LCA & EcoDesign for space

ESA Clean Space Team
UN / UNOOSA Training

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Agenda

1. **Context**
   - ESA Clean Space Overview
   - Concept of Ecodesign
   - Environmental performance of a product
2. **Life Cycle Assessment (LCA)**
   - LCA overview
   - LCA methodology
3. **LCA and Ecodesign at ESA**
   - LCA specificities to space sector
   - Ecodesign definition
   - Ecodesign approach
   - Ecodesign principles application – examples
4. **Conclusion**

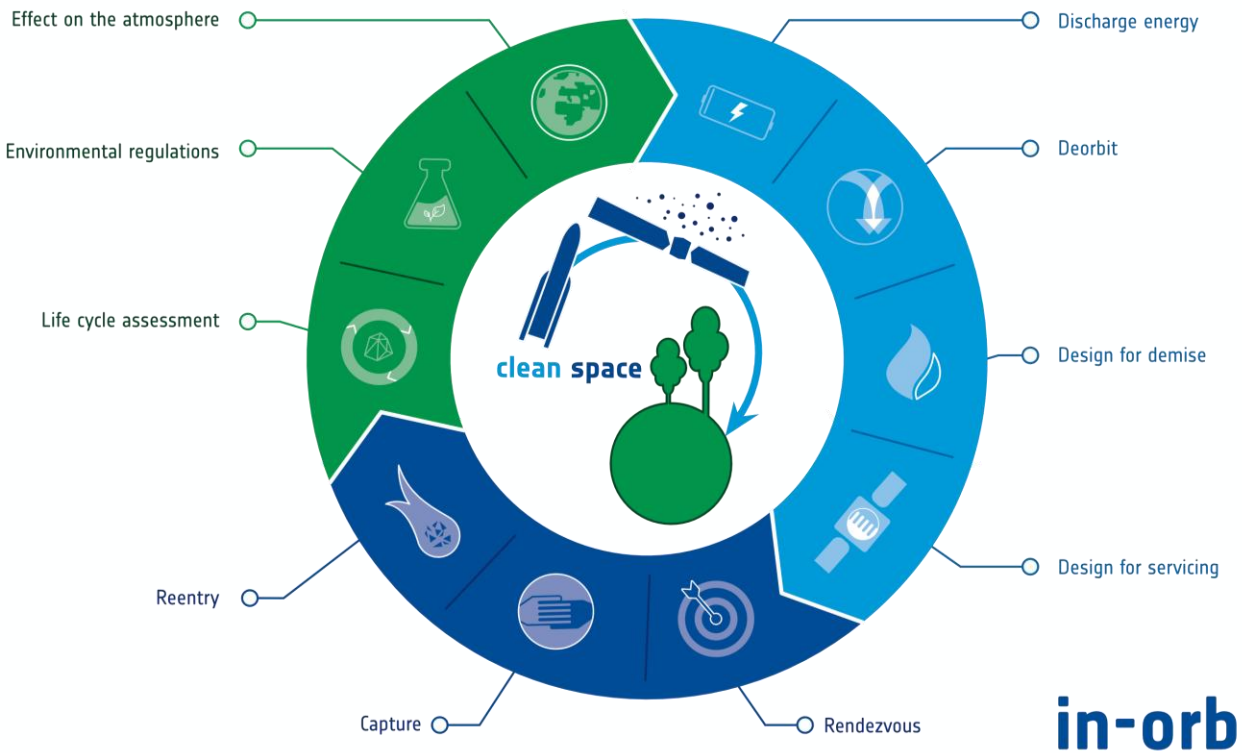
Clean Space

ecodesign

→ REDUCING IMPACTS

management of end of life

→ SPACE DEBRIS REDUCTION



in-orbit servicing

→ ACTIVE DEBRIS REMOVAL

Clean Space

ecodesign

→ REDUCING IMPACTS

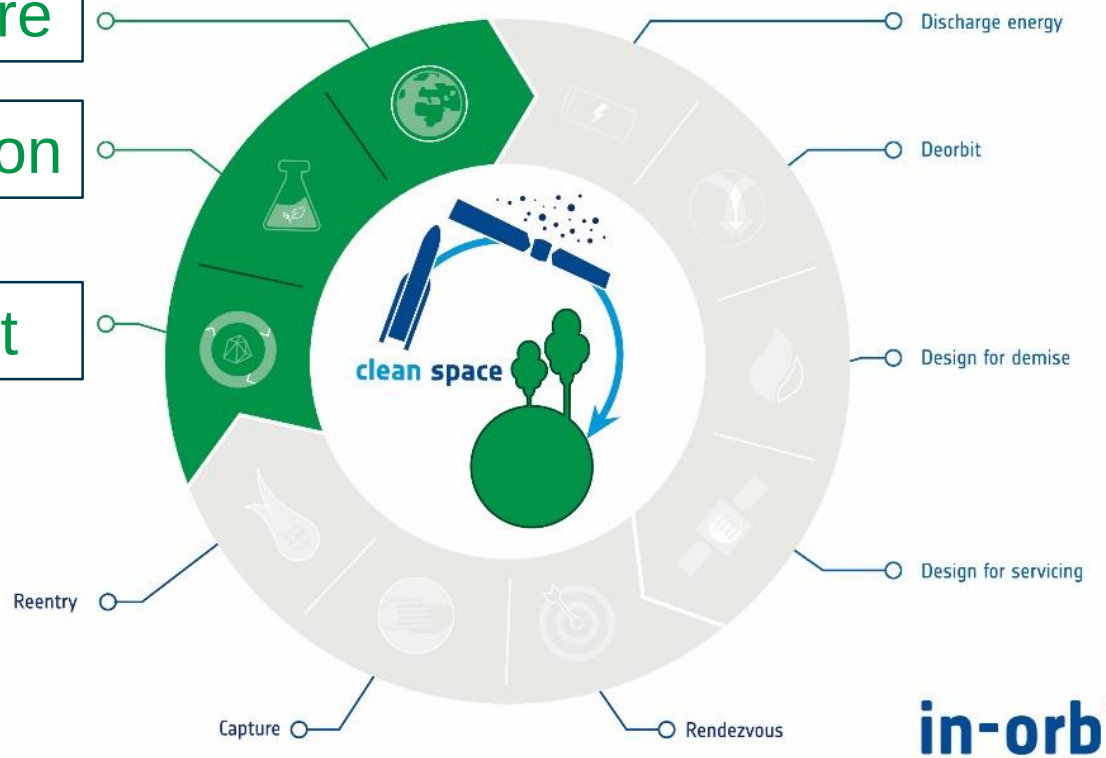
management of end of life

→ SPACE DEBRIS REDUCTION

Effect on the atmosphere

Environmental Regulation

Life Cycle Assessment



in-orbit servicing

→ ACTIVE DEBRIS REMOVAL

EcoDesign Branch

EcoDesign

Is necessary to understand how much space activities pollute on Earth and to identify alternatives to reduce the environmental impacts

LCA (Life Cycle Assessment)

Assessing the environmental impacts of the whole life cycle of the space missions

Eco-design

Identifying alternative processes or technologies that can be used to reduce these impacts

Enuironmental regulation

Finding alternatives to abide by legislations and avoid costly disruptions

ecodesign

Context: Space sector at international level

27.3 States and international intergovernmental organizations should promote the development of technologies that minimize the environmental impact of manufacturing and launching space assets and that maximize the use of renewable resources and the reusability or repurposing of space assets to enhance the long-term sustainability of those activities.

United Nations

General Assembly

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Fifty-fourth session
Vienna, 30 January-10 February 2017

ESA Agenda 2025

ESA Director General's Agenda 2025 reiterated that **making ESA "a greener organisation"** is a **priority**, to support the implementation of the Paris Agreement and the European Green Deal to the fullest extent

Assessment of the environmental performance

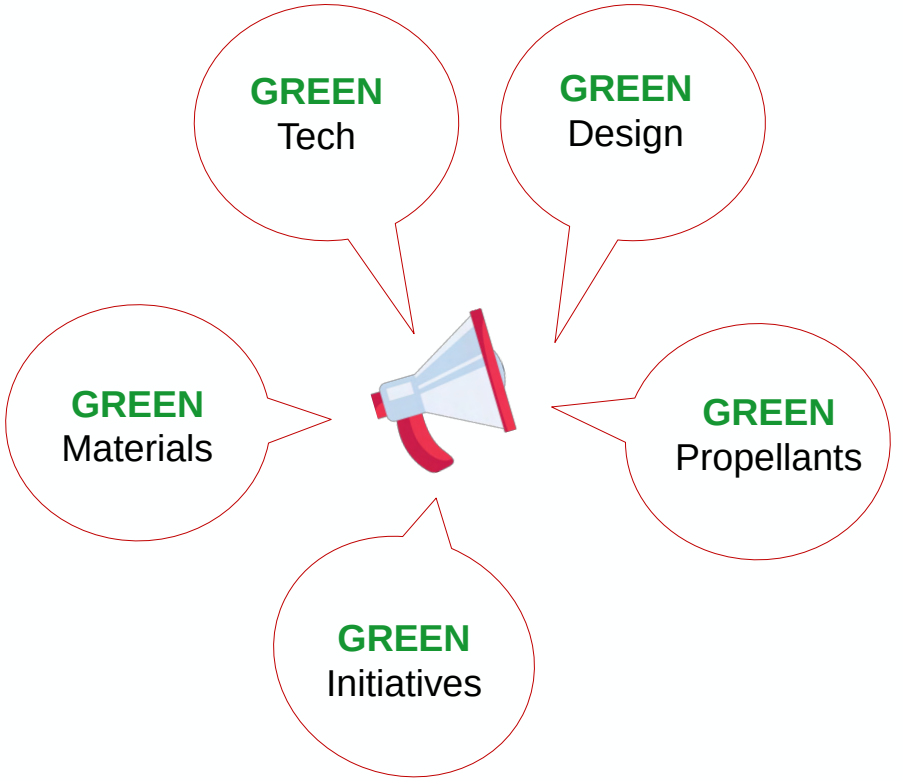
Toxicity ? (impact on Human health)

Eco-toxicity ? (impact on Ecosystems)

Carbon Footprint ? (impact on Climate Change)

Bio-based ? (impact on resource depletion)

Only compliant with the European legislation?



Reliable, comparable and verifiable information also plays an important part in enabling buyers to make more sustainable decisions and reduces the risk of 'green washing'. Companies making 'green claims' should substantiate these against a standard methodology to assess their impact on the environment. The Commission will step up its regulatory and non-regulatory efforts to tackle false green claims.

