMENT

Breakdown of the impacts for each material or input/output flows.





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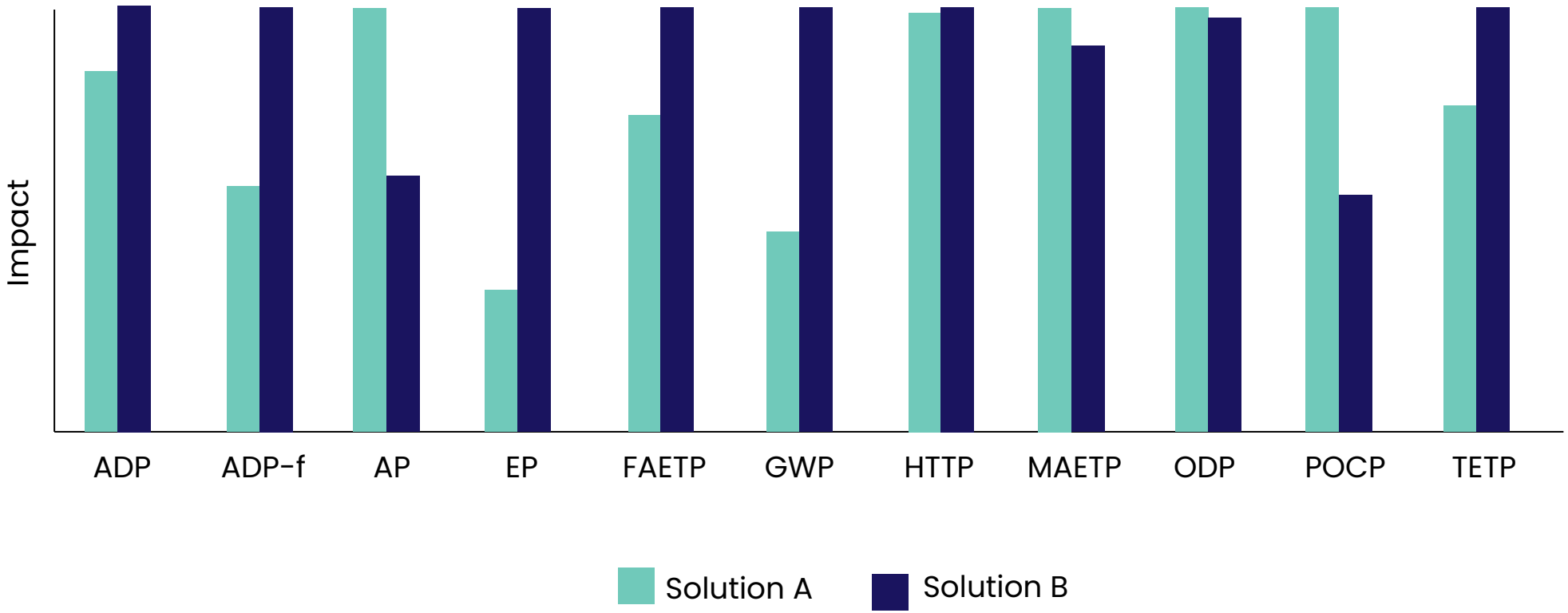
LCA METHODOLOGY

IMPACT ASSESSMENT

Make comparison.



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LCA METHODOLOGY

INTERPRETATION

This step must include:

- Evaluation of the impacts
- Interpretation of the results
- Sensitivity or uncertainty analyses

