Life Cycle Assessment approaches developed for glass sustainability

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SUSTAINABLE DEVELOPMENT STRATEGY

https://www.youtube.com/watch?v=VFkQSGyeCWg

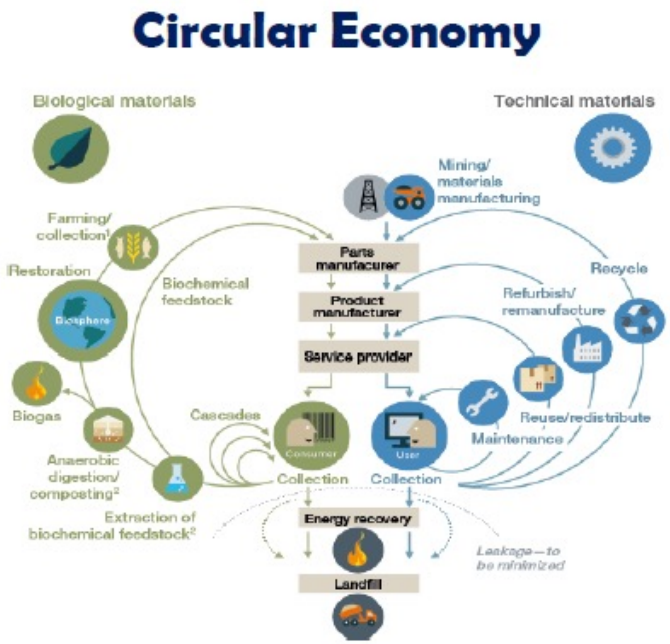
Sustainability and Sustainable Development: What is the difference?

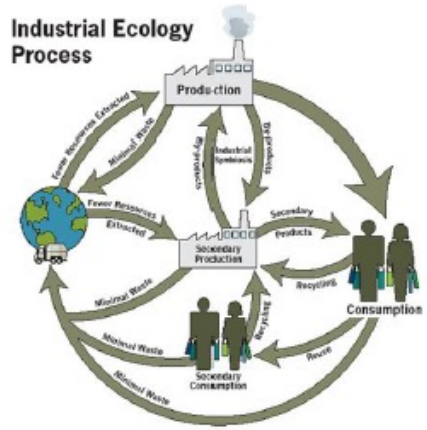
Sustainability is focused on the balance of environmental, social and economic aspects.

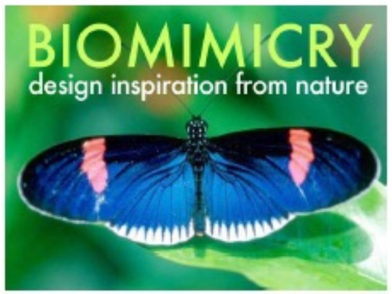
Sustainable development aims at satisfying the needs of the present without compromising those of future generations.

Sustainability is a fundamental requirement for sustainable development.

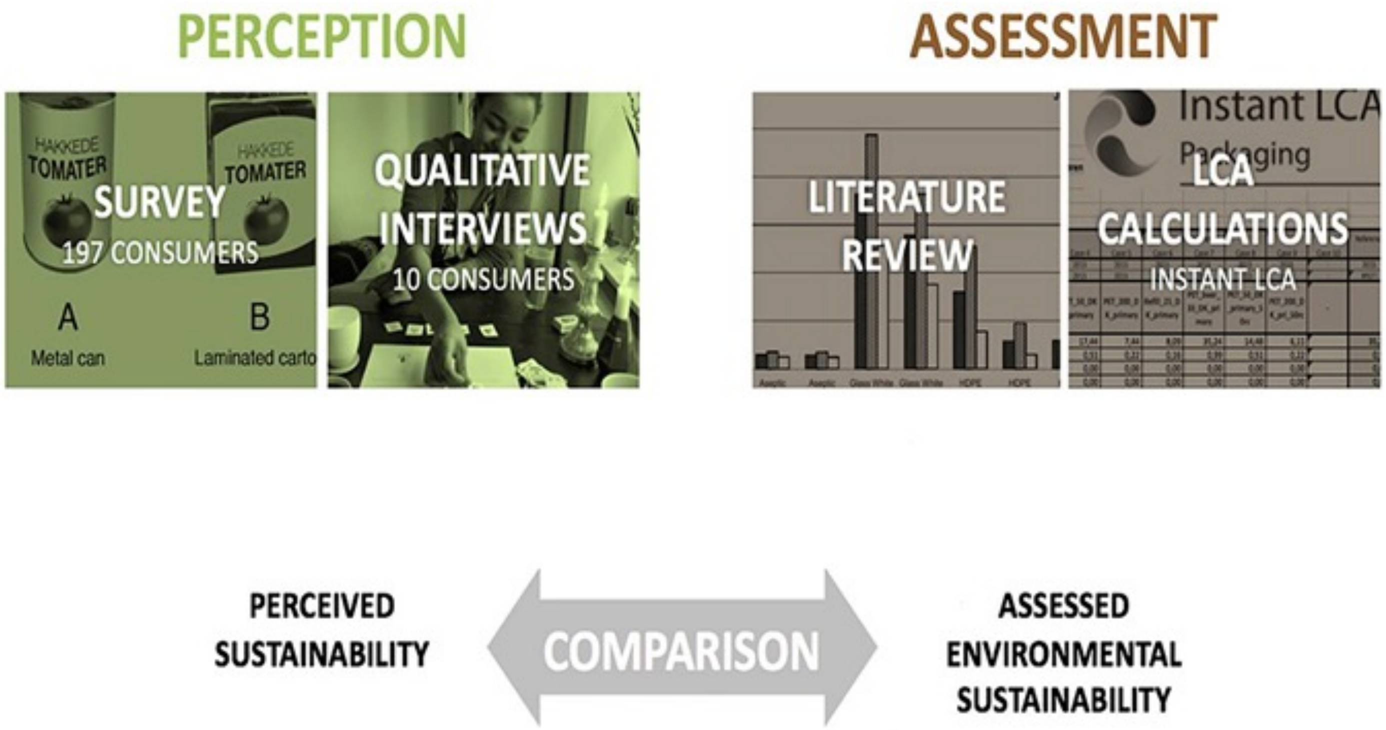
Zero-impact initiatives?



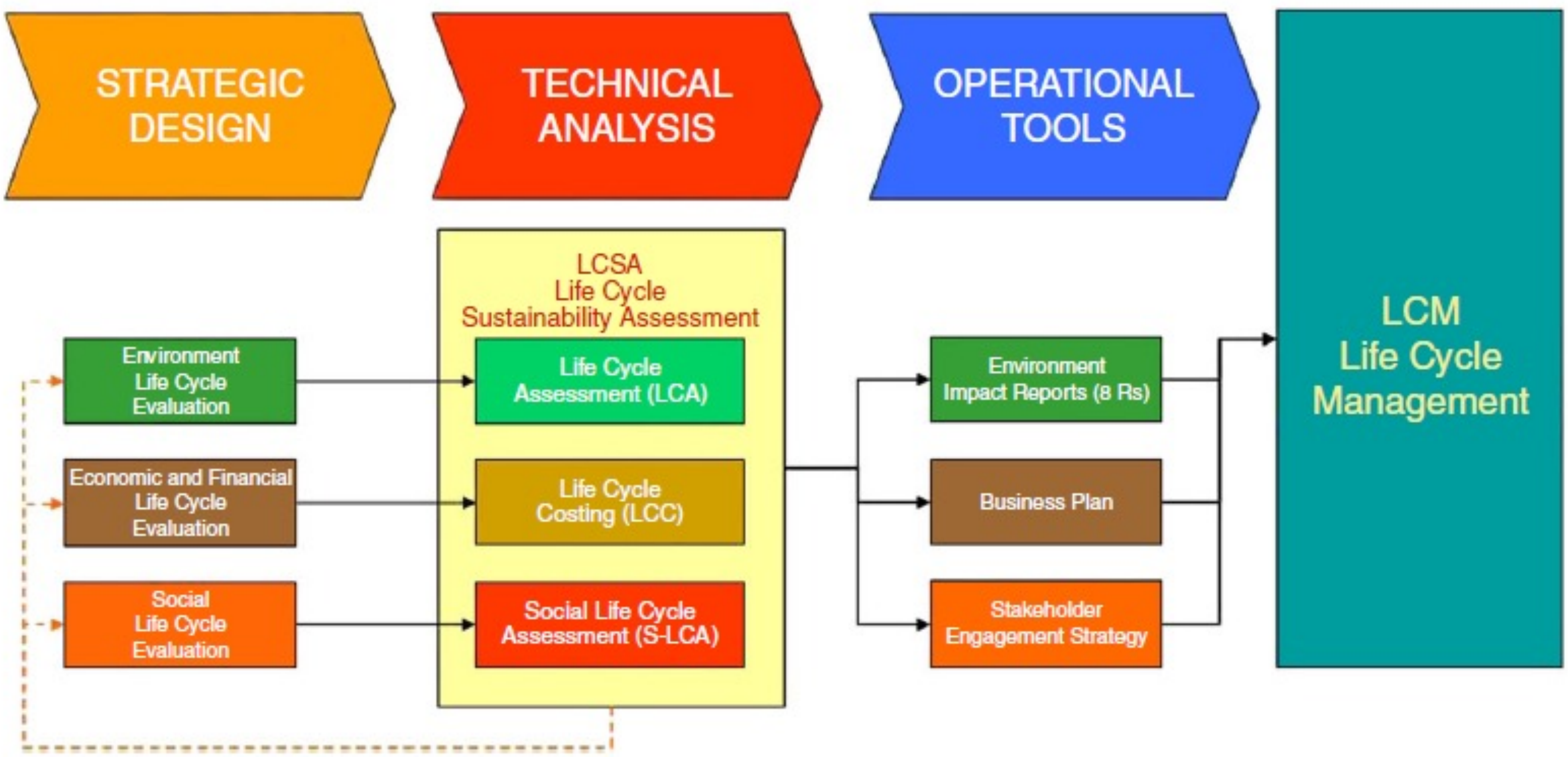




Does Sustainability Perception Meet Reality?