Brussels, 11.12.2019
COM(2019) 640 final

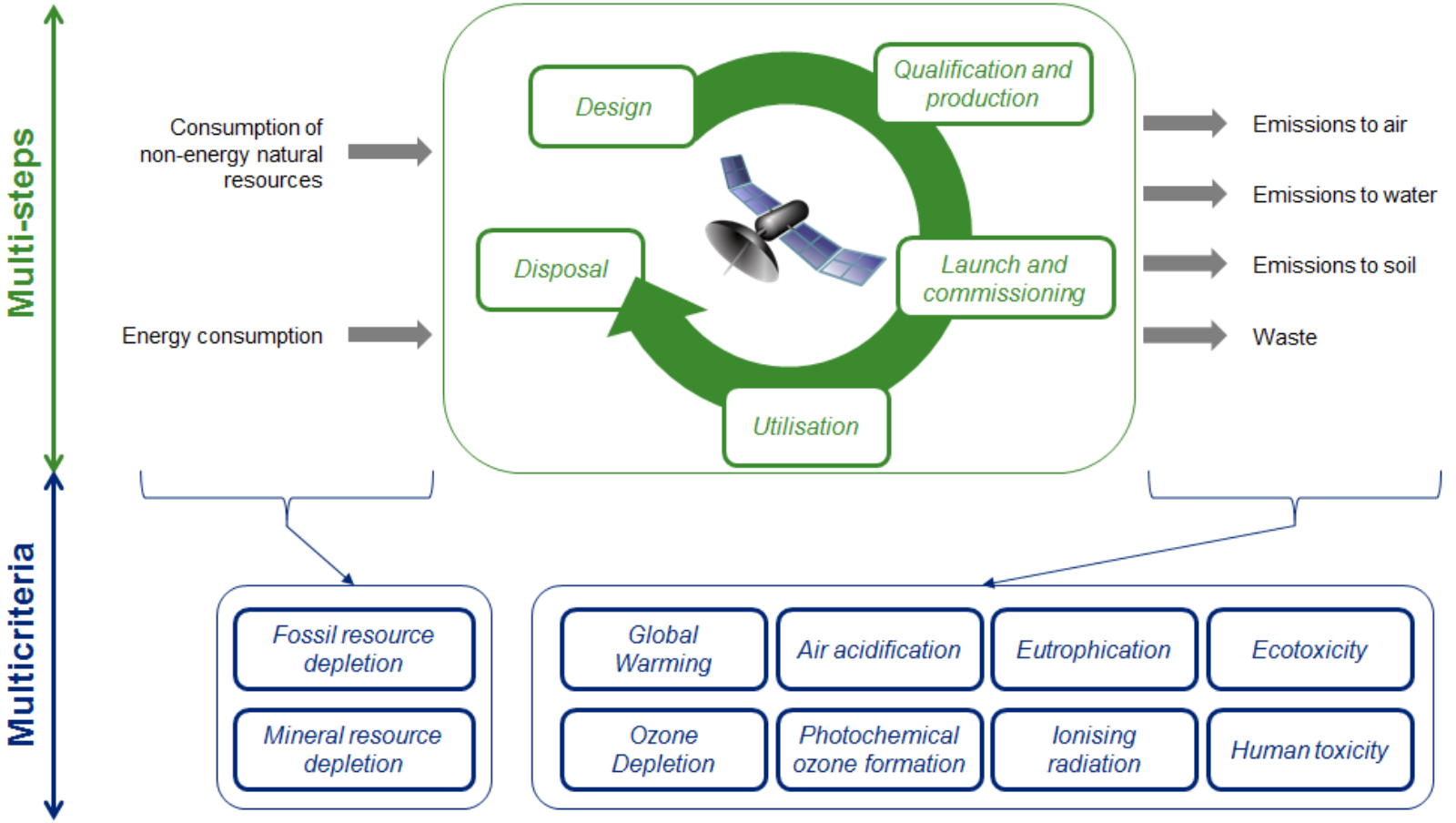
How to perform a Life Cycle Assessment?

Life Cycle Assessment – Definition

LCA is an ISO-standardised tool to quantitatively assess the potential environmental impacts of product, process or service

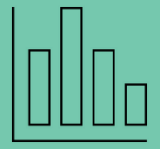
- ✓ **Multi-step analysis**
  The environmental impacts are assessed across all stages of existence.

- ✓ **Multi-criteria analysis**
  The outcomes are expressed with several quantified environmental indicators (impact categories).



Life Cycle Assessment – Rationale

Why LCA?



Takes in account full life cycle and full set of environmental impacts
To have a complete picture, not only focused on one impact category

Identifies environmental hotspots
To provide a basis for environmental impact mitigation

Performs technology trade-off
To support eco-design and avoid burden shifting (i.e., reducing impact from impact category but increase it in another)

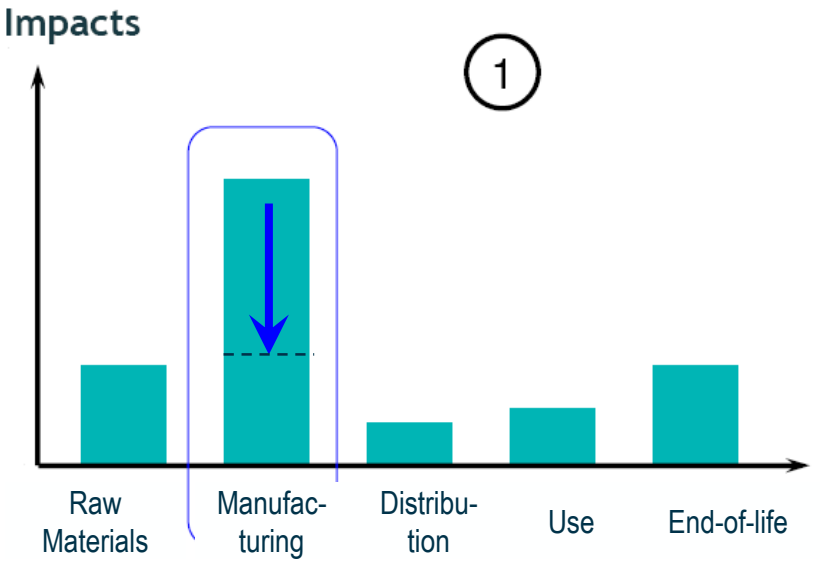
Delivers visual clear outputs
To support communication on environmental issues

Better monitoring of the supply chain
To trace compliance with environmental legislations and avoid potential project disruption

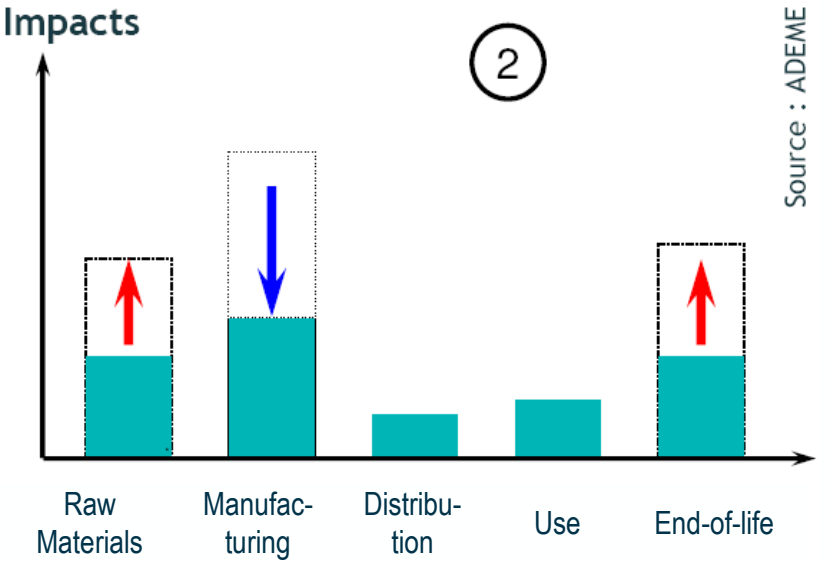
Burden Shifting

- Avoid burden shifting:
  - from a life cycle step to another one
  - from a location to another one
  - from an ecosystem to another one
  - from an impact category to another one