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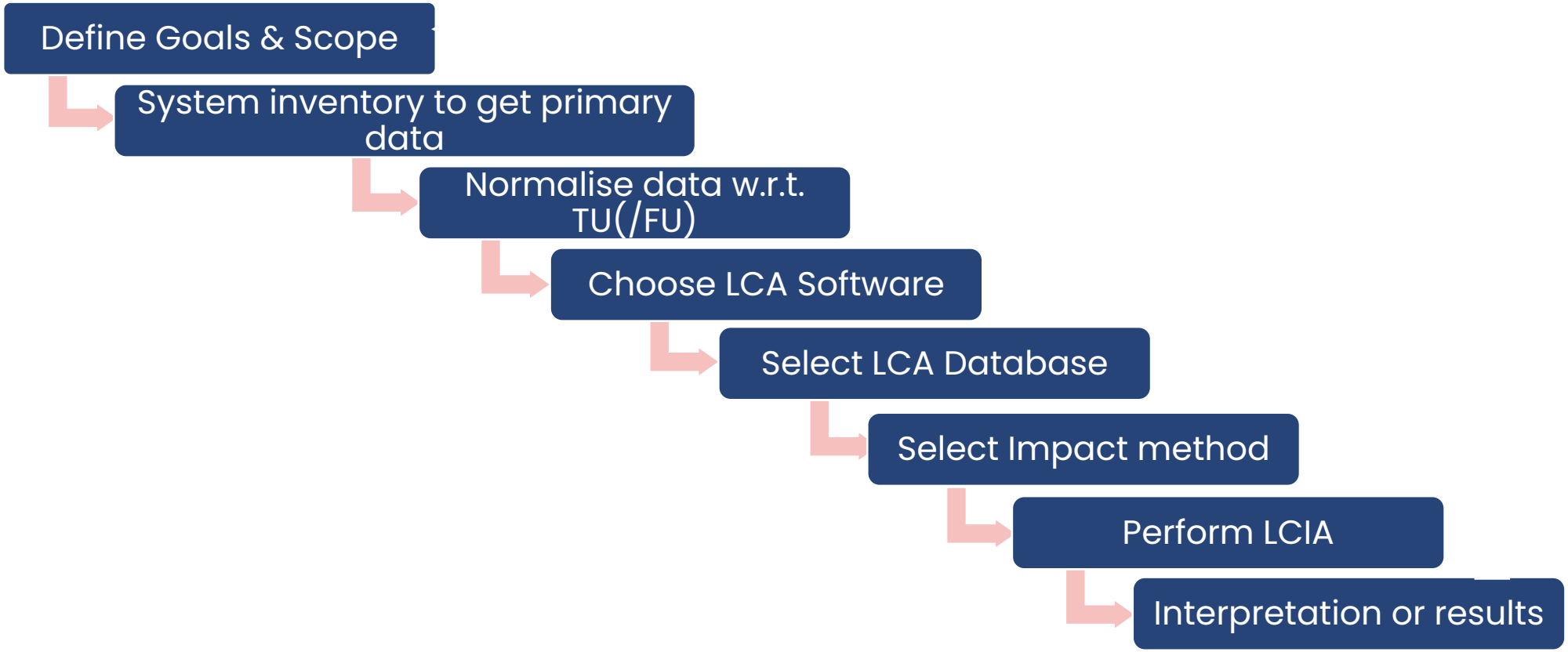
LCA METHODOLOGY