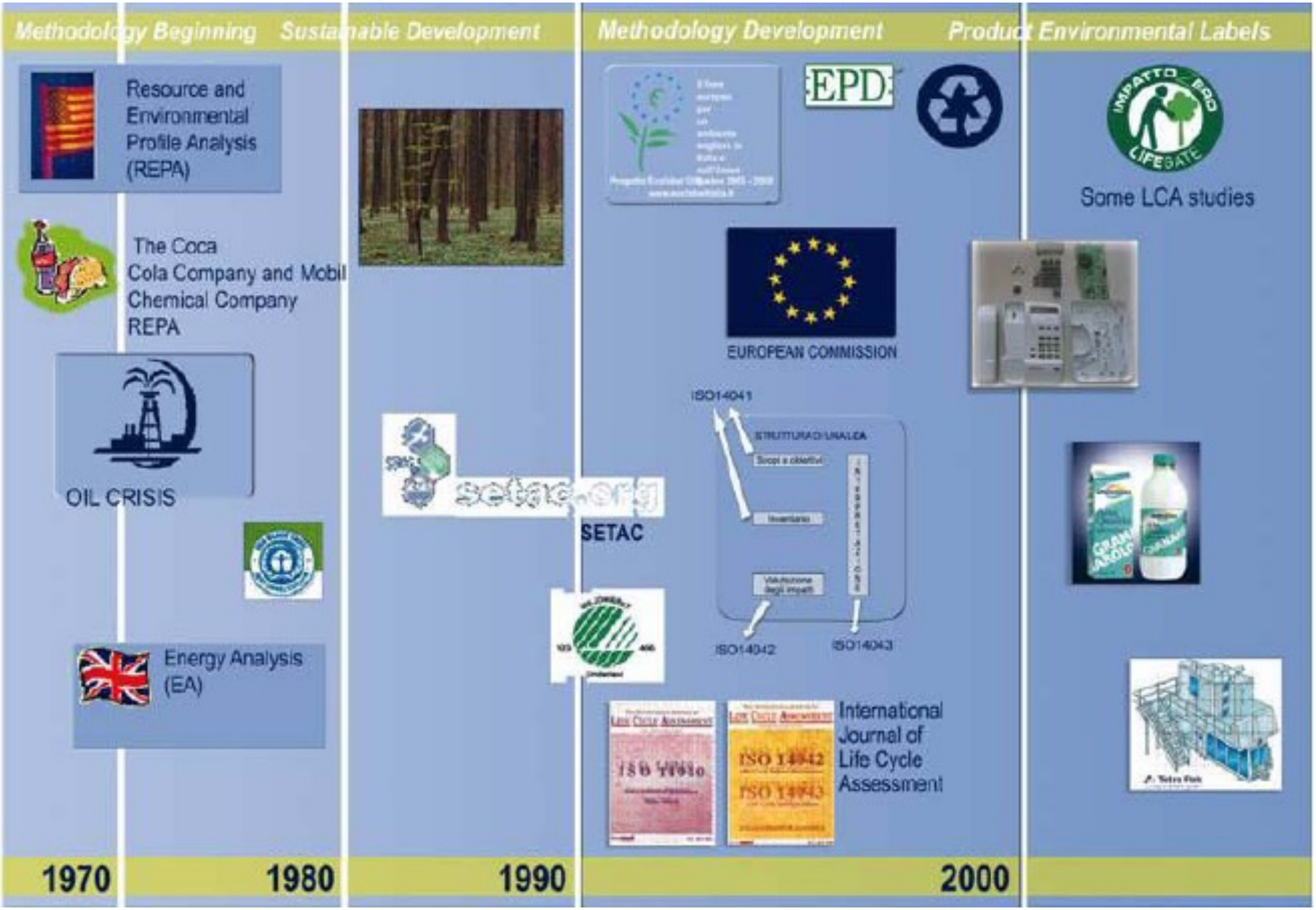


Life Cycle Model Framework



LIFE CYCLE ASSESSMENT

The origin of Life Cycle Assessment



LIFE CYCLE ASSESSMENT (LCA) - Definition

"Life-Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements.

The assessment includes the entire life-cycle of the product, process, or activity, encompassing extracting and processing raw materials; manufacturing; transportation and distribution; use, re-use, maintenance; recycling, and final disposal"

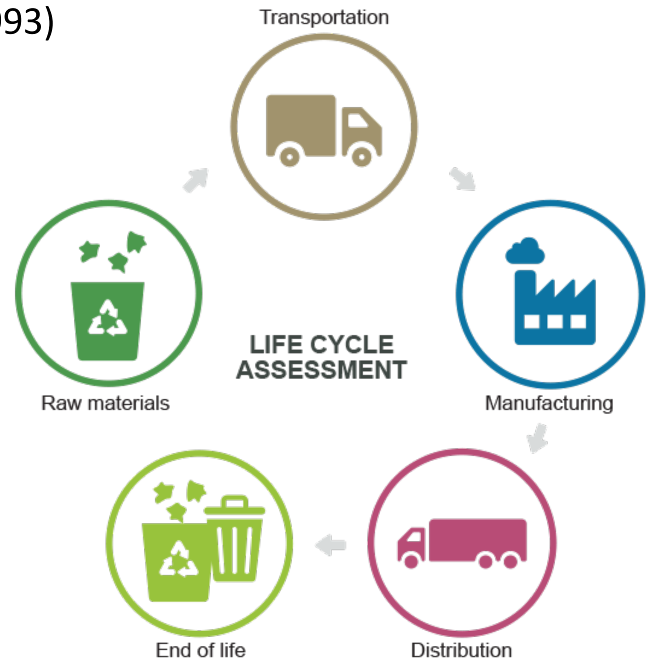
*SETAC (Society of Environmental Toxicology and Chemistry, 1993)

→ *Objectivity*

→ *Energy and environmental impacts*

→ *Product, process, service*

→ *Entire life cycle*



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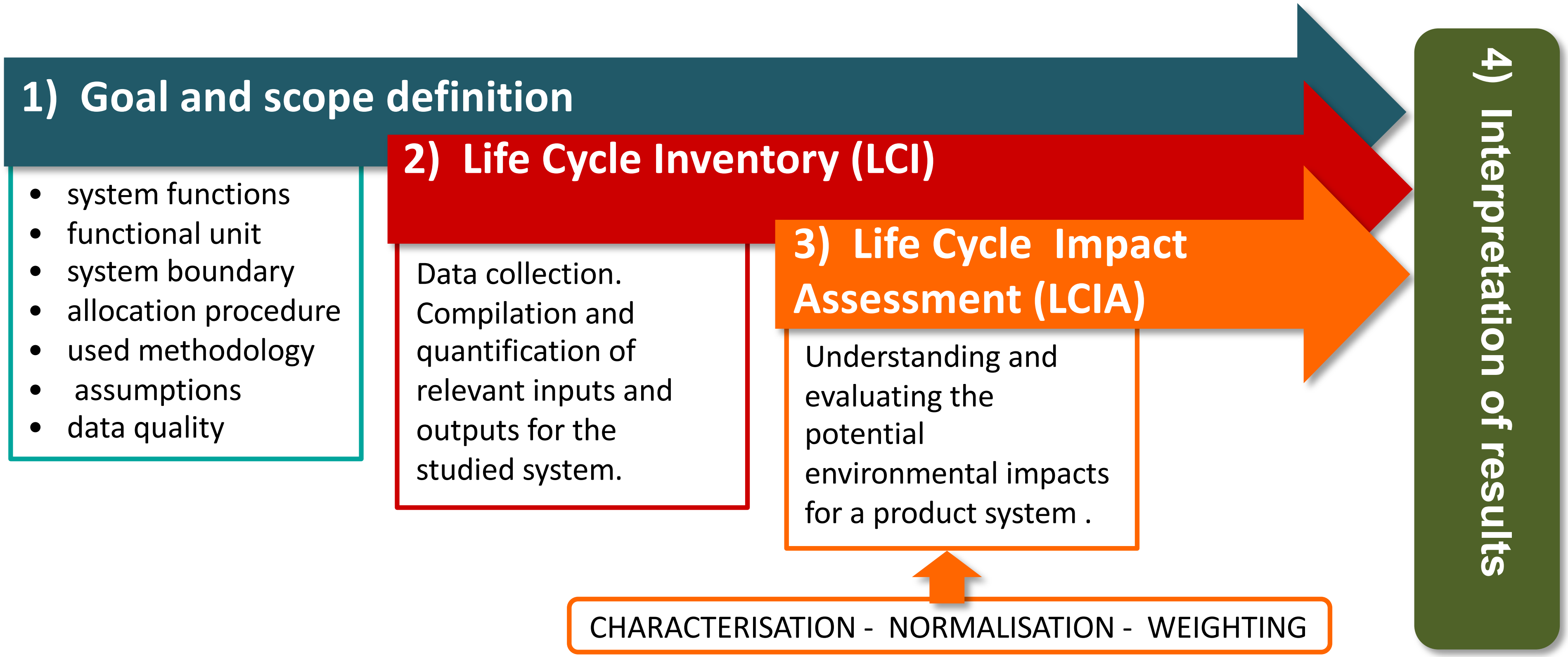
LCA METHODOLOGY (ISO 14040-14044)



PHASE 1 – GOAL AND SCOPE DEFINITION

Phase that identifies the main reasons for which the LCA is performed, describes the system being studied and its boundaries, decides the level of detail to be achieved, the assumptions and limits.

<u>Objective of the study</u>

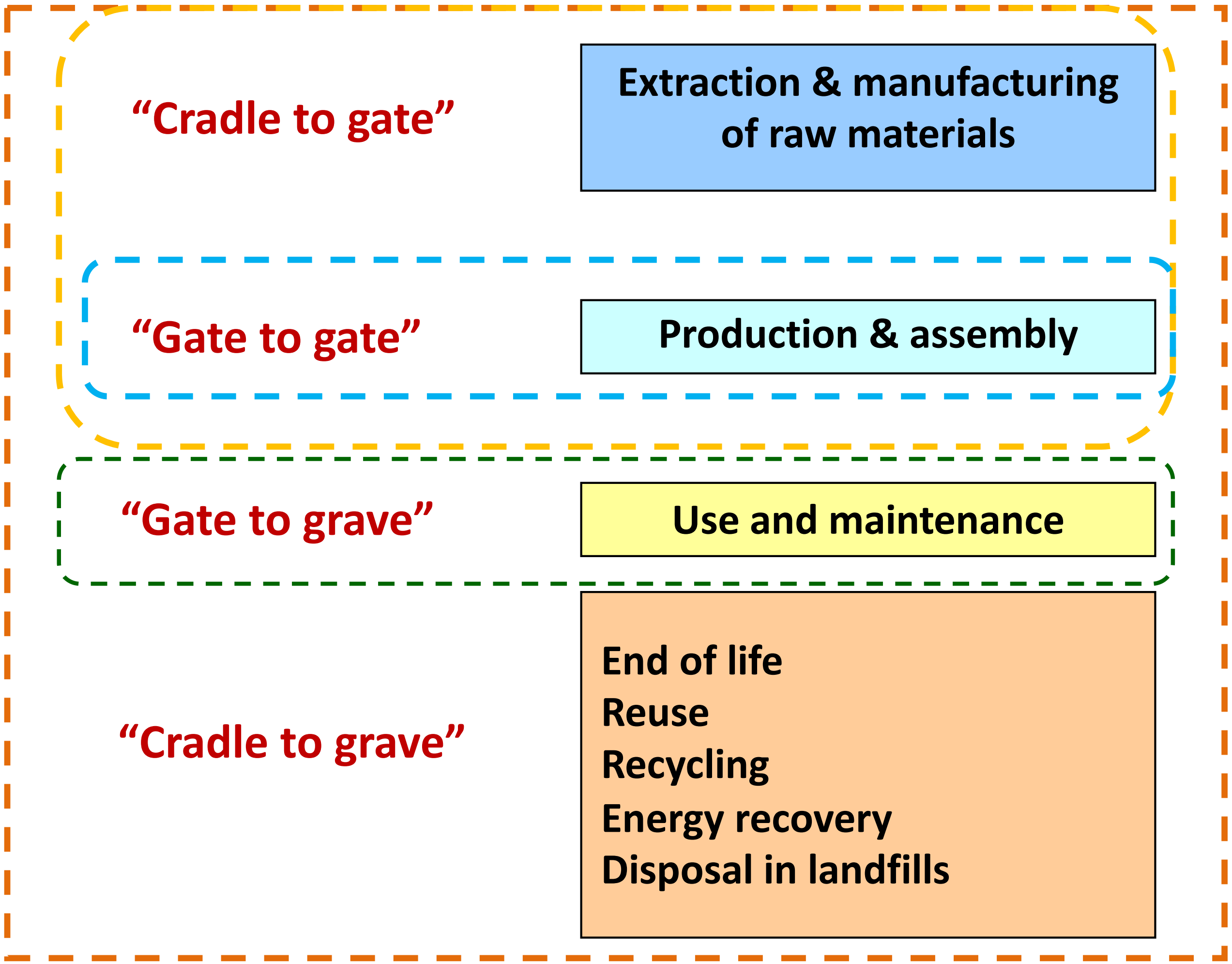
- reasons for conducting the study

<u>Scope of the study</u>

- *system function*: represents the characteristics and performance of the product;
- *functional unit*: indicates the reference with respect to which all the data making up the environmental balance of the studied system will be normalized;
- *system boundaries*: that determine the process units to be included in the LCA;
- *data quality*: establishes the quality of the acquired data and therefore the reliability of the study results.