Improvement of manufacturing:
Reduction of impacts



But **aggravation in other steps**



Example: Burden Shifting

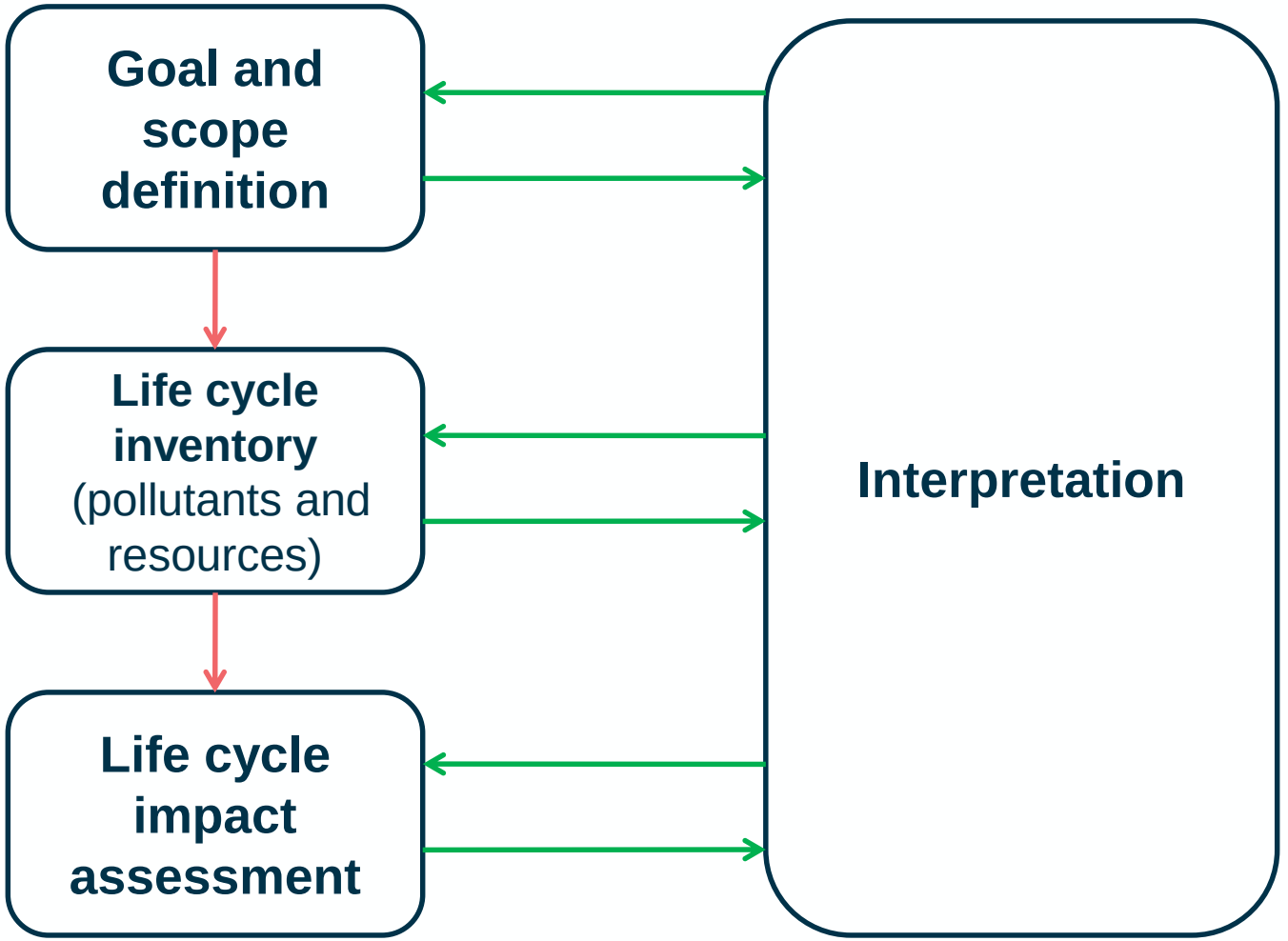
Fossil CO_2

Electric uehicles

Decrease of the impact « climate change » during the use phase

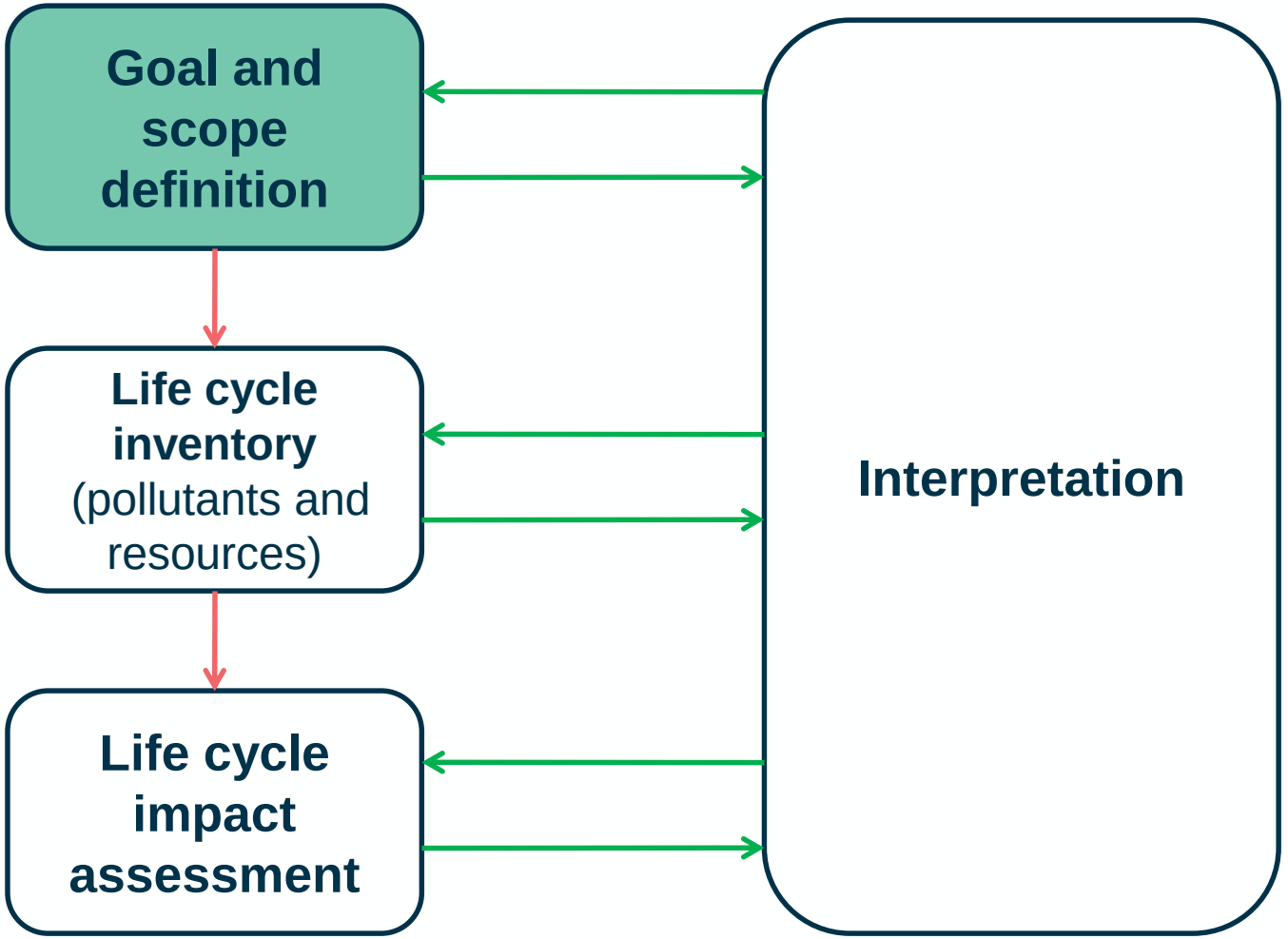
generation of other impacts during the production of electricity !

LCA: Four major steps



ISO 14040 - 14044

1st Step: Goal and Scope definition



Definition of the goal

The first step consists in defining the objectives of the study and the system that will be studied

Examples of common goals for an LCA:

- Identify the main sources of impacts of a product for improving its environmental performance
  - (Eco-design purpose)
- Environmental communication, eco labelling
- Assist decision makers / public policies
- Regulation, certification
  - (e.g. sustainable criteria of biofuels [Directive 2009/28/EC])

Goal and Scope - Functional Unit

To compare 2 systems (or 2 scenarios of a same system) we need to define a common function => we define a functional unit:

The reference value

Depends on the function of the product (provided service)

All the flows depends on the functional unit

Measurable and additive

In general, a functional unit is expressed as :

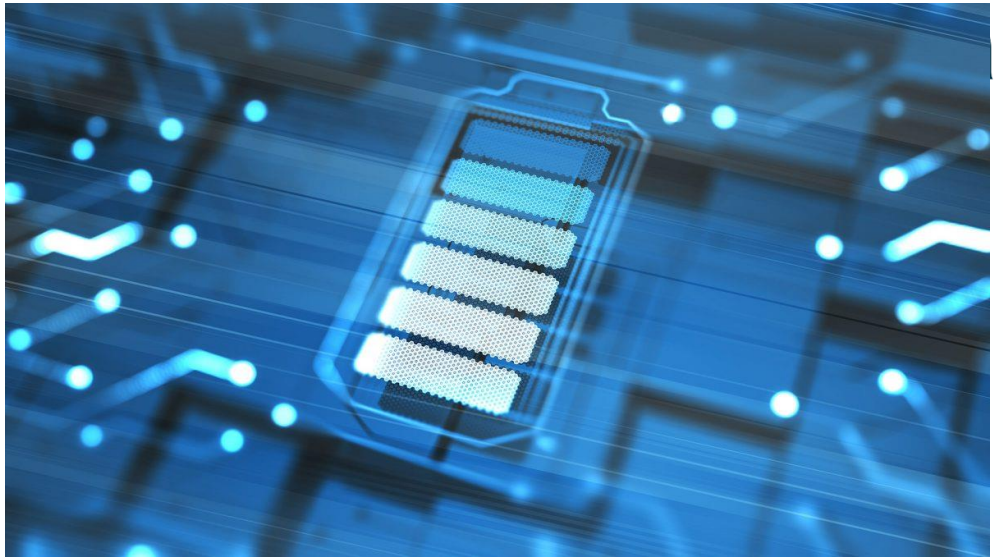
1 action verb + 1 quantity (targeted performance level) + a condition (optional)

Example to compare hand driers

Dry 1 pair of hands in less than 15 seconds

Functional Unit

What?	Electrical energy, measured in Wh or kWh (current and voltage during a unit of time).
How much?	1 kWh of the total energy delivered over service life (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle).
How well?	Maximum specific energy (measured in Wh/kg). Specific product standards and technical properties of the high specific energy rechargeable batteries PEF shall be declared in the PEF documentation
How long?	The amount of cumulative energy delivered over service life of the high specific energy rechargeable batteries (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle). The time required to deliver this total energy is not a significant parameter of the service.



Source: EIT innoEnergy

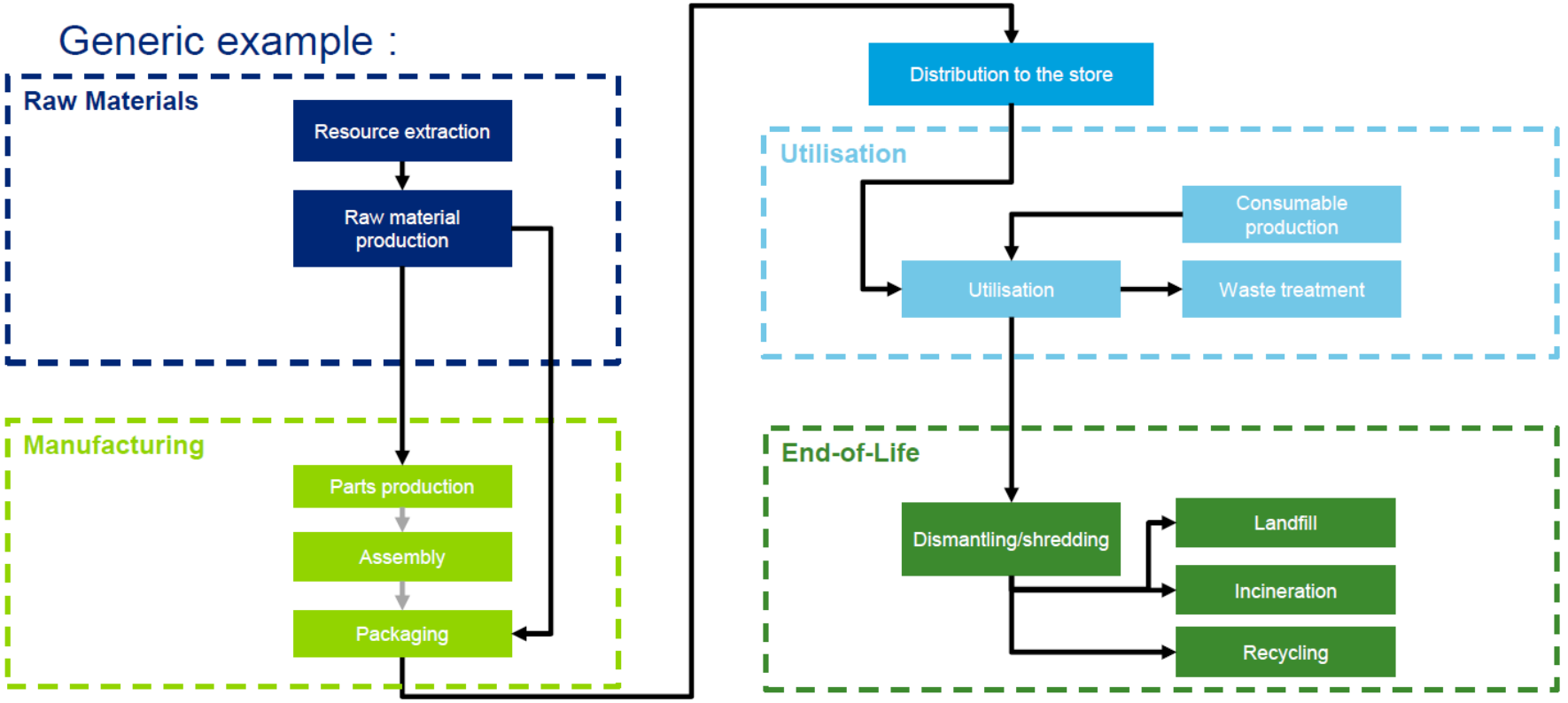
Source: Recharge (2020) PEFCR for high specific energy rechargeable batteries for mobile application

Abbr.	Parameter	CPT battery	Unit
Edc	Energy delivered per cycle	0,045	kWh/cycle
Nc	Number of cycles	400	number
Acc	Average capacity per cycle	80%	%
QUa	Quantity of functional unit	14,4	kWh over service life / per battery

*A: **1** kWh of <u>the total energy provided</u> over the service life by the battery system*