How to & Workflow



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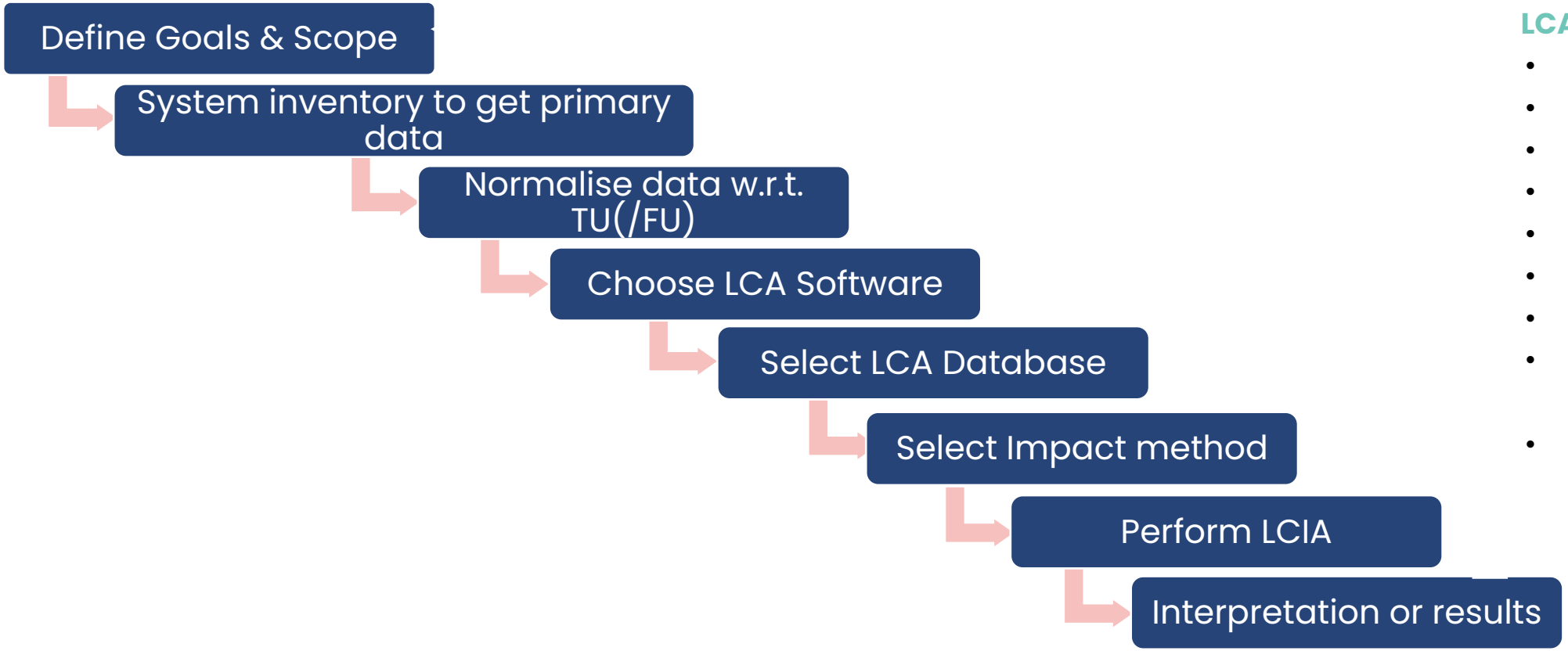
LCA METHODOLOGY

How to & Workflow



LCA Databases

- Ecoinvent
- Simapro database
- Gabi
- EF 3.1
- The Bousted Model
- IVAM LCA
- SALCA (Agro)
- US Life Cycle Inventory Database
- …

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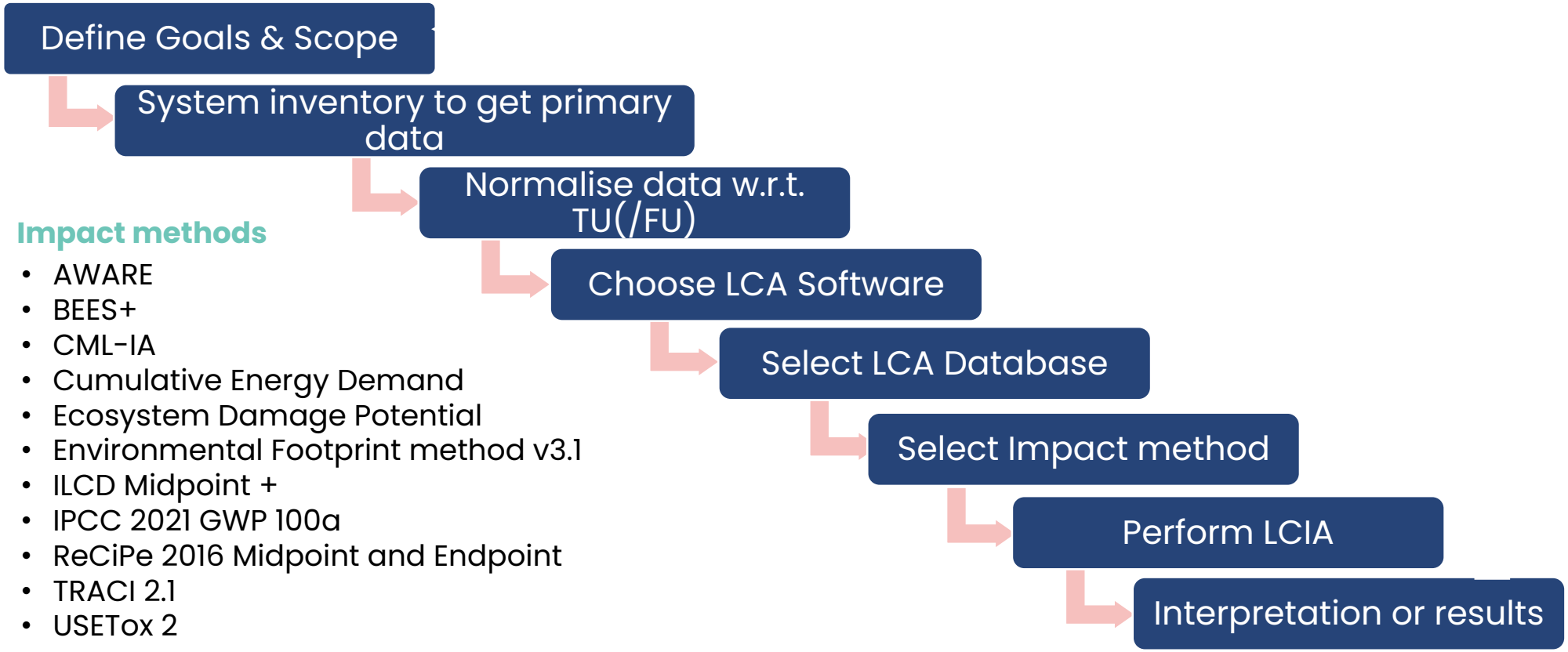
LCA METHODOLOGY