SOURCE IMAGE: https://cdn-az.allevents.in/banners/f54f1b7ca7d5c8d8970abdcb96119f6f

PHASE 1 - GOAL AND SCOPE DEFINITION - *System boundaries*



gate to gate only what is inside the "company gates" is considered, excluding the supply and distribution of the finished product.

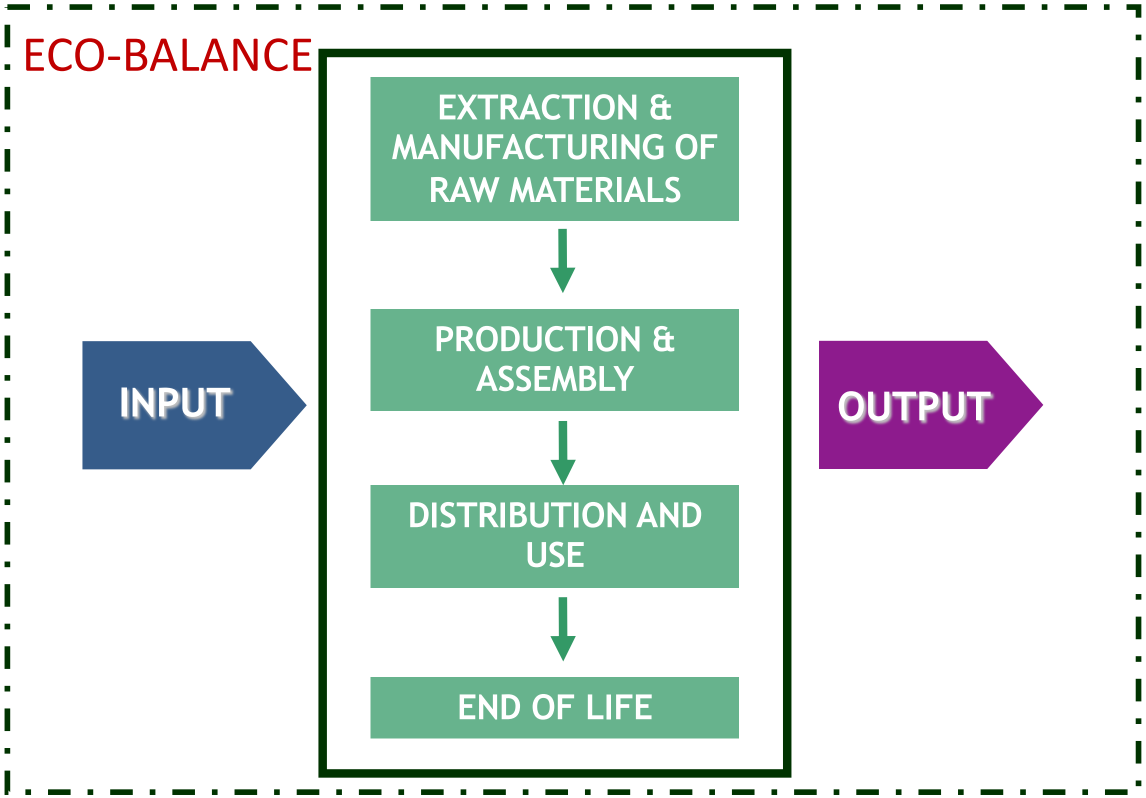
cradle to gate from the extraction of raw materials to the production and assembly of the product in the company that places it on the market.

gate to grave it includes the phases relating to distribution, use and disposal at the end of use.

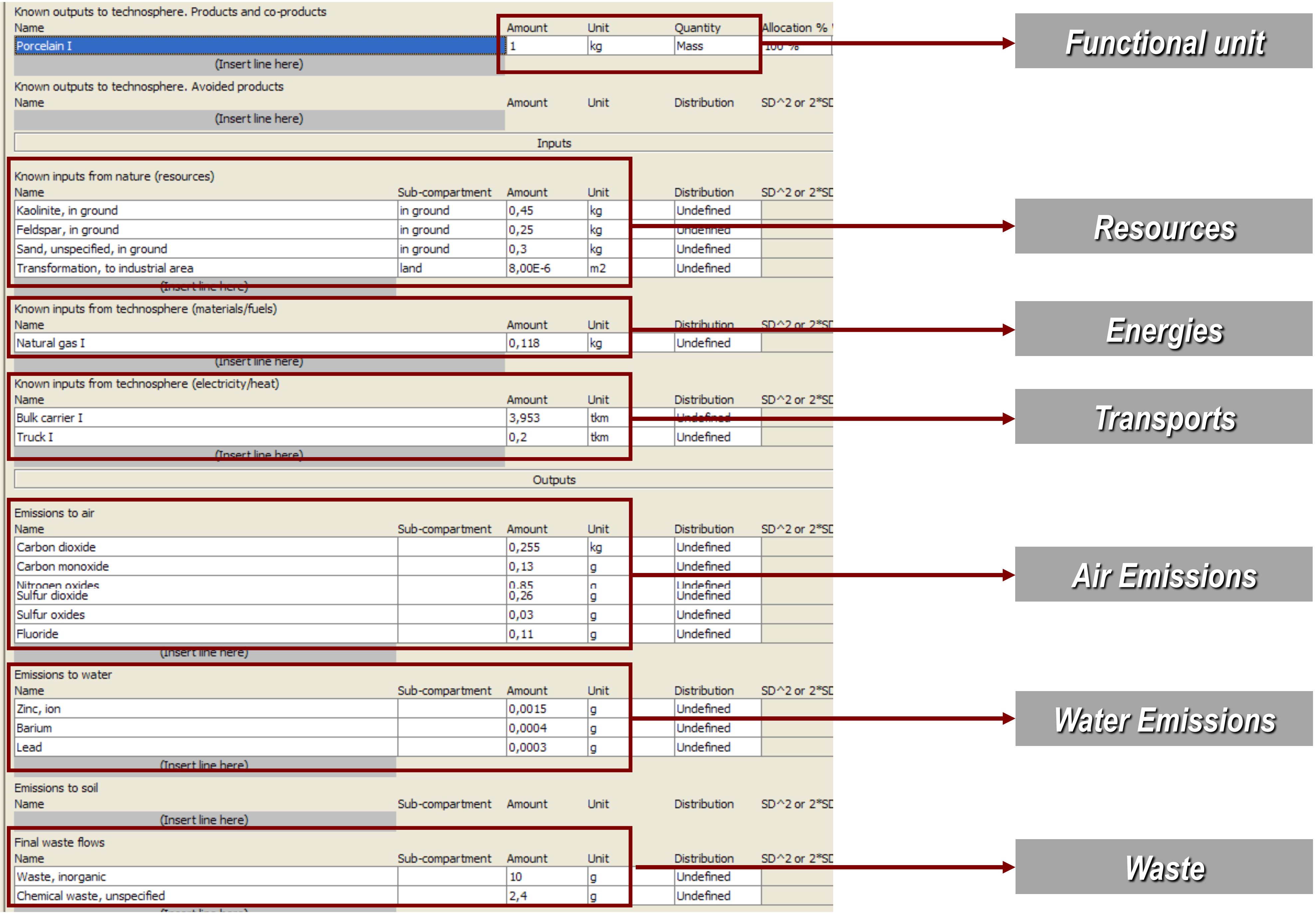
cradle to grave from the extraction of raw materials to the return to the earth as waste or a releases.

PHASE 2 – Life Cycle Inventory (LCI)

Phase in which the **flows of energy and materials** of all the processes that allow the functioning of the studied system are reconstructed. It consists of a data collection for the construction of a model capable of representing as faithfully as possible all the exchanges between the individual operations belonging to the production, distribution and disposal chain.



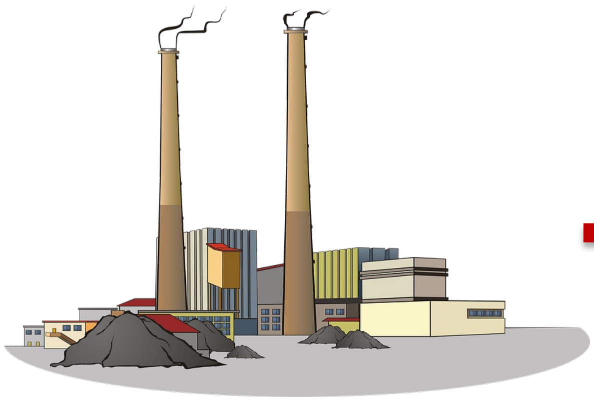
PHASE 2 – LCI: Example of modeling in the calculation software



PHASE 3 – LIFE CYCLE IMPACT ASSESSMENT (LCIA)

It aims to highlight and quantify the extent of the environmental changes that are generated as a result of releases into the environment (emissions or waste) and the consumption of resources and materials.

The goal is to **associate the consumption and emissions** obtained in the LCI with **specific impact categories** referable to known environmental effects, quantifying, with appropriate **characterization** methods, the amount of the overall contribution that the product makes to the effects considered.