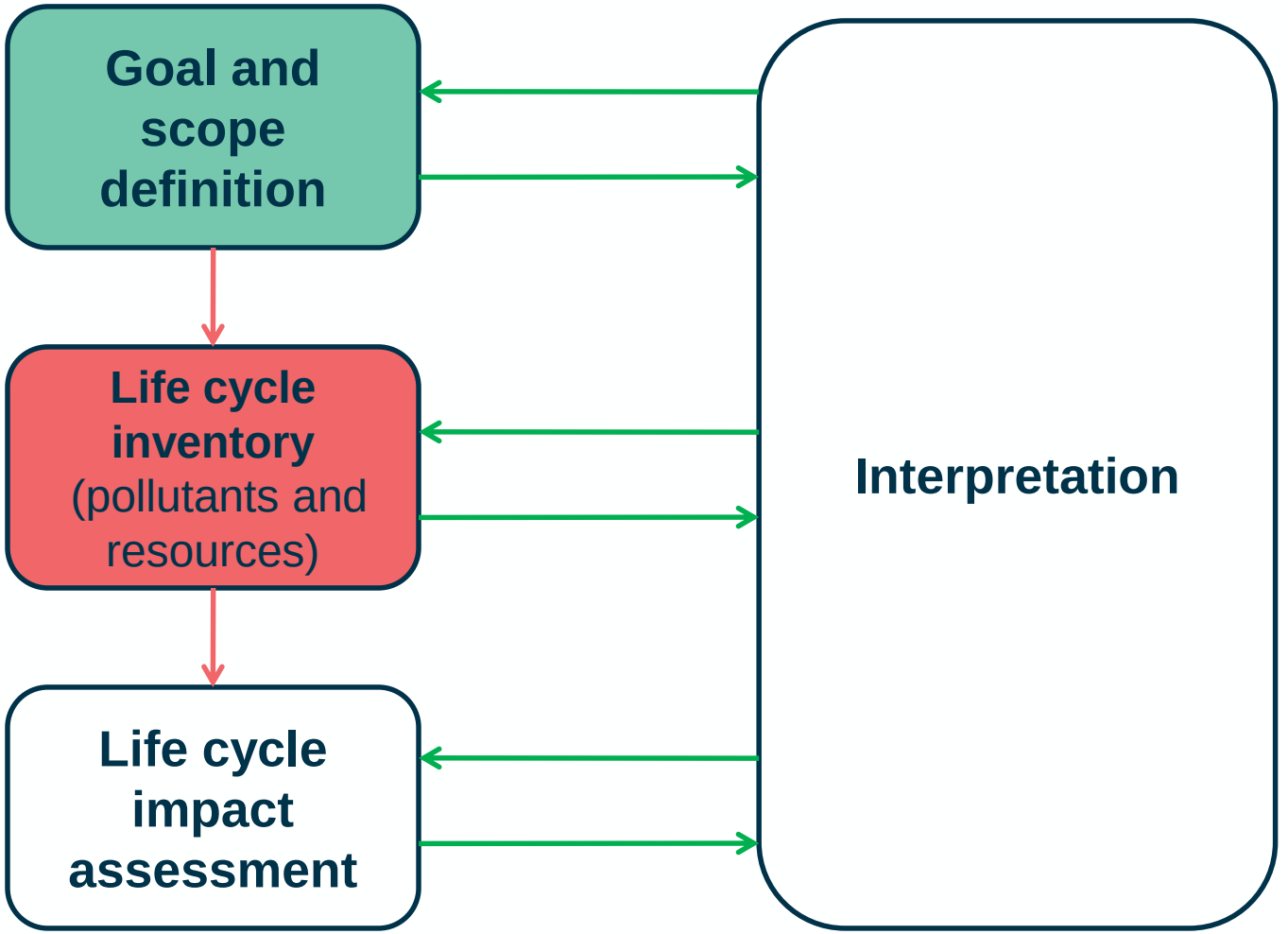
Goal and Scope – System boundaries

The system boundary should include all activities that contribute to fulfilling the functional unit



Credit: Deloitte Sustainability

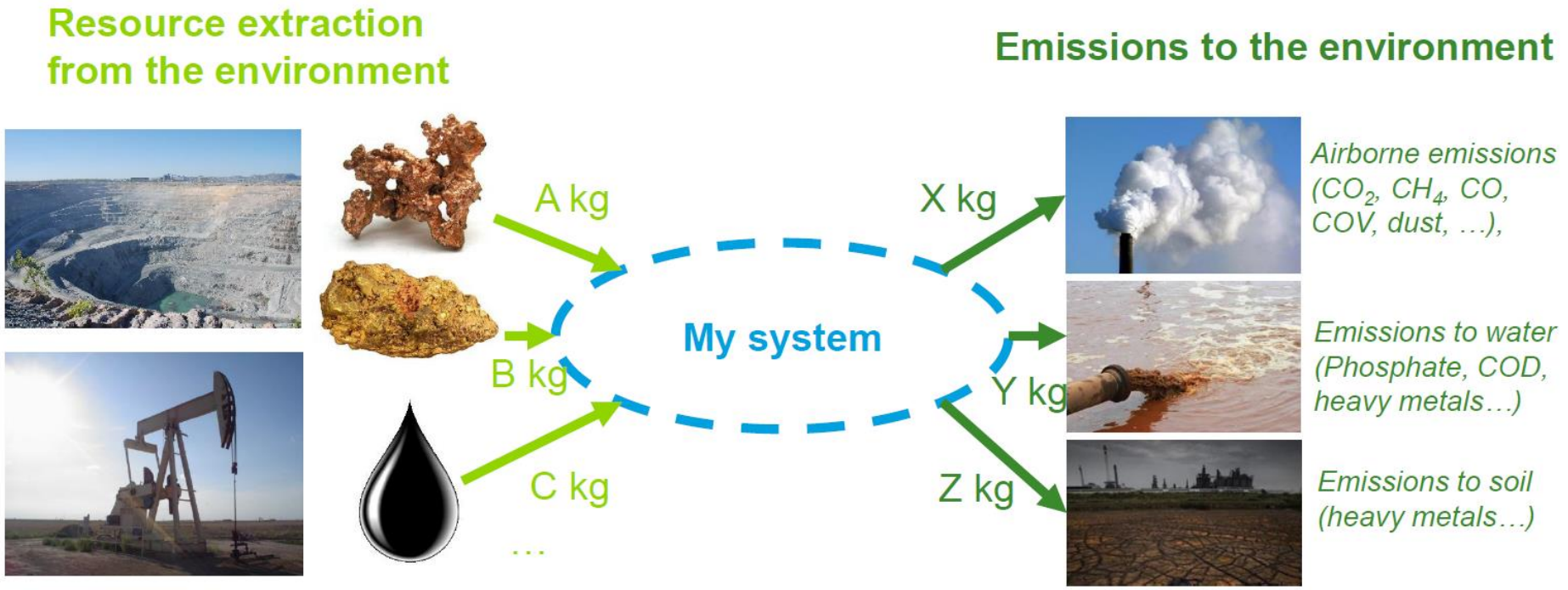
2nd Step: Life Cycle Inventory (LCI)



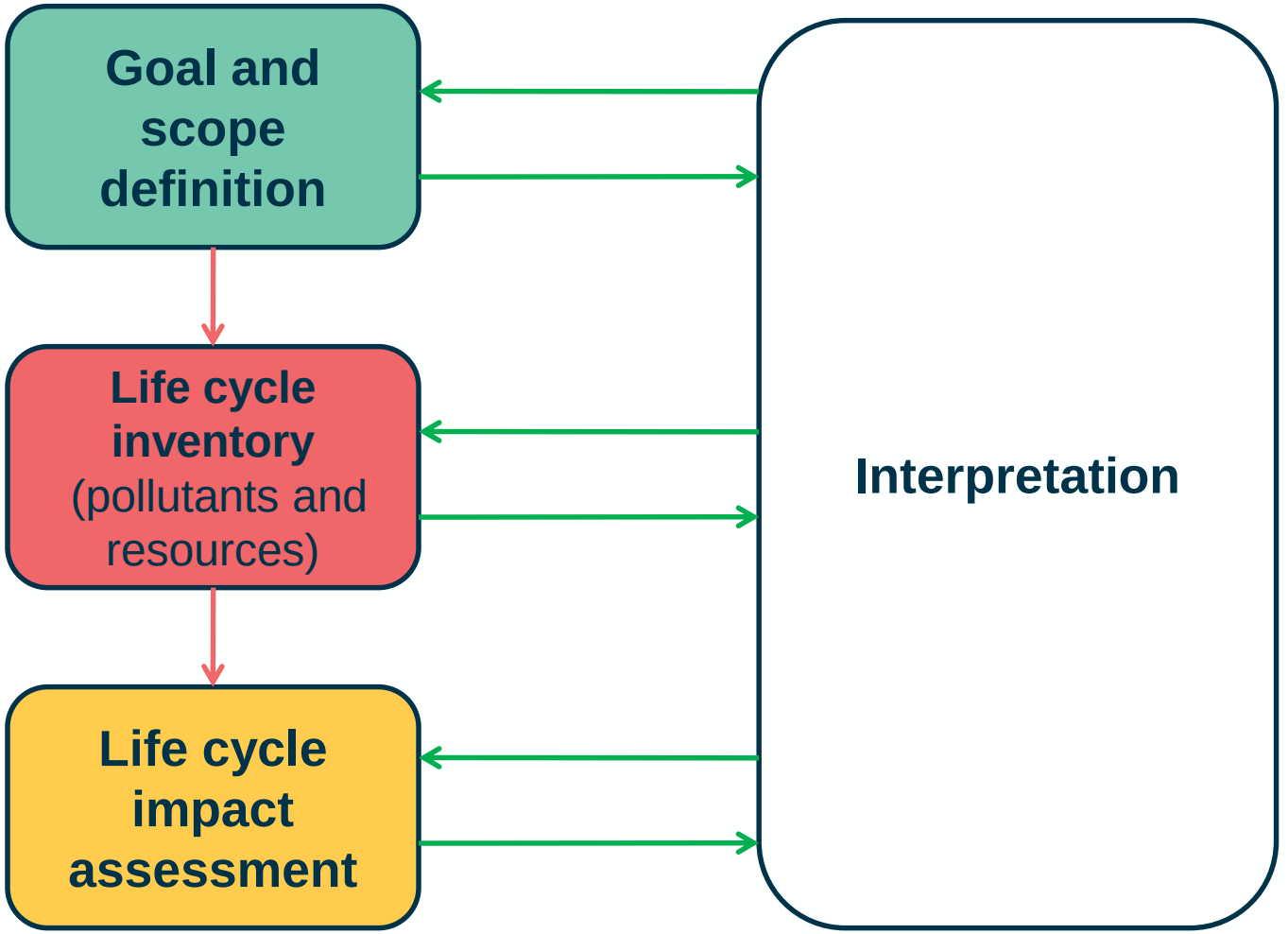
Life Cycle Inventory (LCI)

The life cycle inventory analysis consists in compiling all the elementary flows that either come in or come out of the system in order for it to fulfill its function.

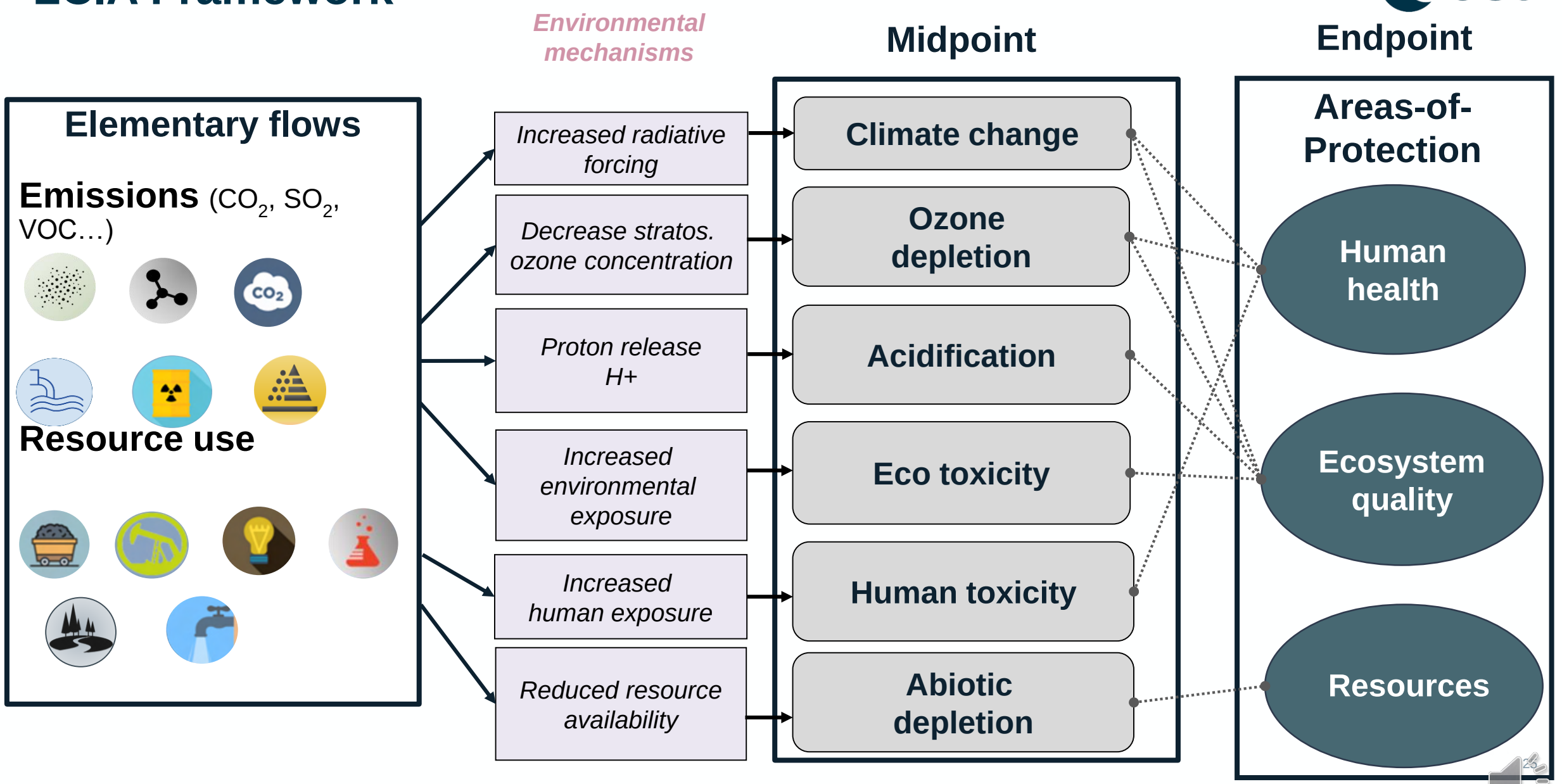
Elementary flows correspond to exchange of matter or energy between the system and the environment. The following categories of elementary flows are typically covered:



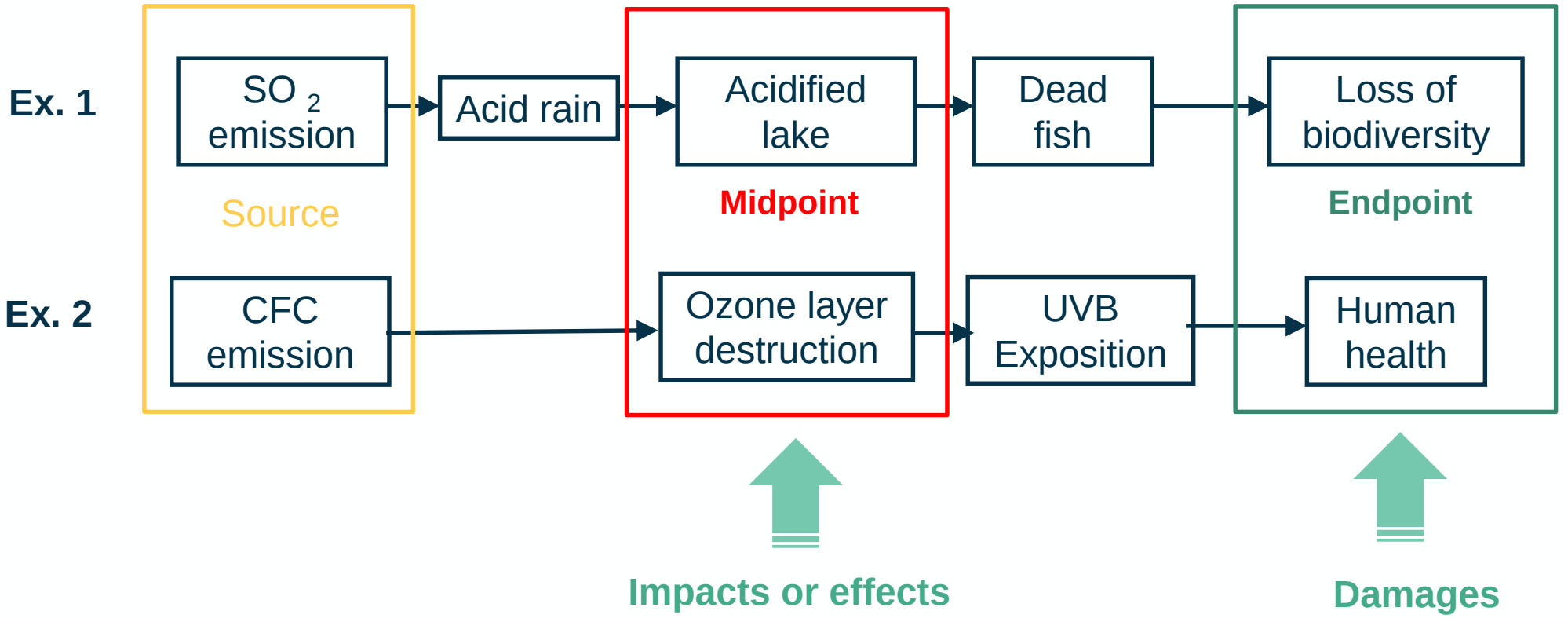
3rd Step: Life Cycle Impact Assessment (LCIA)



LCIA Framework

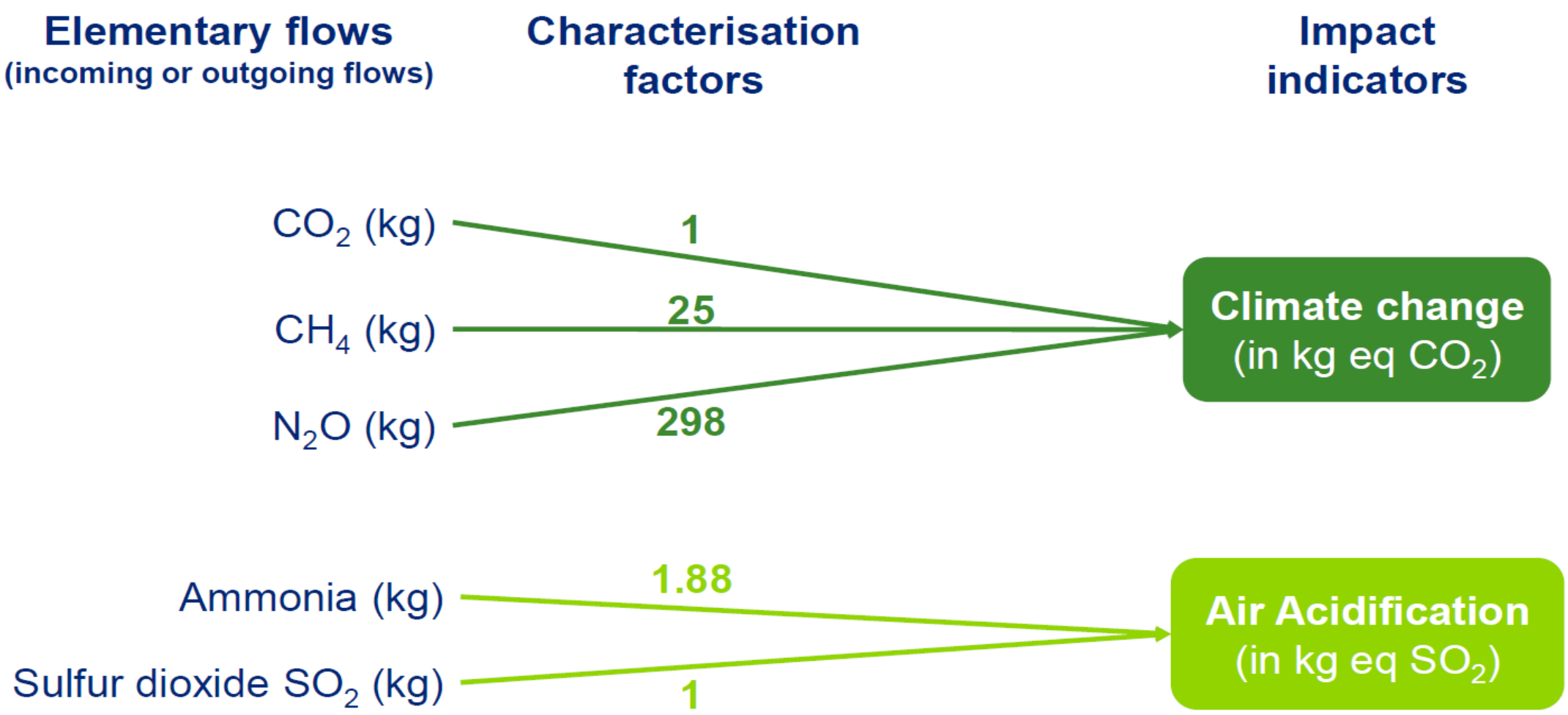


LCIA Framework (examples)

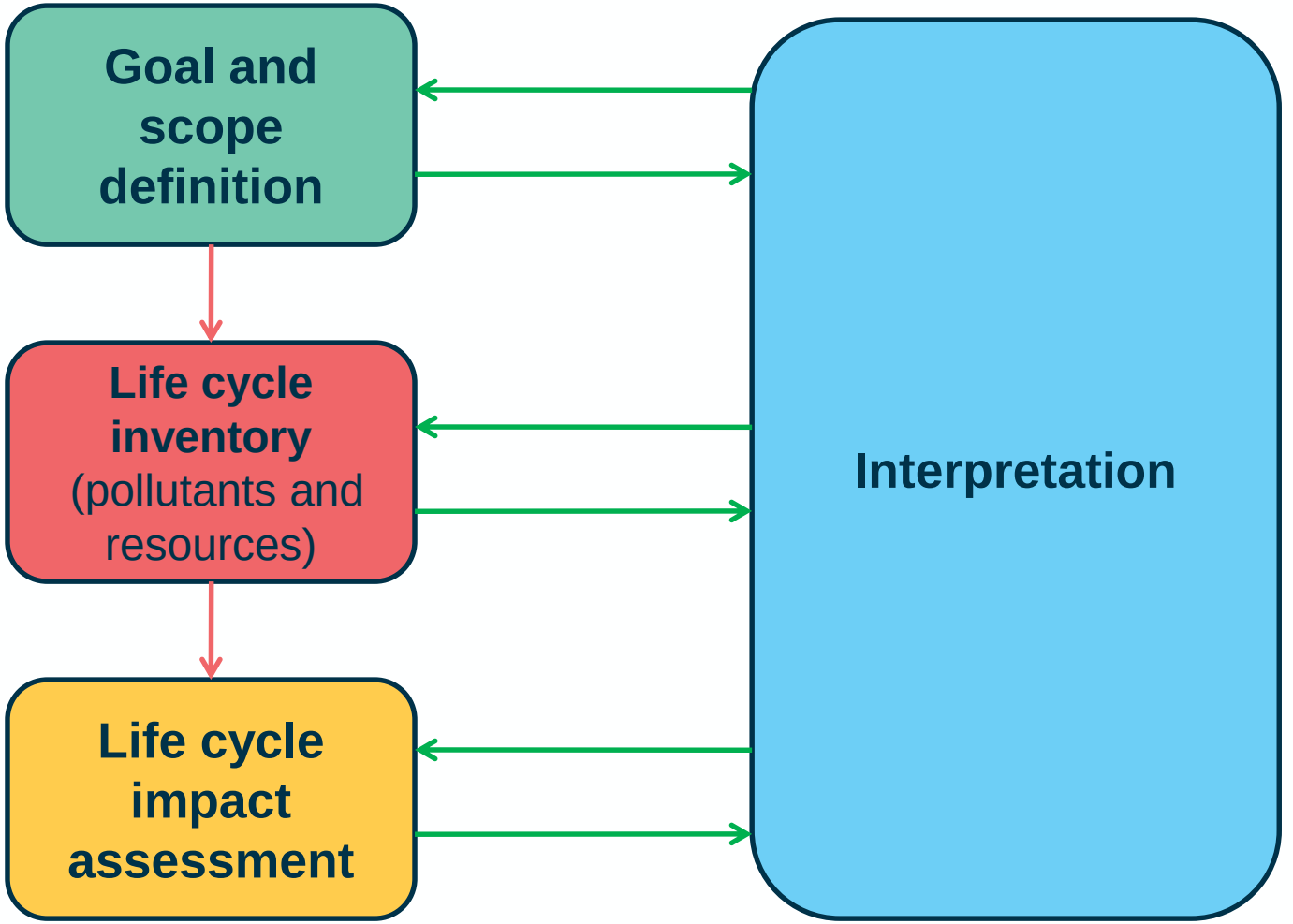


Source: Geyer, 2006

LCIA – In practice



4th Step: Interpretation



Main analysis for interpretation

Contribution analysis

Identification of principal life cycle stages contributing to the impacts→ Hotspot analysis