How to & Workflow



Impact methods

- AWARE
- BEES+
- CML-IA
- Cumulative Energy Demand
- Ecosystem Damage Potential
- Environmental Footprint method v3.1
- ILCD Midpoint +
- IPCC 2021 GWP 100a
- ReCiPe 2016 Midpoint and Endpoint
- TRACI 2.1
- USETox 2

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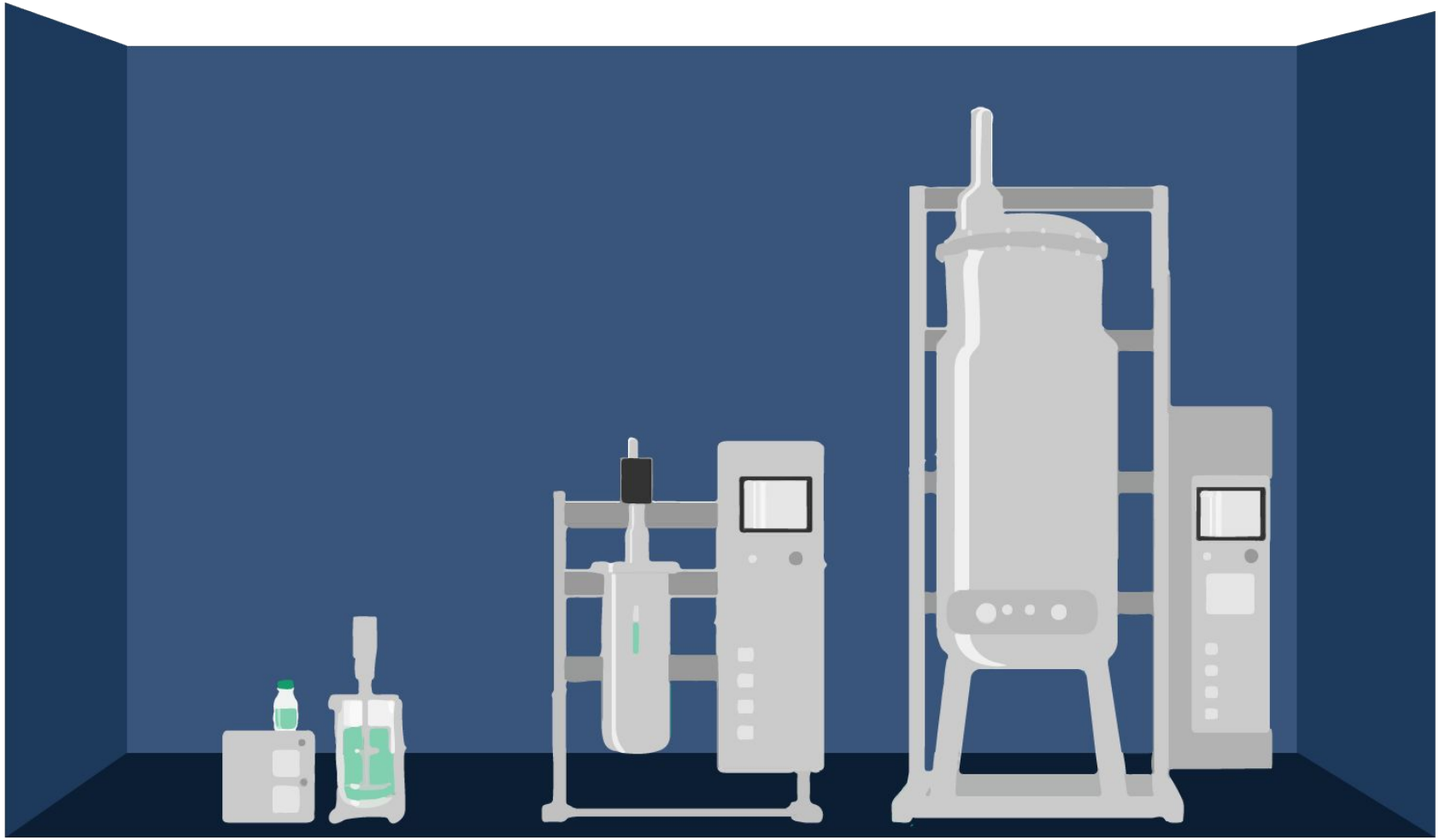
ADDITIONAL KEY CONCEPT