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PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Structure*

Mandatory steps — **MID POINT ANALYSIS**

- IMPACT CATEGORIES SELECTION
- ↓
- CLASSIFICATION
- ↓
- CHARACTERIZATION

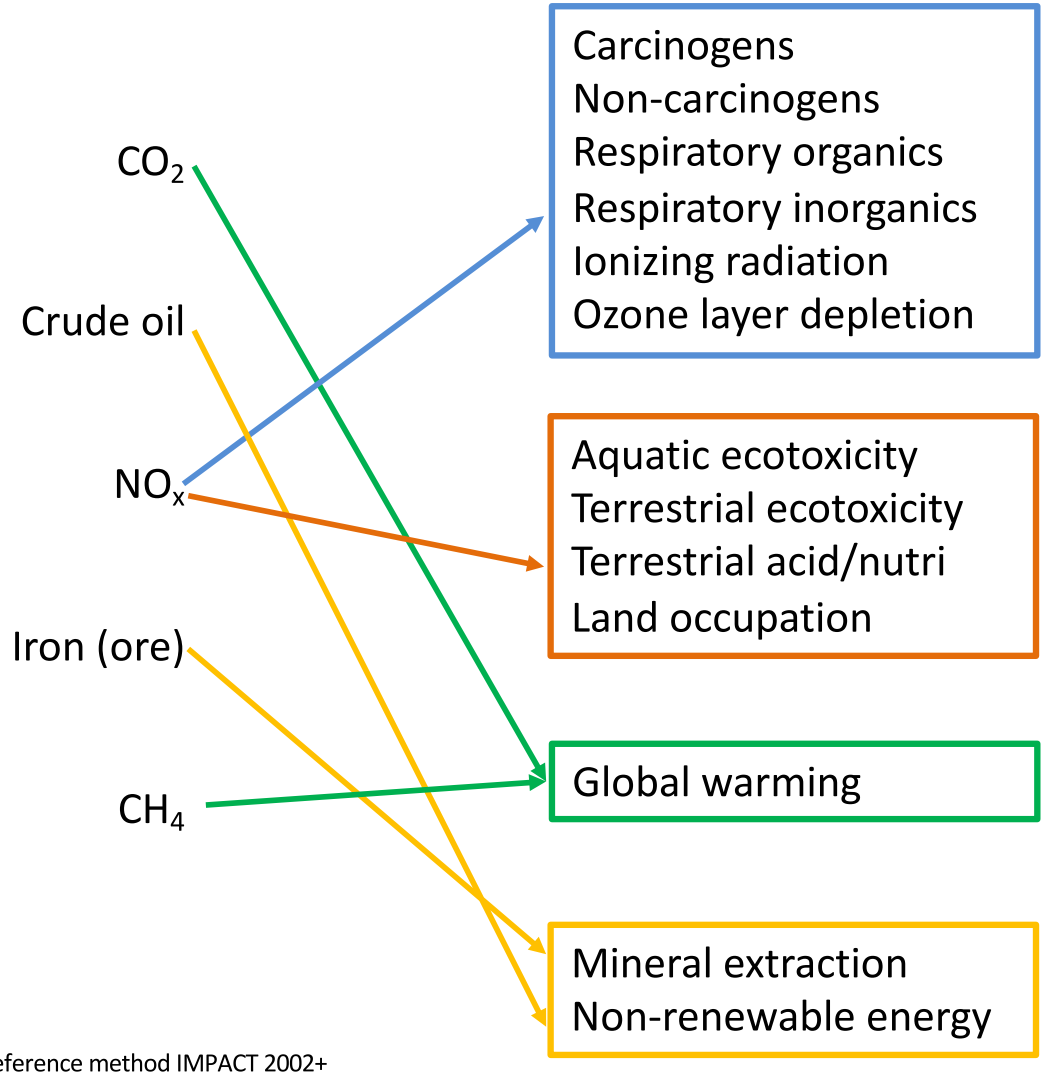
Optional steps — **END POINT ANALYSIS**

- NORMALIZATION
- ↓
- WEIGHTING

PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Classification*

Inventory ***Classification***

Each substance (input and output of the life cycle phases), quantified in the inventory phase, is "classified" on the basis of the environmental problems to which it can potentially contribute.

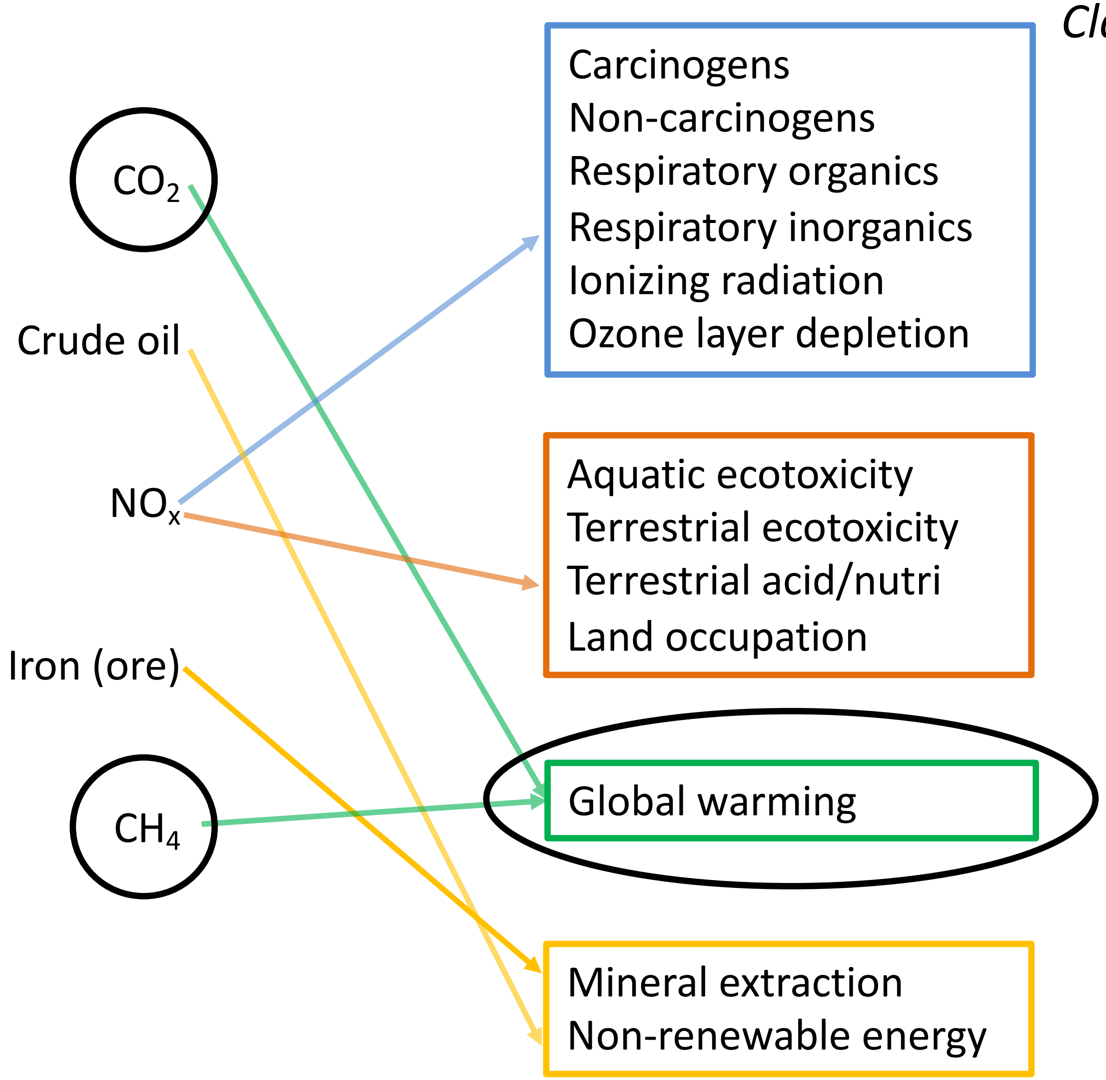


MULTIPLE CONTRIBUTIONS

Reference method IMPACT 2002+

PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Characterization*

Inventory *Classification* ***Characterization***



Classification → *Characterization*

$kg_{substance}$ * *characterization factor*

CFs express how much a single unit of mass of the intervention contributes to an impact category;

EXAMPLE:
- the Global Warming category is measured in **kg CO_2 eq**;
- the CO_2 substance is the reference substance and therefore has as characterization factor **1** ($kgCO_2$ * 1);
- the methane has **7,6** as a characterization factor ($kgCH_4$ * 7,6).

Reference method IMPACT 2002+

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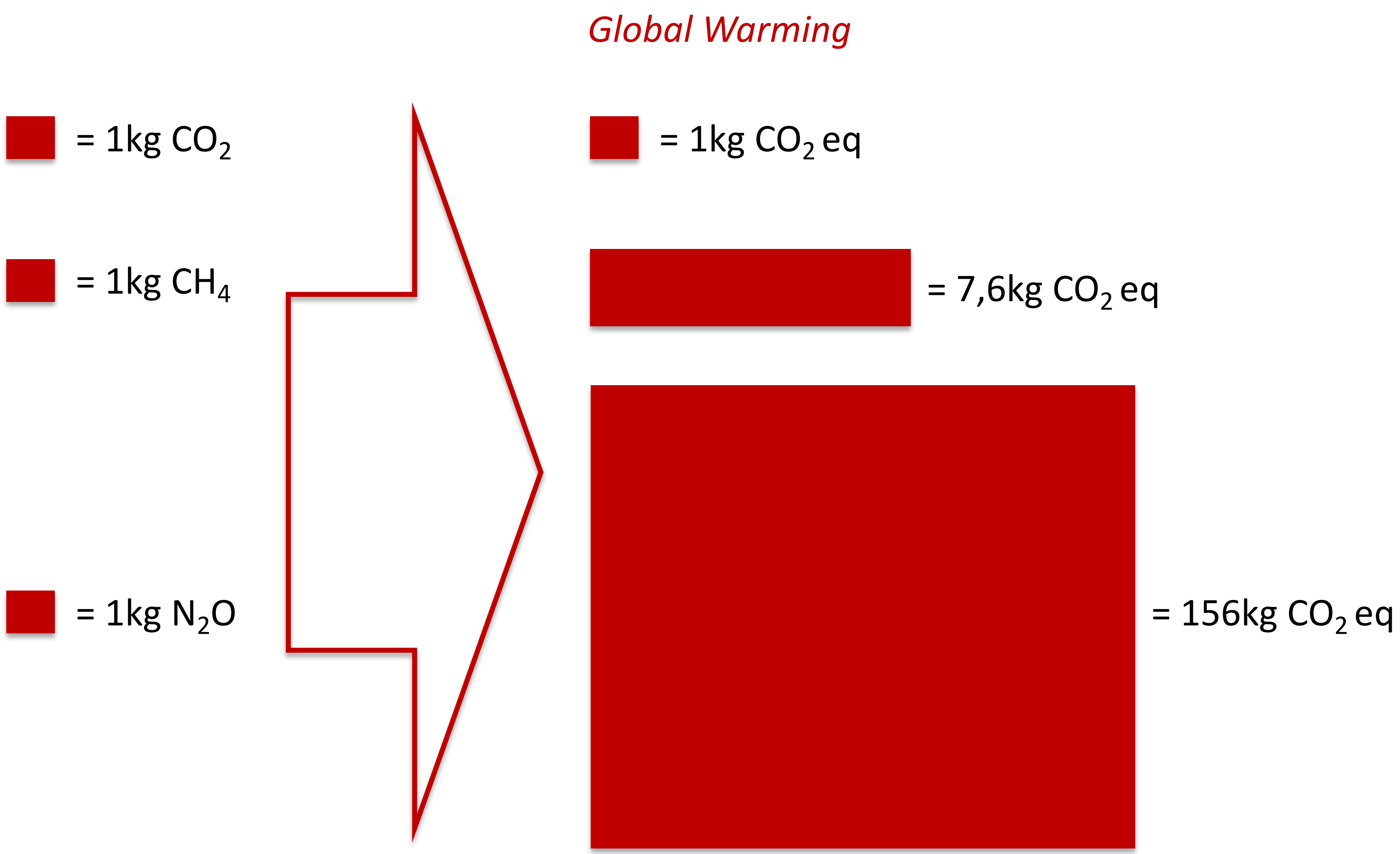
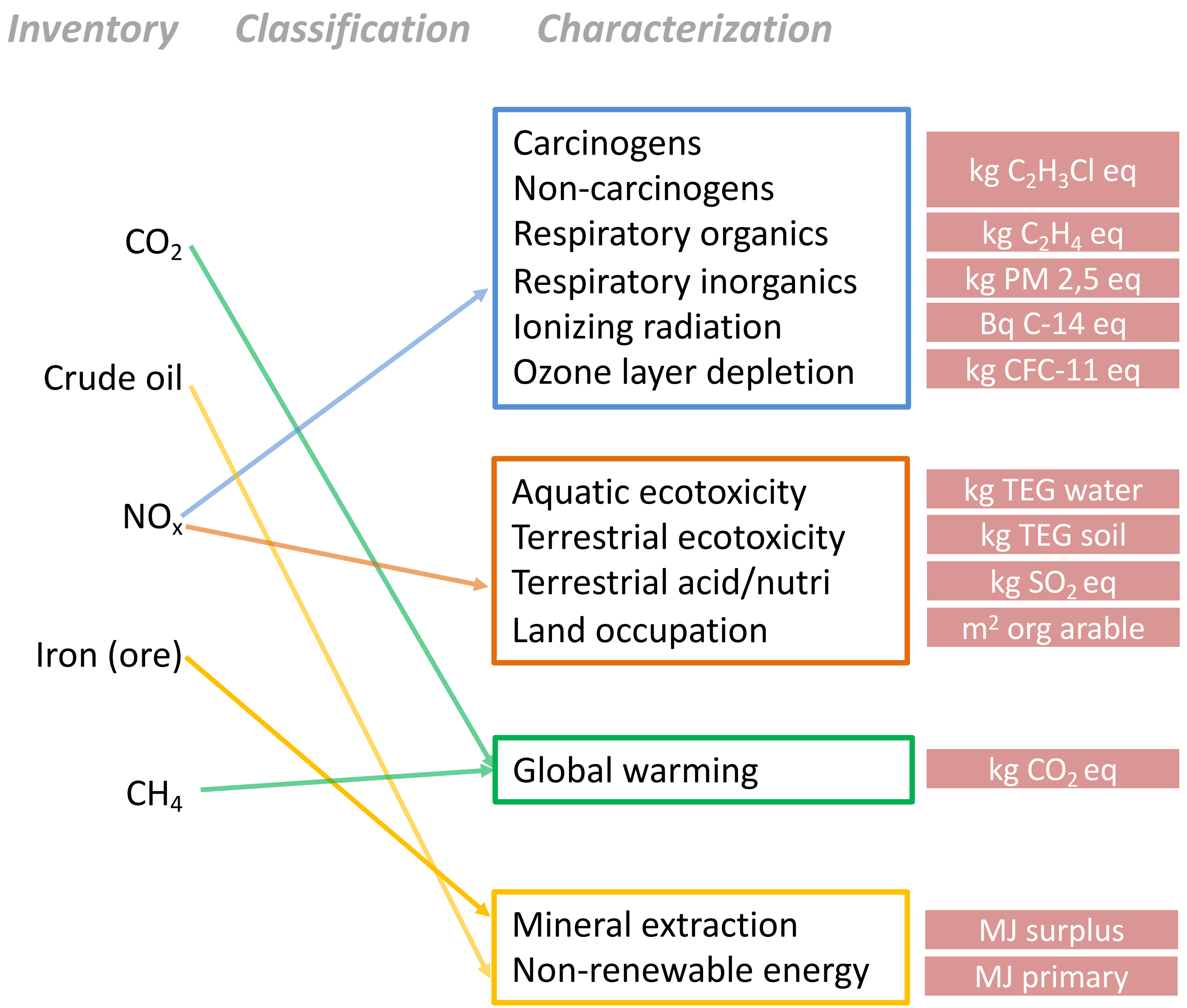
PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Characterization*



PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Characterization*



Reference method IMPACT 2002+

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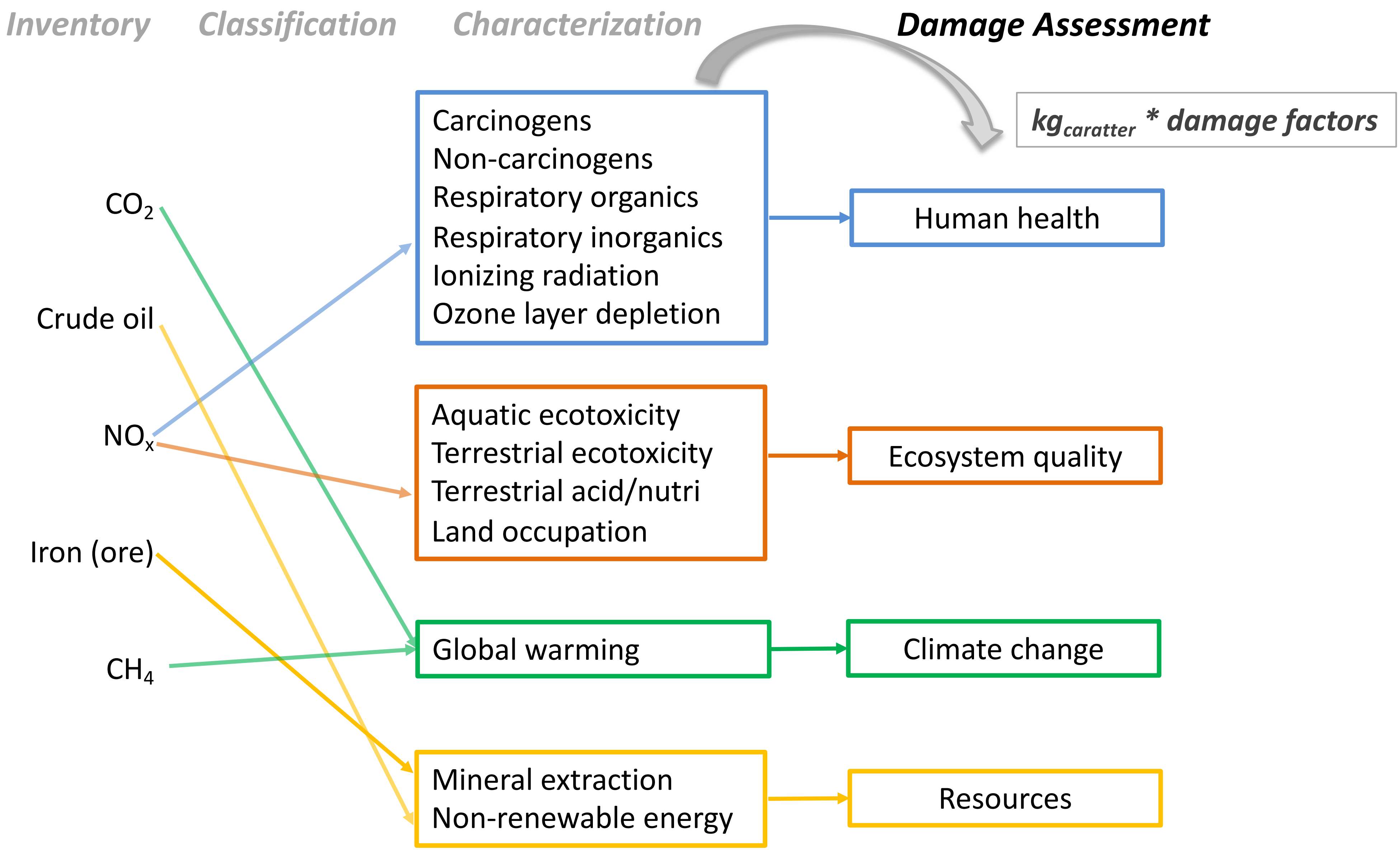
PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT – *damage assessment*



Reference method IMPACT 2002+

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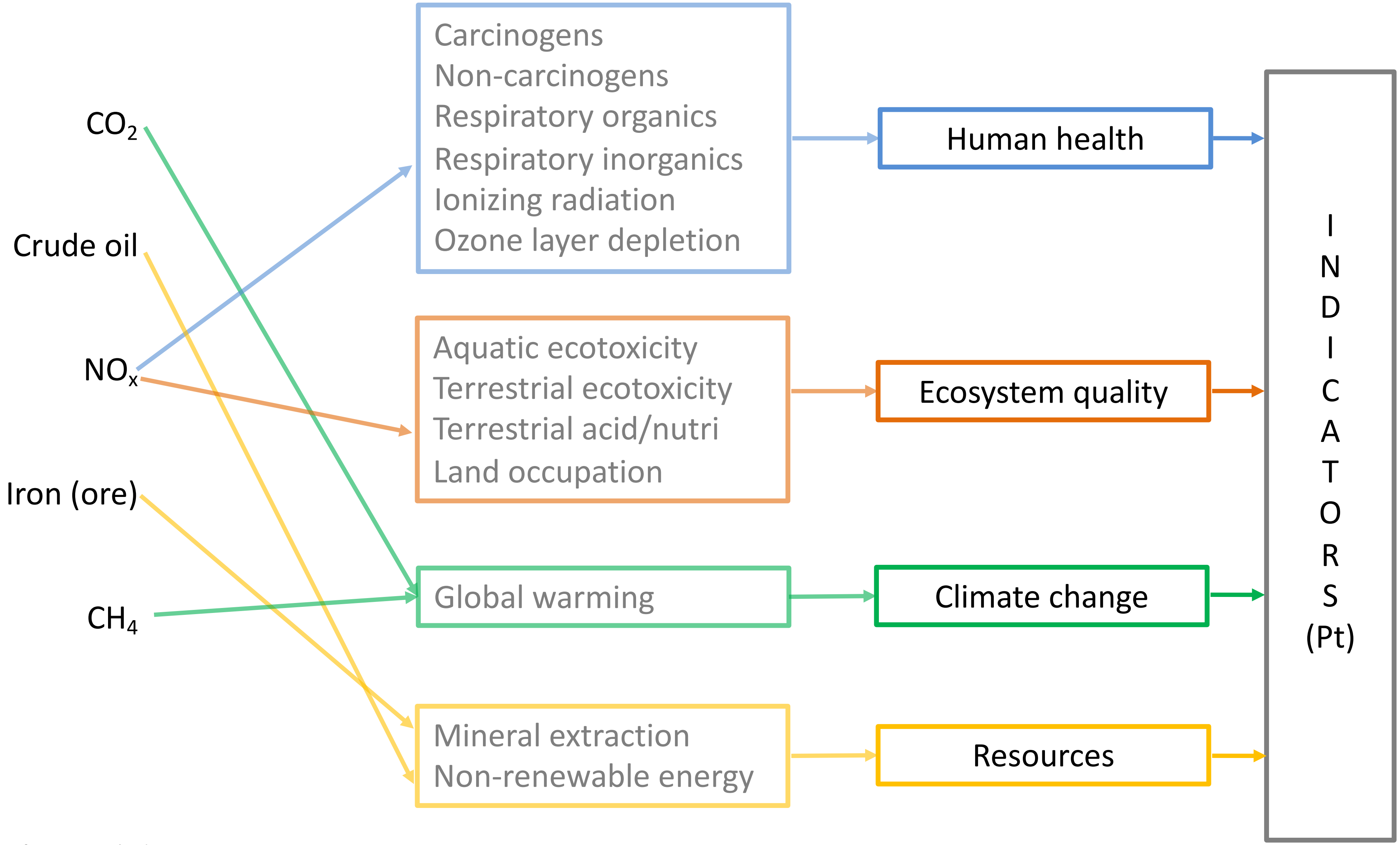
PHASE 3 - LIFE CYCLE IMPACT ASSESSMENT (LCIA) - *Optional*