Potential detection of errors …

Sensitivity and scenario analysis

To verify data quality and hypotheses validity

Test different input parameters

Uncertainty analysis

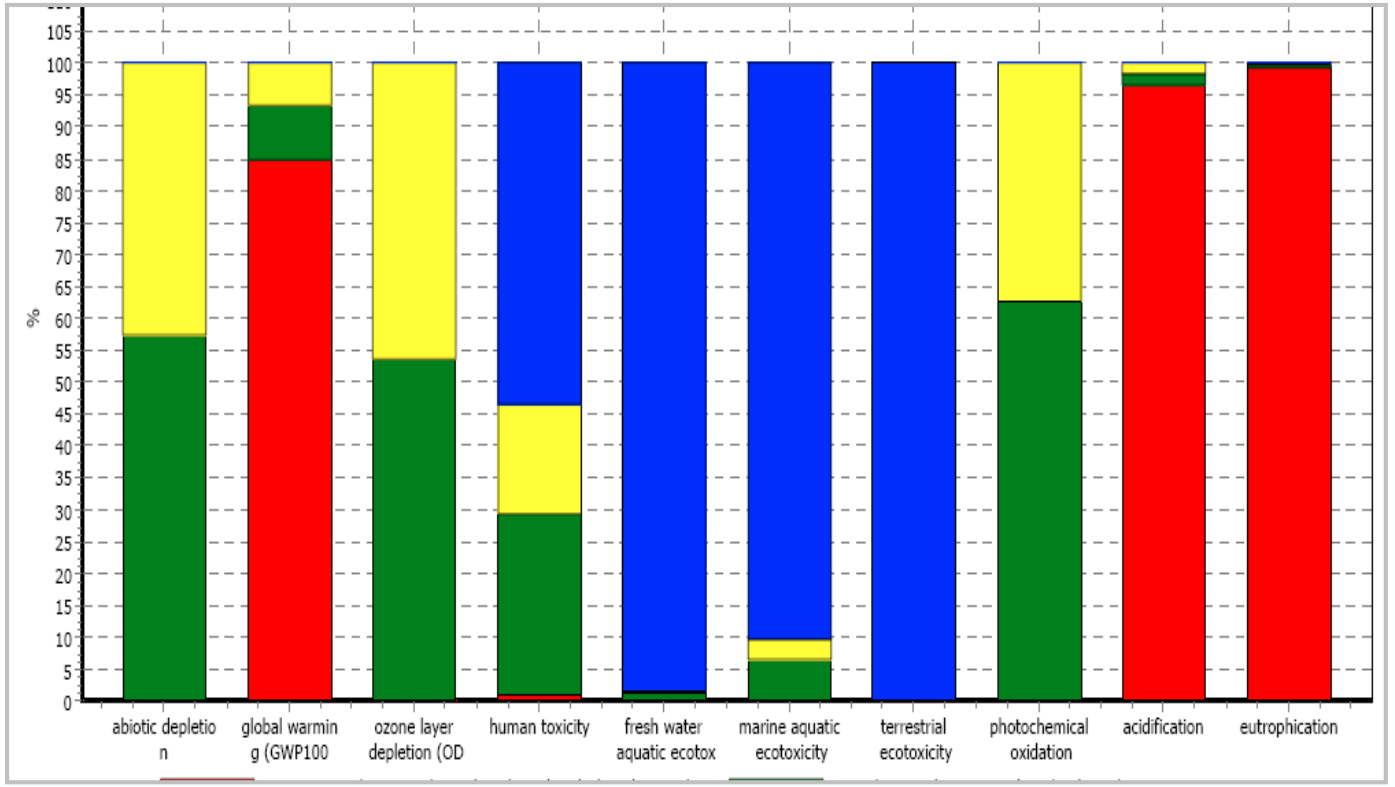
Need the statistical distribution of inputs …

Monte-Carlo method (Random process aiming at determine the distribution of results)

Critical review from an external reviewer

Verifying the validity of hypotheses and data

Transparency



Example: Definitions

Goal of study

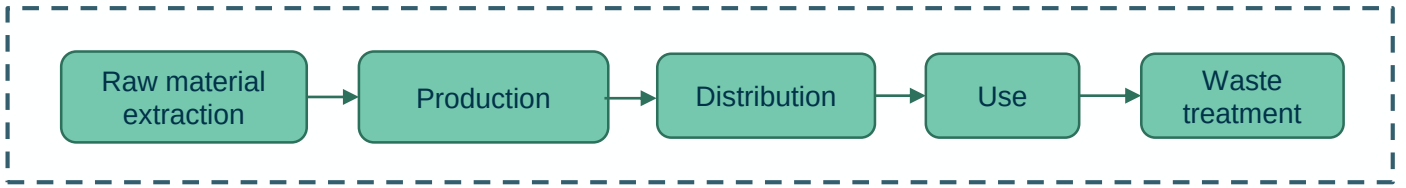
Compare the environmental impacts between reusable and disposable coffee cups.

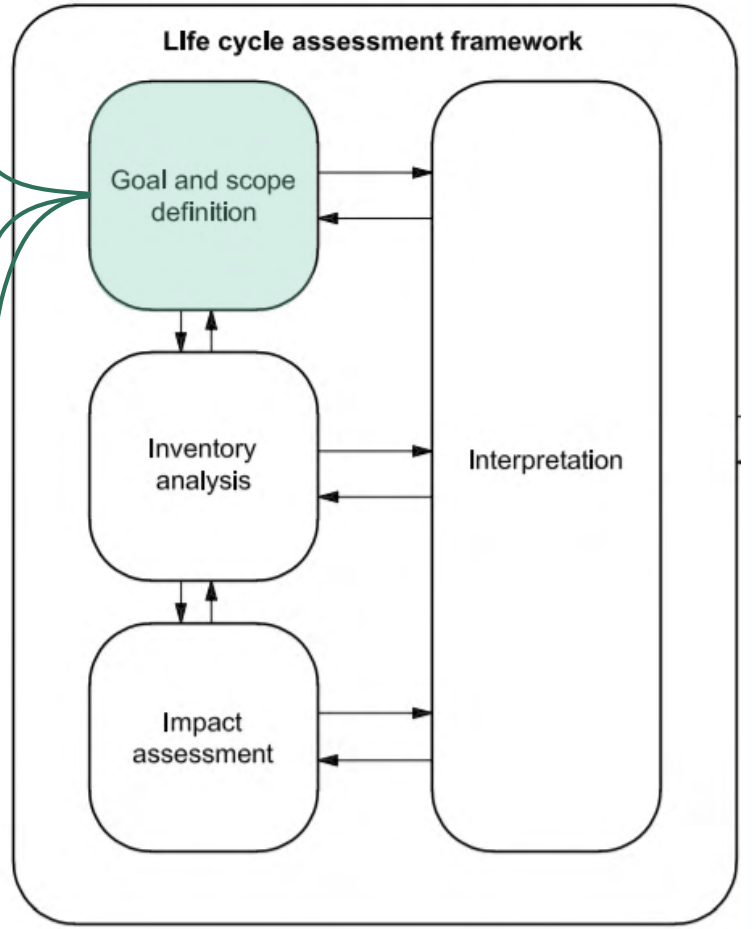
Functional Unit

To drink 2 cups of coffee per day for 500 days (1000 coffees)

 ... vs 

System boundaries





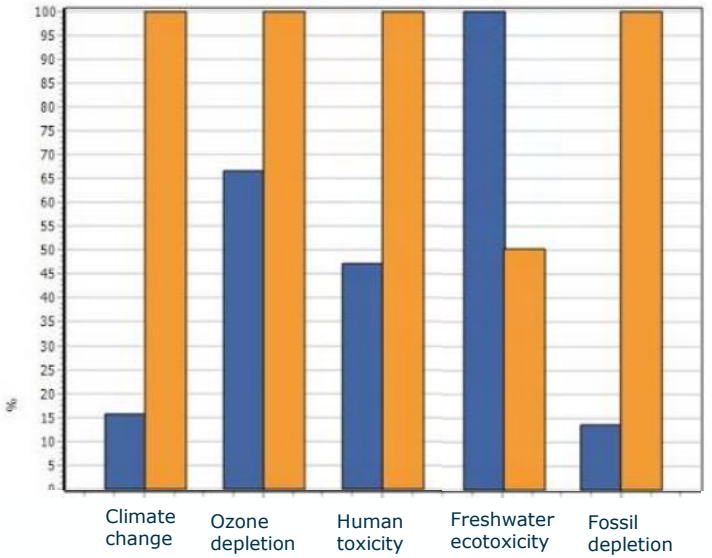
Ref: ISO 14040 - 14044

Example: Definitions

Category	Inputs	Quantity
Materials	Paper	
Processes	Production process	
	Recycling of paper	
	Municipal waste collection by truck	
	Treatment of municipal solid waste	

Category	Inputs	Quantity
Materials	Raw materials	
Processes	Production process	
	Washing cycle (with detergent)	
	Treatment of municipal solid waste	