Laboratory vs. pilot scale vs. industrial scale process



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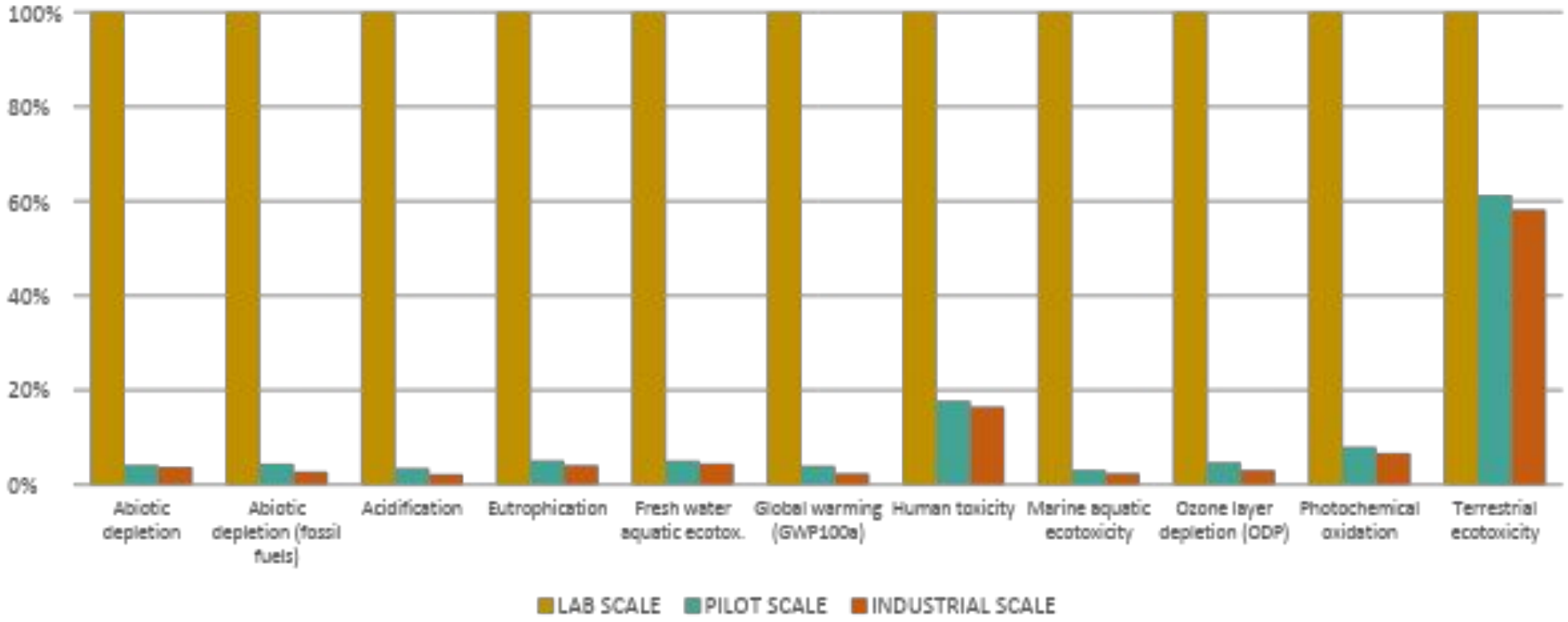
ADDITIONAL KEY CONCEPT
Laboratory vs. pilot scale vs. industrial scale process