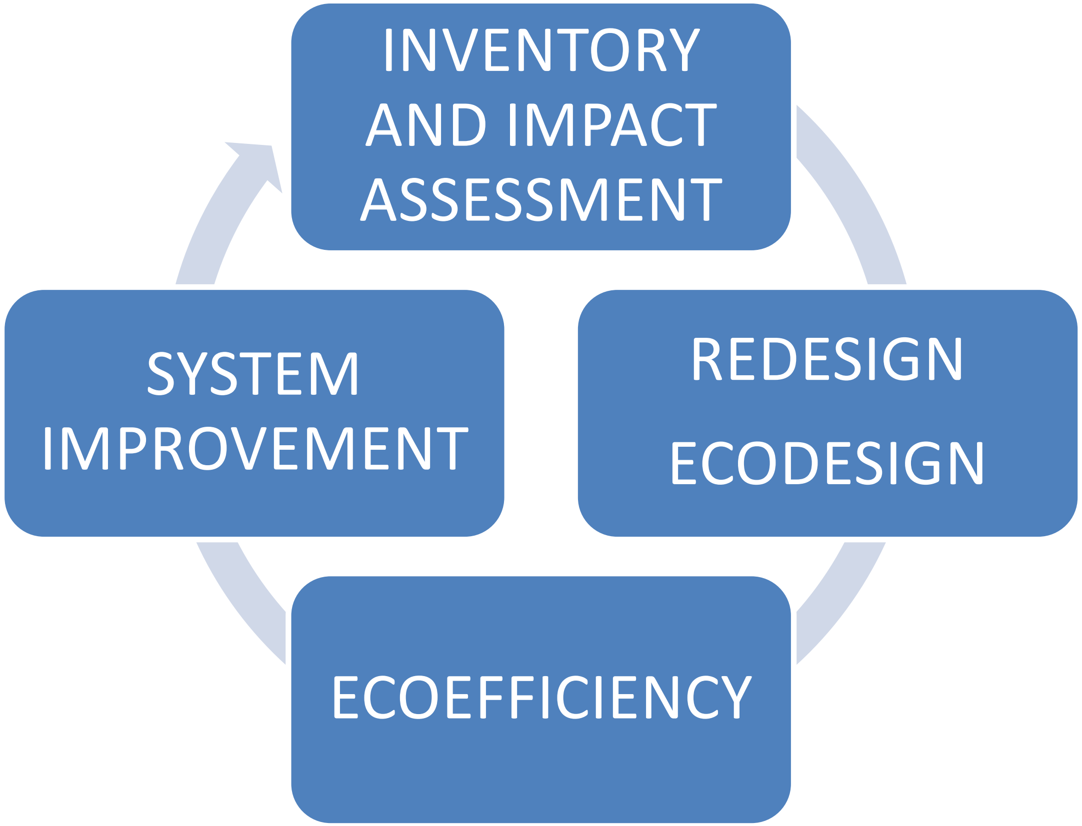
Inventory *Classification* *Characterization* ***Normalization and Weighing***



Reference method IMPACT 2002+

PHASE 4 – LIFE CYCLE INTERPRETATION

- Interpreting the results of an LCA is not simple: it requires **huge attention**.
- It is often necessary to make **assumptions**, estimates and decisions that are based on personal opinions or the decision makers involved.
- LCA provides decision makers with a **better understanding of the environmental and health impacts** associated with each solution examined by the study.

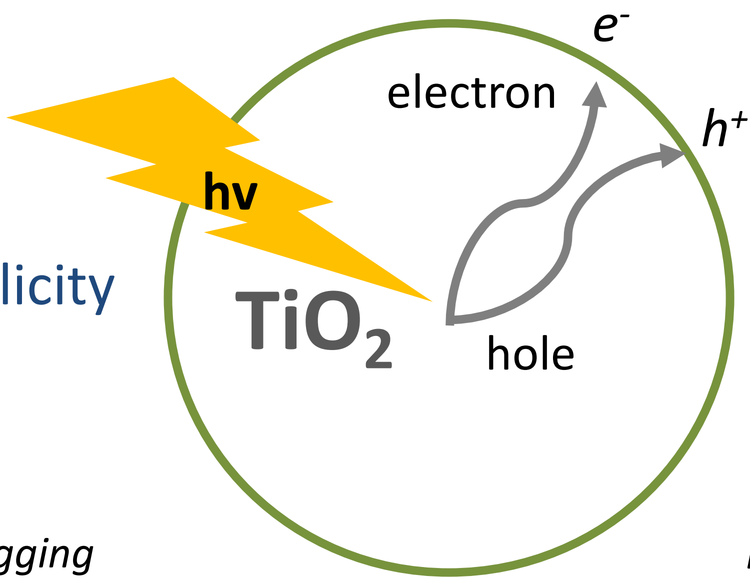


Life cycle assessment of nanoTiO_2 coated self-cleaning float glass

Self-cleaning float glass

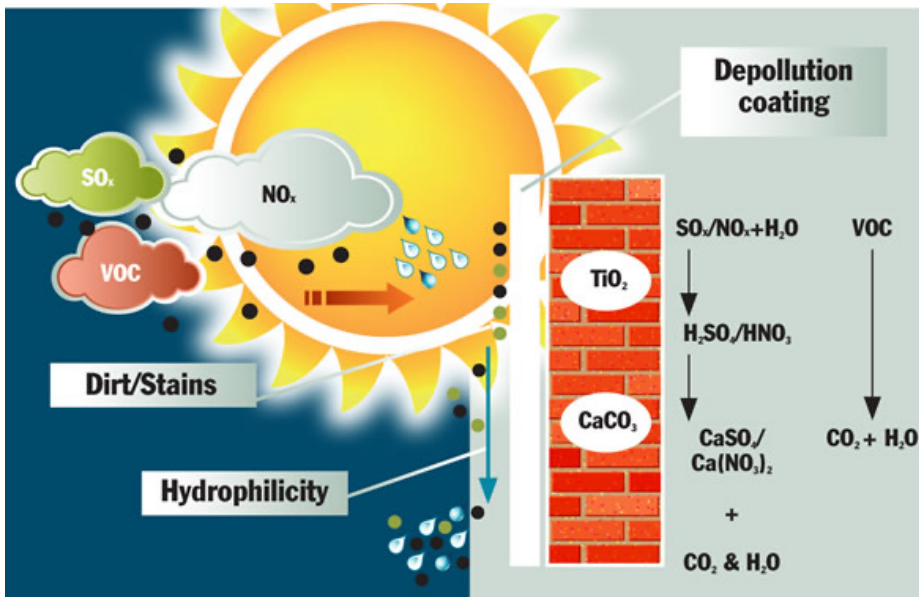
Self-cleaning glass is the largest commercial application of self-cleaning coating

Superhydrophilicity



Photocatalysis

Self-cleaning and Antifogging

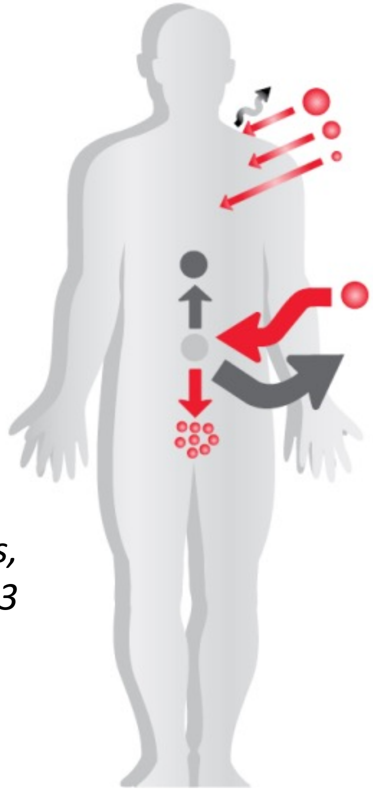


Decomposition of airborne pollutants

Nano-TiO_2: toxic and harmless?

Uncertainties and lack of knowledge on the behaviour and toxicity of nanoparticles:

References	
NIOSH *National Institute for Occupational Safety and Health*	**0.3 mg/m^3 = occupational exposure limits for ultrafine TiO_2** (concentration that would be sufficient to reducing the risk of lung tumors to a 1/1000 lifetime excess risk level)
IARC *International Agency for Research on Cancer*	**TiO_2 in Group 2B = "possibly carcinogenic to humans"** (sufficient evidence of carcinogenicity in experimental animals and inadequate evidence of carcinogenicity in humans)



Source: *Life cycle assessment of nanoTiO2 coated self-cleaning float glass, M.Pini, A.M.Ferrari, E.I.C.Gonzales, P.Neri, C.Siligardi / Proceeding of Nanotech 2013*

Determination of **damage on Human Health** caused by indoor and outdoor emissions of nanoTiO_2

In collaboration with EMPA - Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, ERAM Group - St. Gallen, Switzerland

	Outdoor emissions	Indoor/Inhaled emissions
Characterization factor	0.109 kg $_{C2H3Cl}$/kg $_{nanoTiO_2}$	1kg $_{C2H3Cl}$/kg $_{nanoTiO_2}$
Damage assessment factor	2.8 E-6 DALY/kg*	5.5 DALY/kg
New substance	***Particulates, <100 nm***	***Particulates, <100 nm indoor/inhaled***
Impact category	Carcinogens*	**Carcinogens inhaled**
Damage category	Human Health*	**Carcinogens inhaled**
Data input	emissions not captured by air filter and emissions not inhaled by workers	emissions not captured by face mask and so inhaled by workers

** Unchanged with respect to IMPACT 2002+*

Source: *Framework for human health characterization factor calculation of TiO2 nanoparticles,*
M. Pini, A.M. Ferrari, B. Salieri, R. Hischier, B. Nowack
Nanosafe 2014

Overview

- Italian project
  - ➢ 3 companies of Emilia-Romagna region

    → suppliers of building industries,
  - ➢ University of Modena and Reggio Emilia,
  - ➢ University of Bologna.

- Study new and eco-friendly building materials with higher technological properties obtained by the addition of a specific nanomaterial (TiO_2).

NanoTiO_2 coated self-cleaning float glass

System Function

Saint Gobain soda-lime float glass.

Outdoor coating surface with self-cleaning functions.