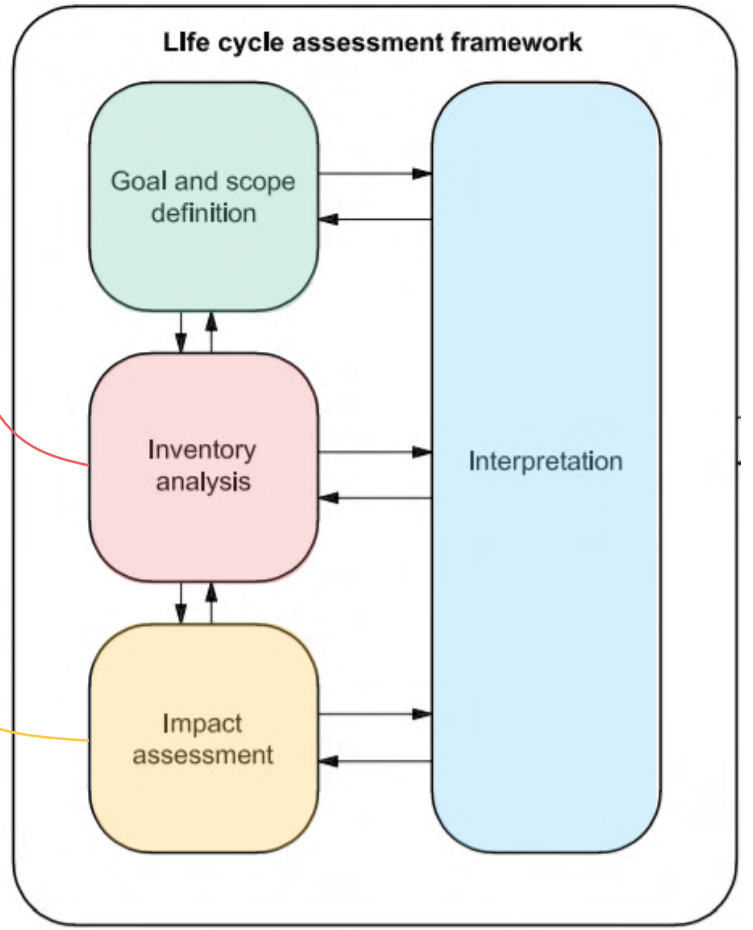
Inventory



Environmental results

Porcelain cup

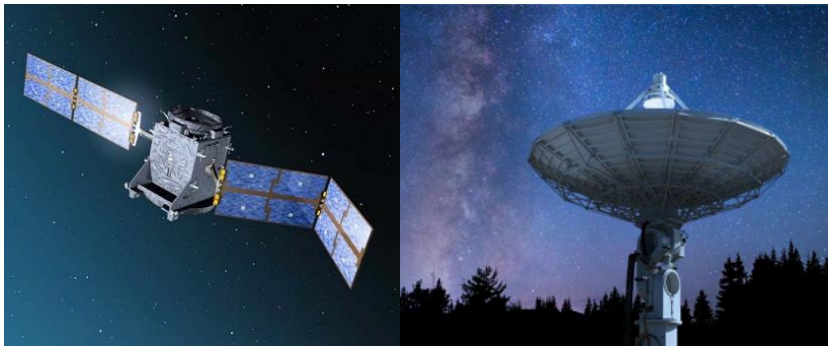
Paper cup

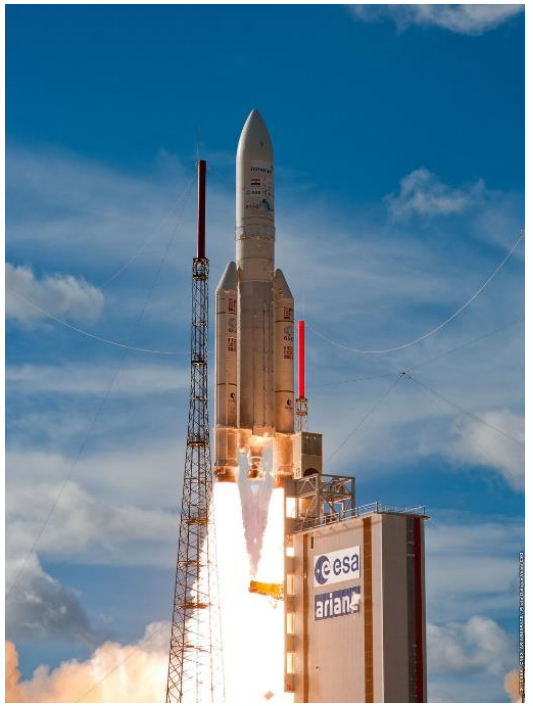


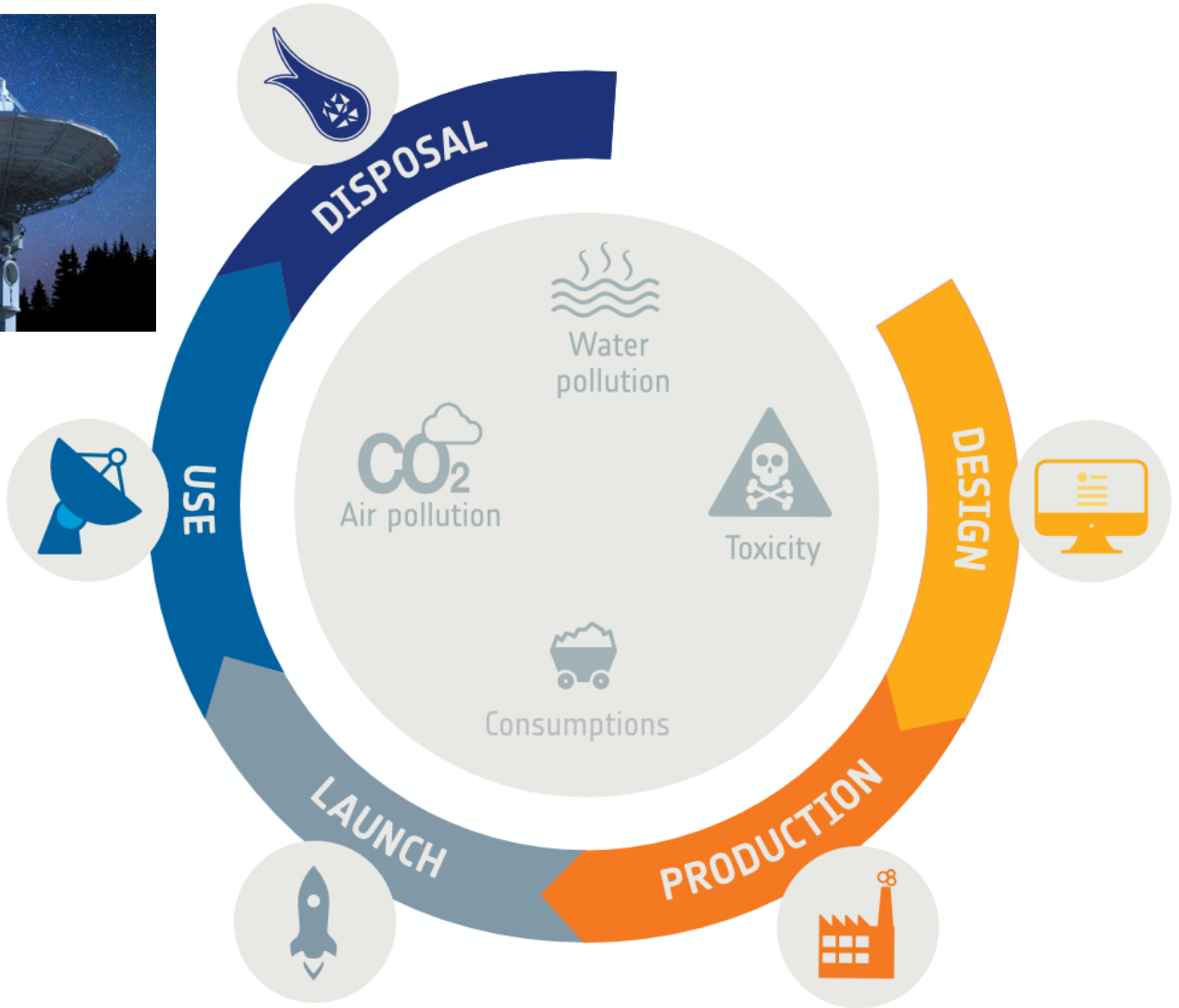
Ref: ISO 14040 - 14044

LCA & Ecodesign at ESA

Space Mission Life Cycle

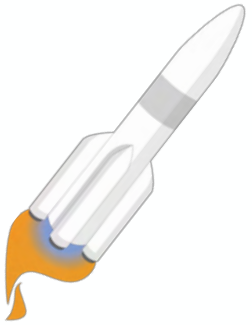




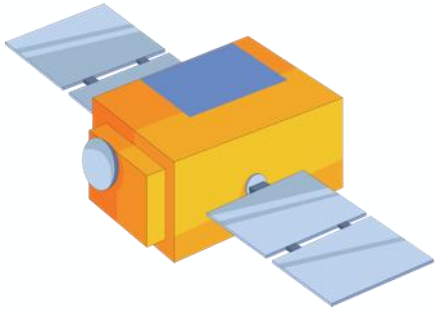


ESA LCA approach

ESA has performed LCA of the 3 different segments:



LCA Launch Segment



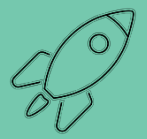
LCA Space Segment

LCA Ground Segment

Applying LCA to space is not straightforward:
Many Specificities!!

Life Cycle Assessment – Application to Space

Specificities of the space sector



- Low production rates
- Use of specific materials and components not included in standard databases
- Direct emissions into all layers of the atmosphere
- Specific and power demanding tests
- Relatively short use phase
- Long time needed for research and development

Adaptation of the LCA had to be performed and specific tools were developed

Eco-design definition and approach

"Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle"

The main objective of eco-design is

- ✓ To **improve the environmental performances** of products and services through the assessment of their environmental impacts
- ✓ Starting from **the design phase** and this,
- ✓ **Without reducing their final quality or performance**.

ecodesign
→ REDUCING IMPACTS

LCA → **Hotspot identification** → **Eco-design**

LCA & EcoDesign applied to space

Goal of study

To reduce the impact of a space mission X

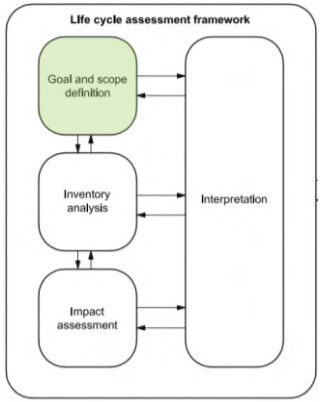
Functional Unit

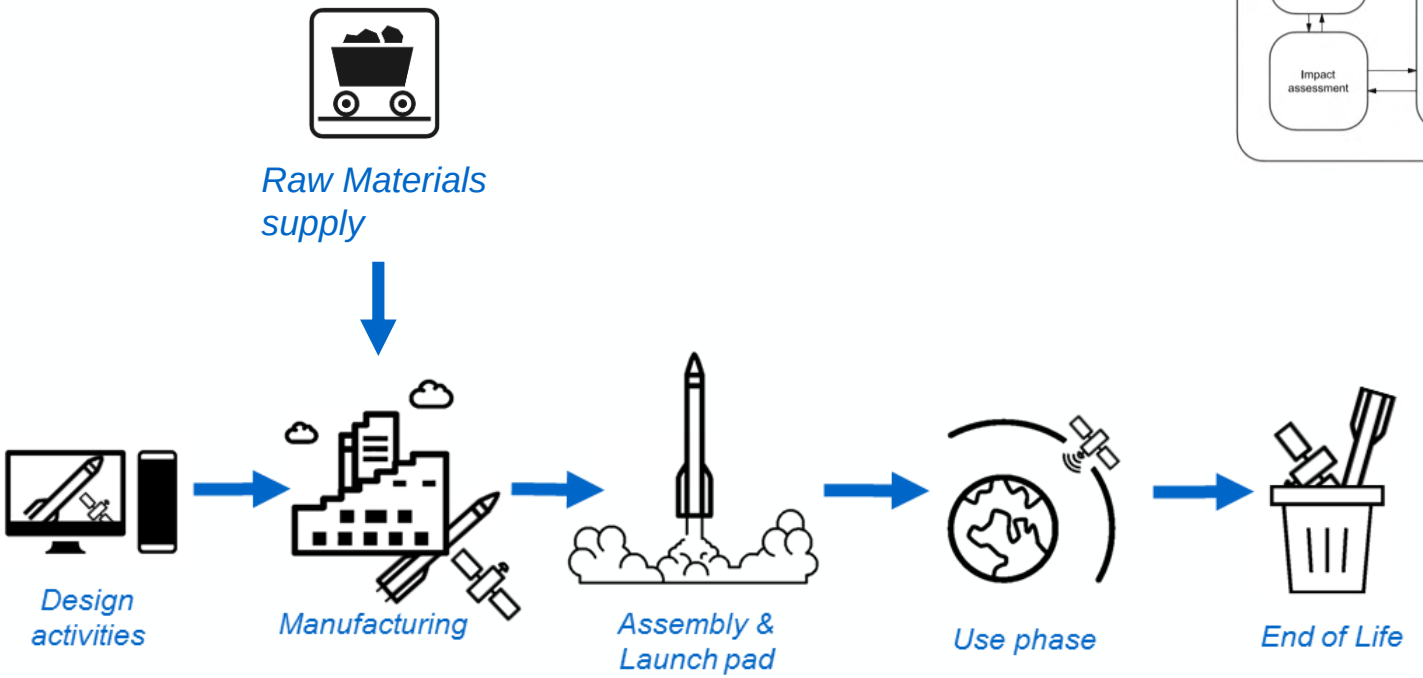
One space mission in fulfilment of its requirements