Expected Environmental Performance achievement by Scaling up a process
Results for antiaging cream with Coenzime Q10 and Vitamin E: NMs synthesis & incorporation



LAB SCALE (100g)

vs.

PILOT SCALE (8kg)

vs.

FULL INDUSTRIAL SCALE (1000kg)

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TAKE HOME MESSAGE

In more detail LCA allows to:

- Increase knowledge of a product/process's **environmental impacts** throughout its life cycle, identifying priorities for action

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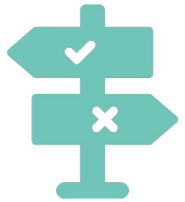
In more detail LCA allows to:

- Increase knowledge of a product/process's **environmental impacts** throughout its life cycle, identifying priorities for action
- Obtain an **eco-design tool** for comparing 2 or more (functionally equivalent) solutions
- **Communicate** the environmental progress of products/process and promote responsible consumption

Market application



Decision makers

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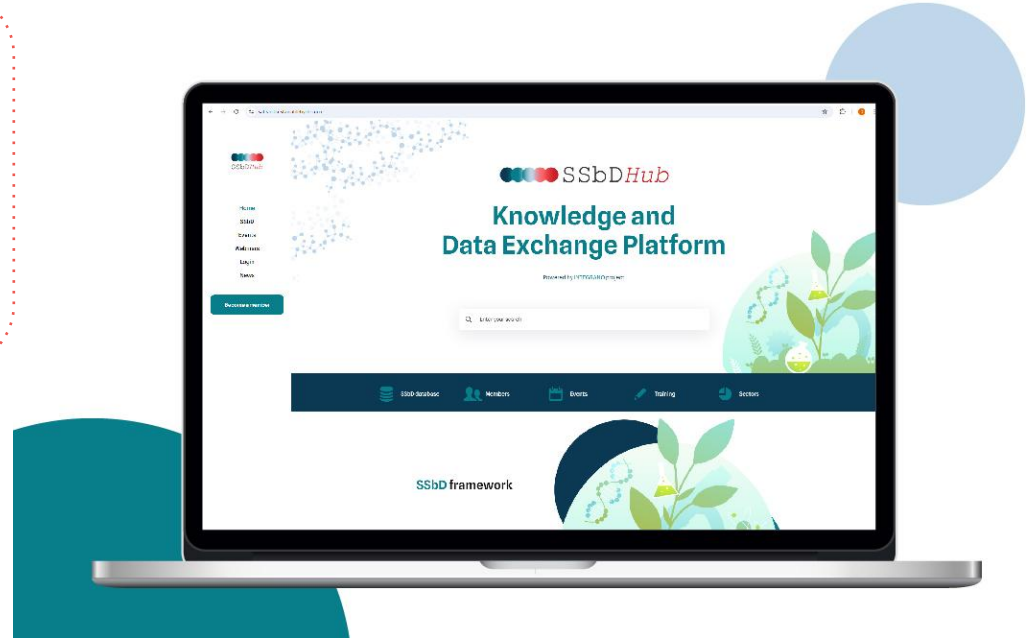
THE “SSBD HUB” PLATFORM

Since July 2024 the platform is **online!** SSbD Hub serves as an **interactive** website and is the main tool for communicating on **project initiatives.**



Free contents:

- Webinars
- Workshops
- Literature

www.safeandsustainablebydesign.eu

You are invited to **become members** and **register** on the platform, to benefit exclusive content.

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PROJECT HUB360

20th ANNIVERSARY 2005-2025

INTEGRANO

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