Functional unit: 1 m^2

System boundaries: *"from cradle to grave"*

Coating lifetime: 10 years

Data quality: primary data and secondary data (literature and DB data)

Calculation software: SimaPro

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Ecodesign of the industrial scale up

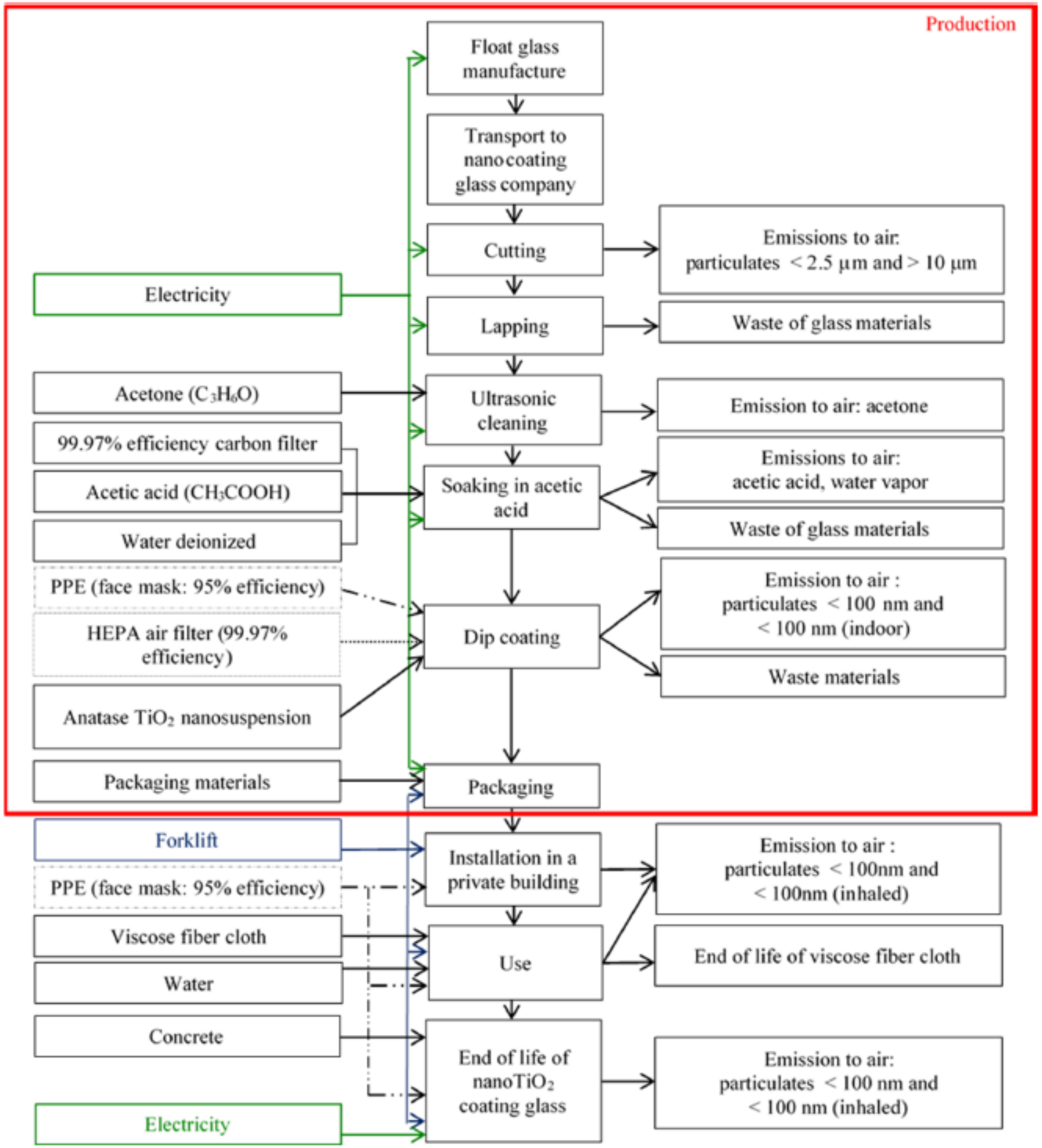
- Developed coating method → LABORATORY DATA

- Machinaries, equipment, internal transports, ordinary maintenance operations
- Installation, use and end of life steps