System boundaries

Exclusions

Space debris are out of the scope



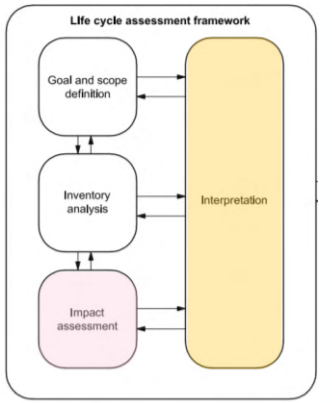


Source: T. Maury

LCA & EcoDesign applied to space

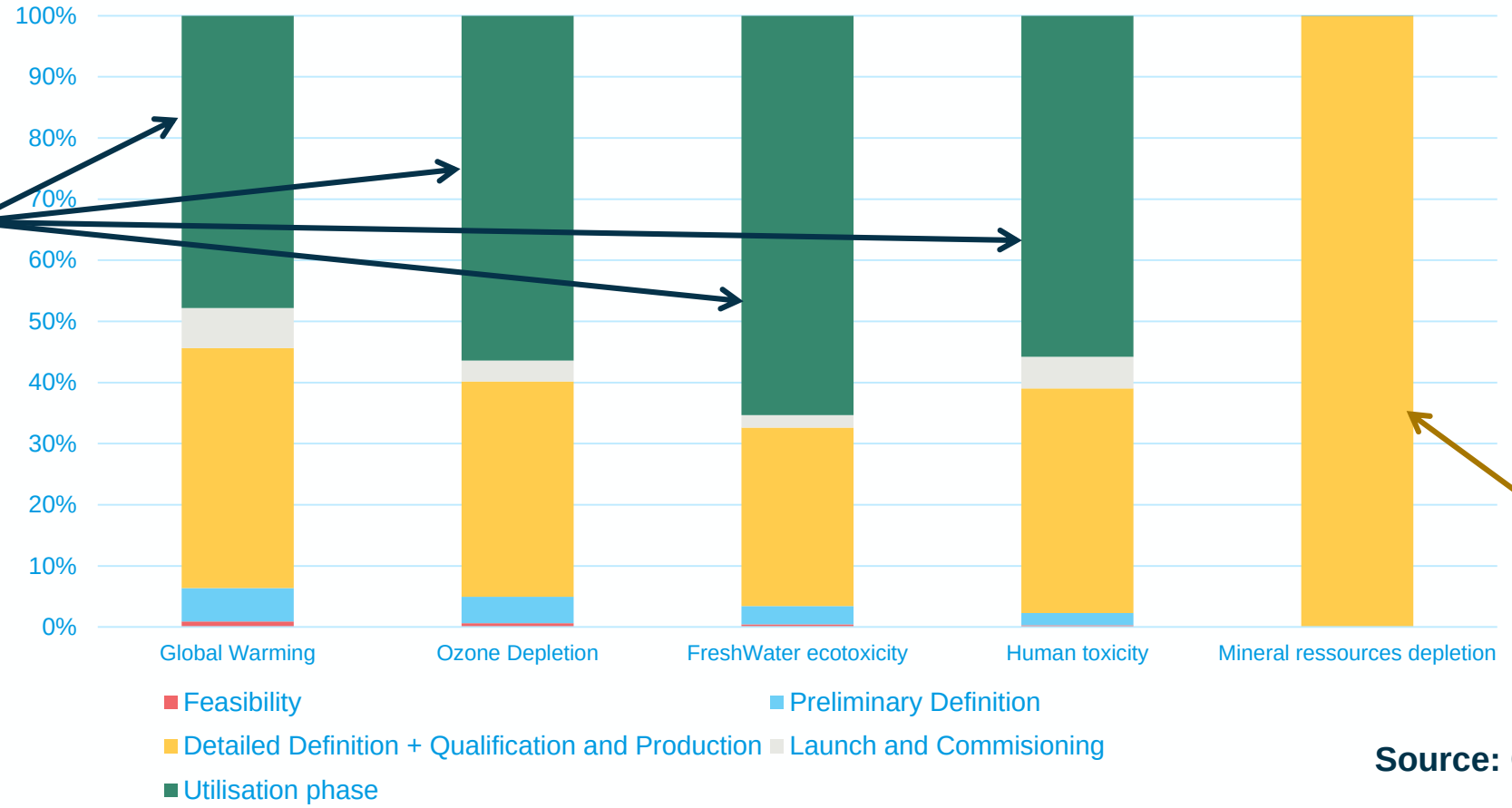
Environmental results

Interpretation



Environmental results of a space mission (without infrastructure and launcher)

Ground segment > Server > Electronics, Electricity consumption



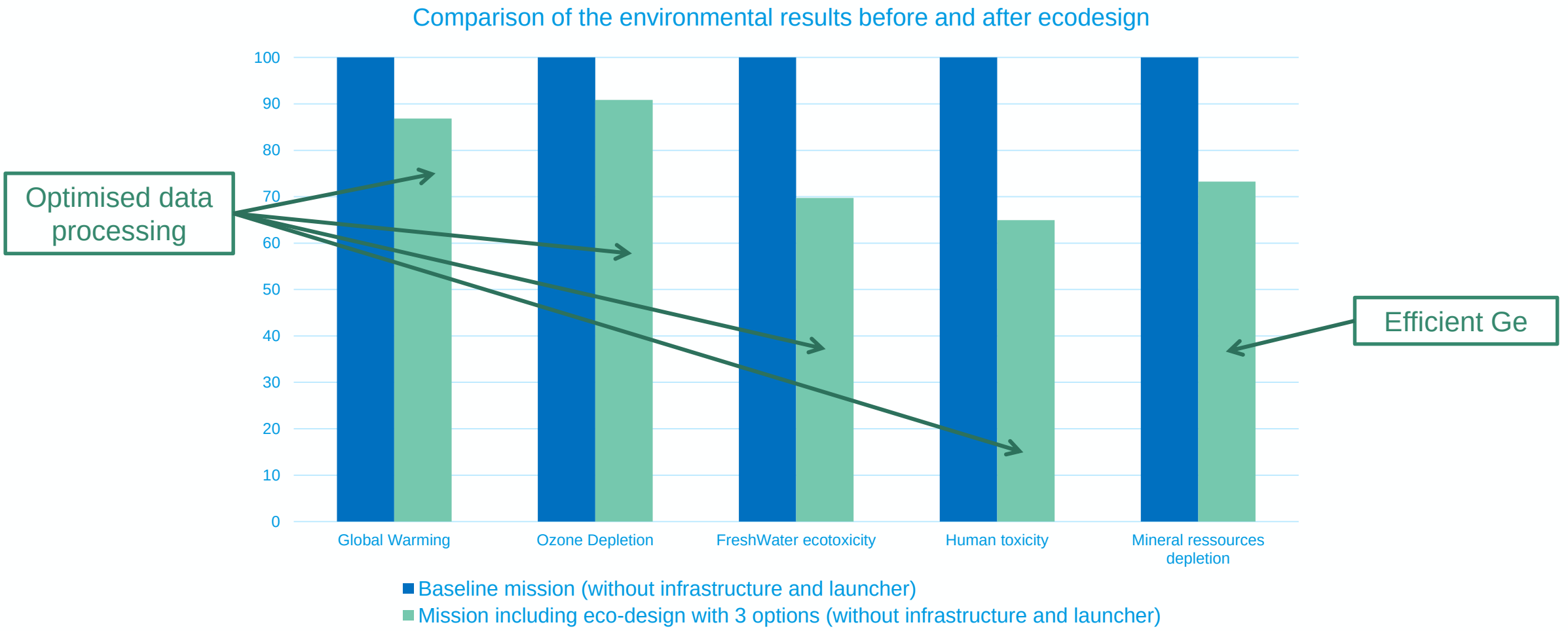
Solar cells production > Germanium extraction consumption

Source: GreenSat

LCA Hot-spot overview

Impact category	Feasibility	Preliminary definition	Manpower for design and production	AOCS	Power supply	Payload production	Transport	Testing	Launch and commissioning	Manpower for utilisation phase	Electricity	Heating	Building	Servers
Global warming														
Ozone depletion														
Human toxicity, non-cancer														
Resource depletion, minerals														
Freshwater ecotoxicity														

LCA & EcoDesign applied to space



Source: GreenSat

Conclusion

Challenges for LCA and Ecodesign applied to space

- Defining the Functional Unit
- Impact of Testing
- Impact of R&D
- Spacecraft demise impact on atmosphere
- Impact on Deep Sea
- Data Management challenge
- Impact of Infrastructure
- Impact of Office Work
- Launch events impact on atmosphere
- Space Debris

Benefits of LCA & Ecodesign activities

BENEFITS TO INDUSTRY

- Corporate Social Responsibility (CSR)
- Environmental reporting
- Environmental communication and public awareness
- Comply with National and International env. legislations
- Opportunity for product development and innovation
  - Reduced costs due to lower material and energy consumption and avoidance of waste and harmful substances
- New market opportunities

BENEFITS TO ESA & European stakeholders

- World leader & reference in LCA and Ecodesign
- First mover stablishing the framework through a specific database & guidelines
- Cooperation with other National & international organisation
- Possibility to prove that Space activities are “greener” than ground ones
- Creating awareness
- Contribution to space sustainability

EcoDesign vision

Green Technologies

ESA Projects

Commercial Projects

- Ariane 6
- Earth Explorer
- Copernicus
- Galileo
- OneWeb
- Ariane Next
- Airbus
- …

Environmental Footprint

Ex: Efficient use of Ge

Environmental Regulation

Ex: Replacement of pyrotechnic powders

ROADMAP

LCA

LCA Launch segment

LCA Space segment

LCA Ground segment

LCA Launch segment - update

LCA implementation in ESA projects

Ariane 6
Earth Explorer 9 & 10
Copernicus Expansion Missions
Galileo 2nd generation
...

Framework

Framework definition
- LCA Handbook
- LCA DataBase

Framework update
- LCA Handbook
- LCA DataBase

Framework consolidation

Eco-Design

GreenSat
First Eco-design implementation

Green technologies roadmap

First **Green Technologies** development

Eco-design implementation in ESA projects

2012 2015 2018 2021 2025 2030

Conclusions & Take Home Messages

1. **LCA** is an **ISO standardized methodology** which prevents burden shifting (multistep and multi-criteria process)
2. LCA & eco-design can be applied to space **after adaptation**
3. Europe and ESA are world **leader & reference** for LCA and Ecodesign applied to space by creating **framework** thanks to the first **LCA Database** and **Handbook** for space systems
4. EcoDesign needs to be applied from **early phases** of the mission development
5. Opportunity for product development and innovation
6. **Reduced costs** due to lower material and energy consumption and avoidance of waste and harmful substances
7. Awareness is also necessary

Let's stay in touch!

today

Recordings of previous Clean Space webinars

https://blogs.esa.int/cleanspace/clean-space-webinars/

LCA and Ecodesign training for Space

16 September @ online

Clean Space Industry Days

10-14 October @ ESTEC

Registration:

https://indico.esa.int/e/CSID2022

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https://fr.linkedin.com/showcase/esa-clean-space

Zero Debris:

https://www.linkedin.com/groups/12670558/

cleanspace@esa.int

Useful Resources

- Ecodesign articles and updates from ESA Clean Space
- European Commission Environmental Footprint
- Global normalisation factors for the Environmental Footprint and Life Cycle Assessment
- Development of a weighting approach for the Environmental Footprint
- Raw Materials Information System
- ISO 14044:2006 - Environmental management — Life cycle assessment — Requirements and guidelines

Thank you for your attention!

ESA Clean Space Team