→ INDUSTRIAL SCALE-UP:
Stakeholder engagement;
Database, literature data

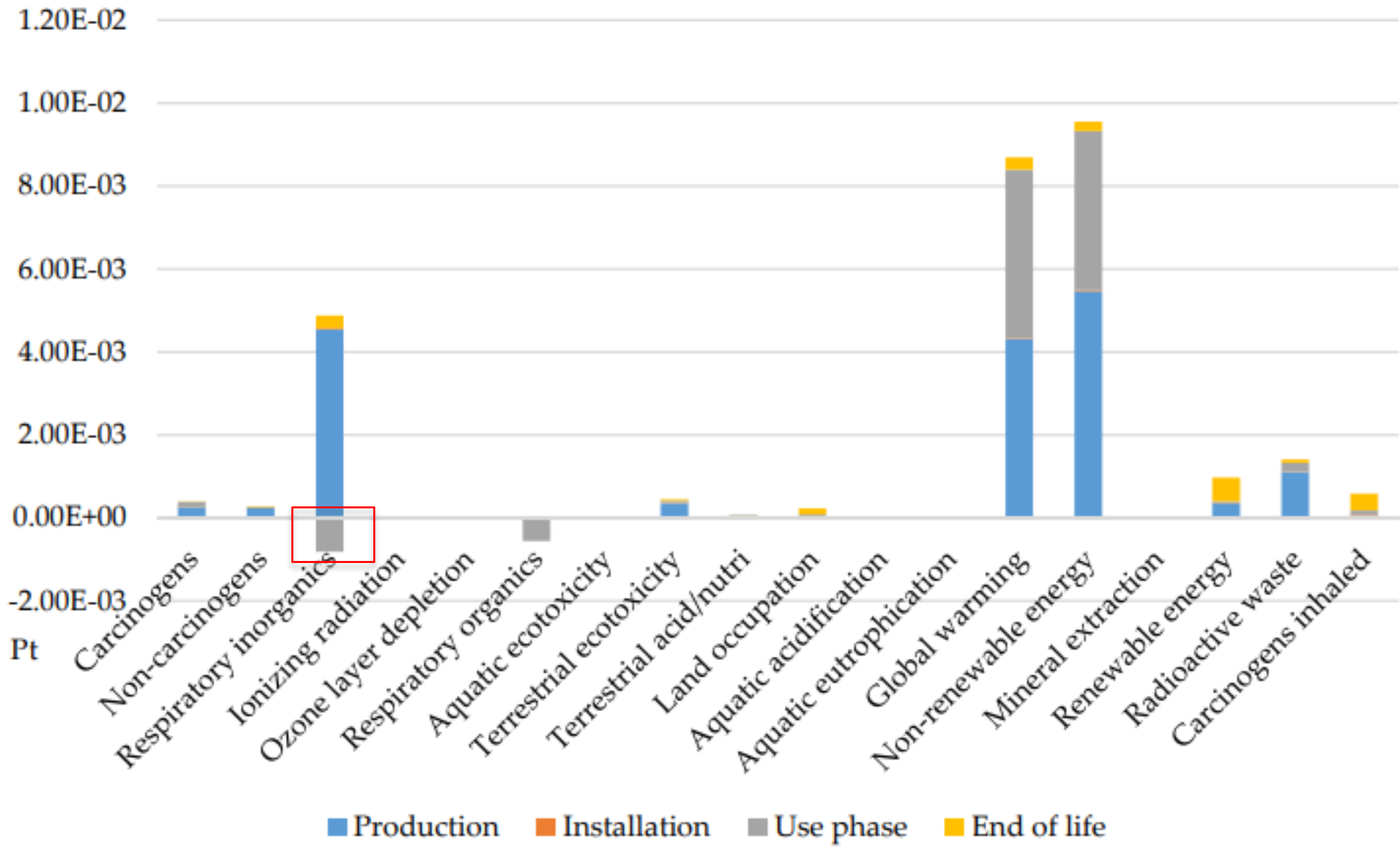
Flow Chart

nanoTiO₂ self-cleaning coated float glass



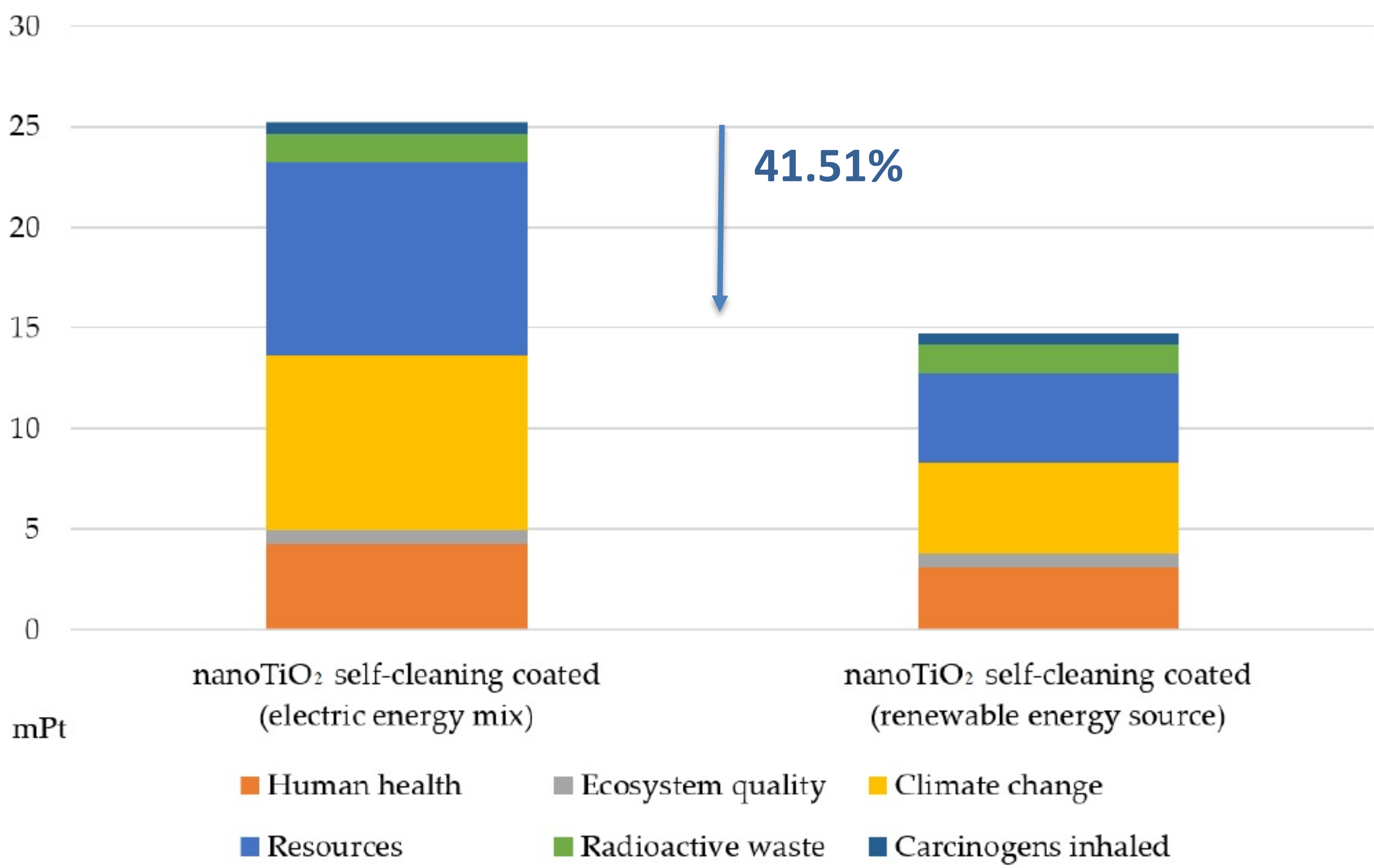
Life Cycle Impact Assessment

Total damage 25.22 mPt

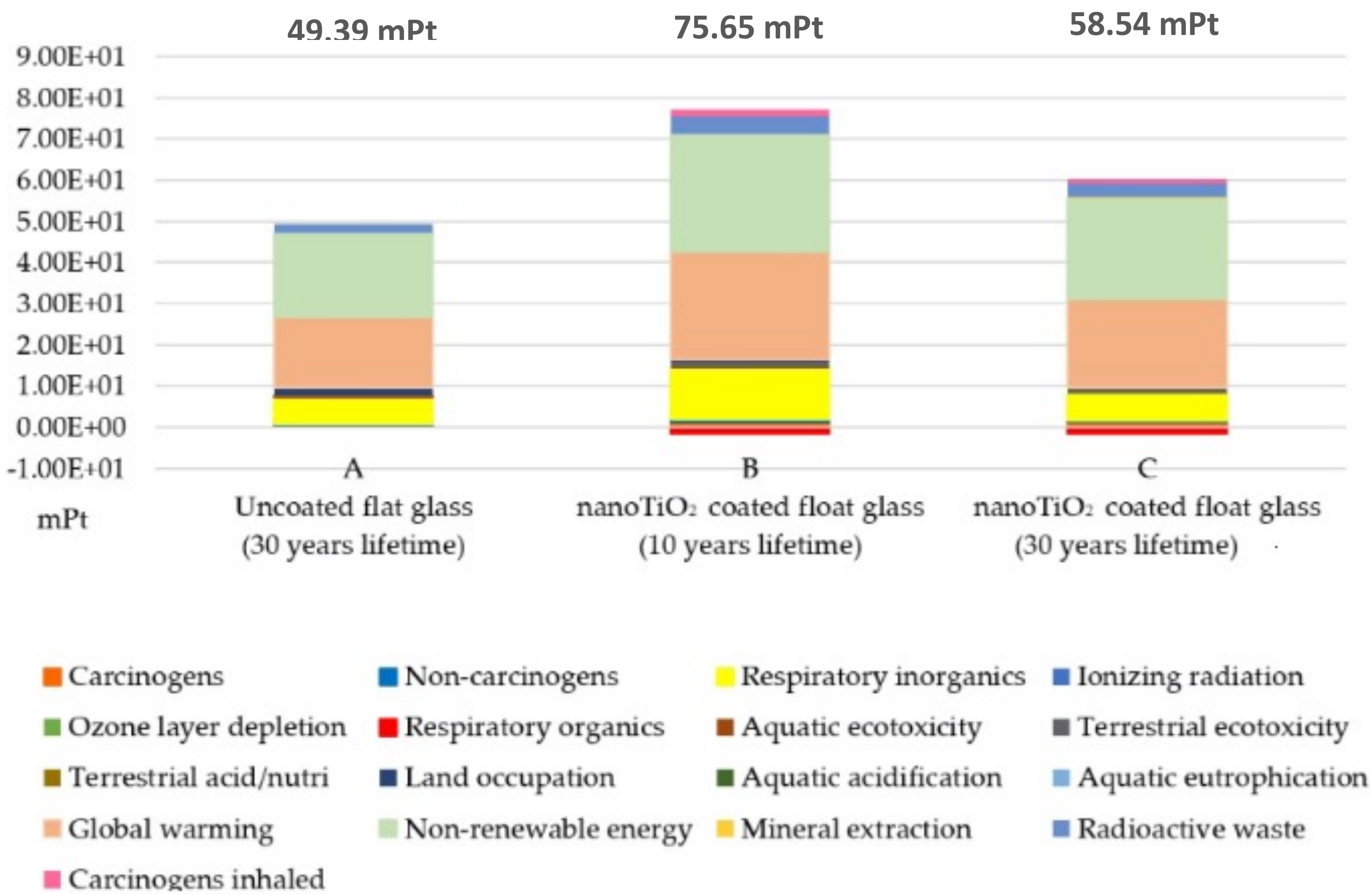


Production	Installation	Use	End of Life
65.08%	0.67%	28.16%	6.08%

Effects of Different Electricity Sources



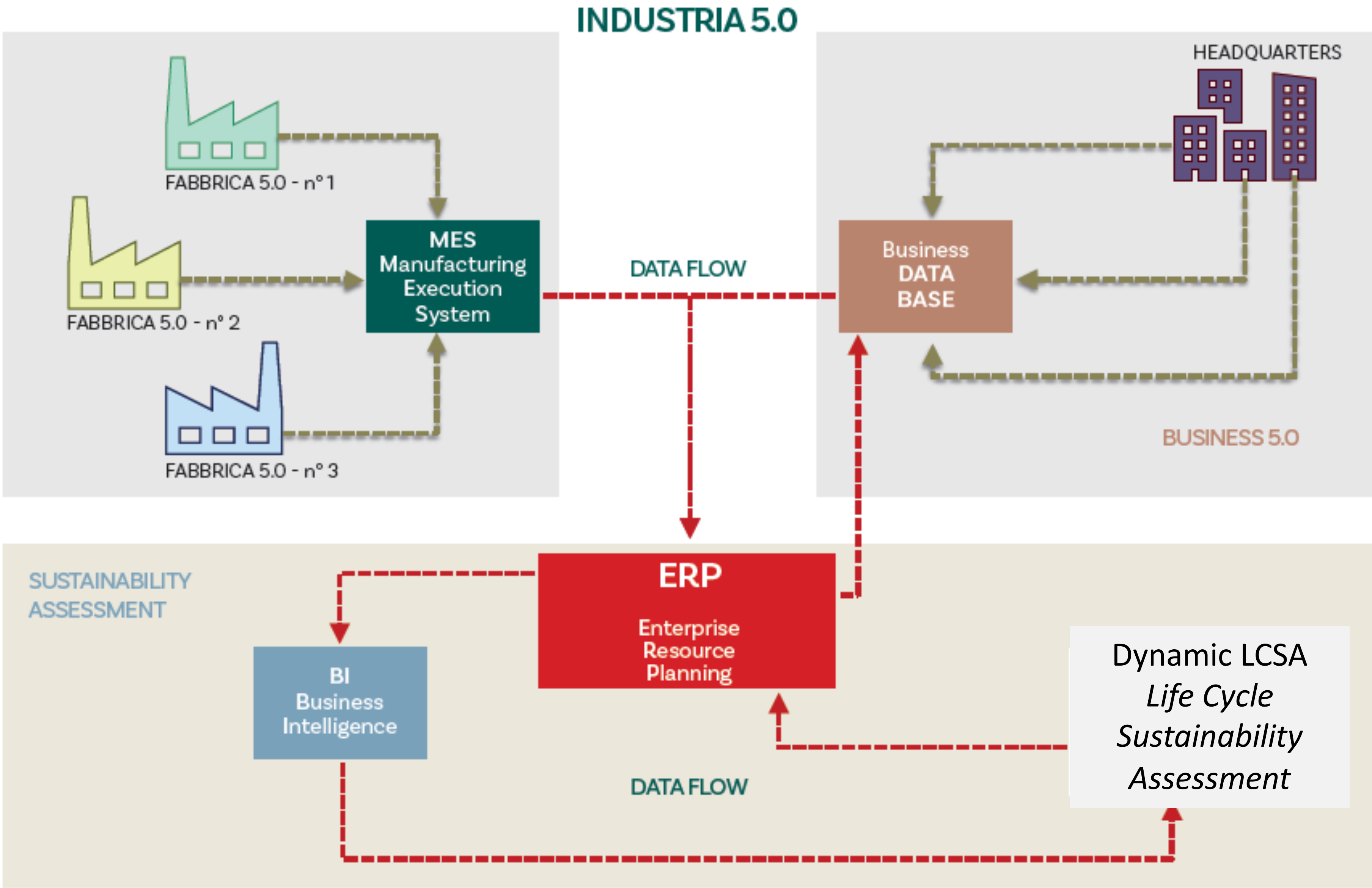
LCIA results of comparative analysis



Limits of LCA Methodology

- ✓ The nature of the choices and assumptions made in LCA can be subjective.
- ✓ The models used for inventory analysis or to assess environmental impacts are constrained by the assumptions that are implicitly contained within them.
- ✓ The results of an LCA study focusing on global or regional issues may not be suitable for more localized applications.
- ✓ The accuracy of an LCA study can be limited by the accessibility or availability of relevant or high-quality information.
- ✓ The lack of spatial and temporal dimensions in the inventory data used introduces uncertainty into the impact results.
- ✓ Being a scientific model, it is by its nature a simplification of a physical system: an absolute and complete representation of every environmental effect is not possible.

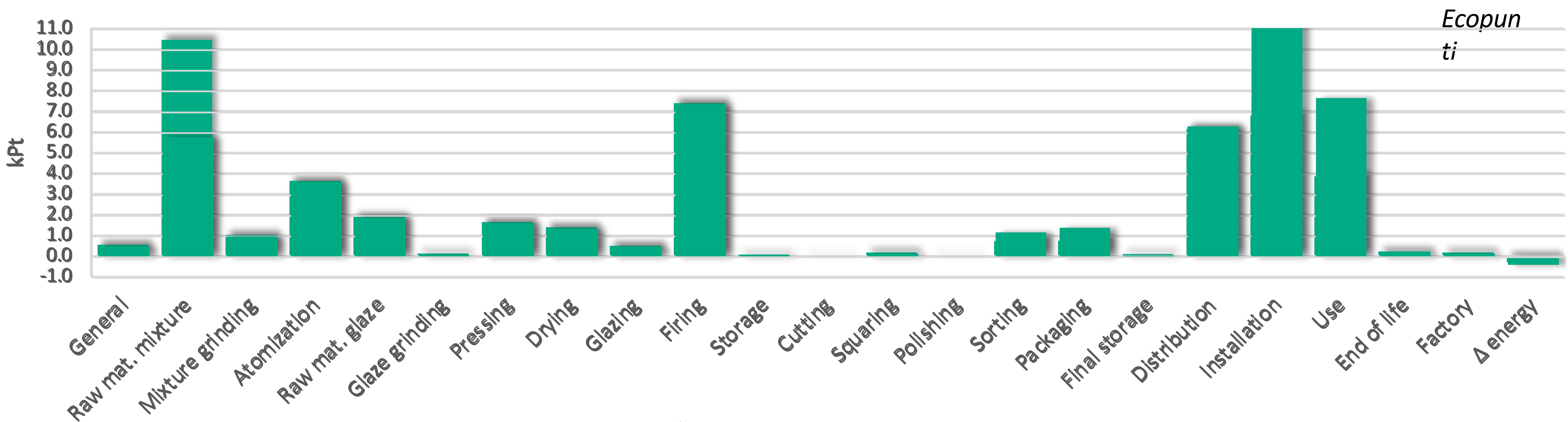
Digital Technologies as enablers of sustainability assessment

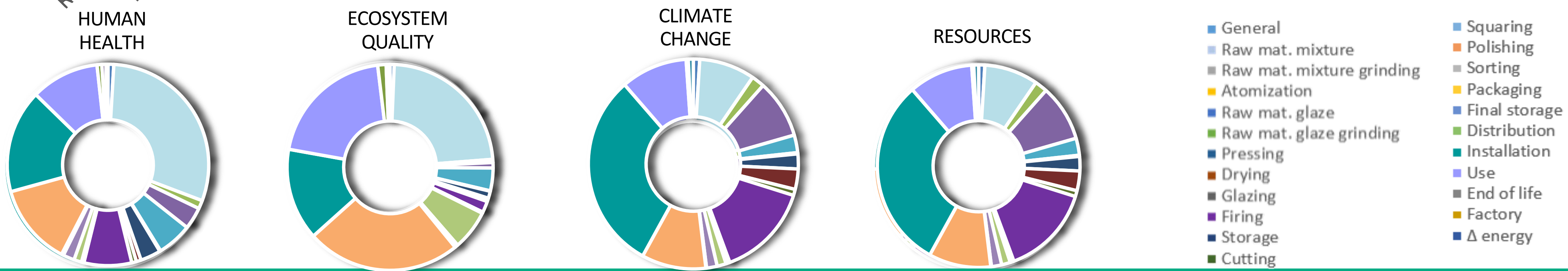


Source: Dott. Settembre Blundo

FORTURE
FORCE OF THE FUTURE

Dynamic LCIA of a porcelain stoneware ceramic tiles production





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GRUPPO CERAMICHE GRESMALT

Universidad Rey Juan Carlos

Thank you for your attention

LCA Working Group

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