EPFL

LCA & Ecodesign

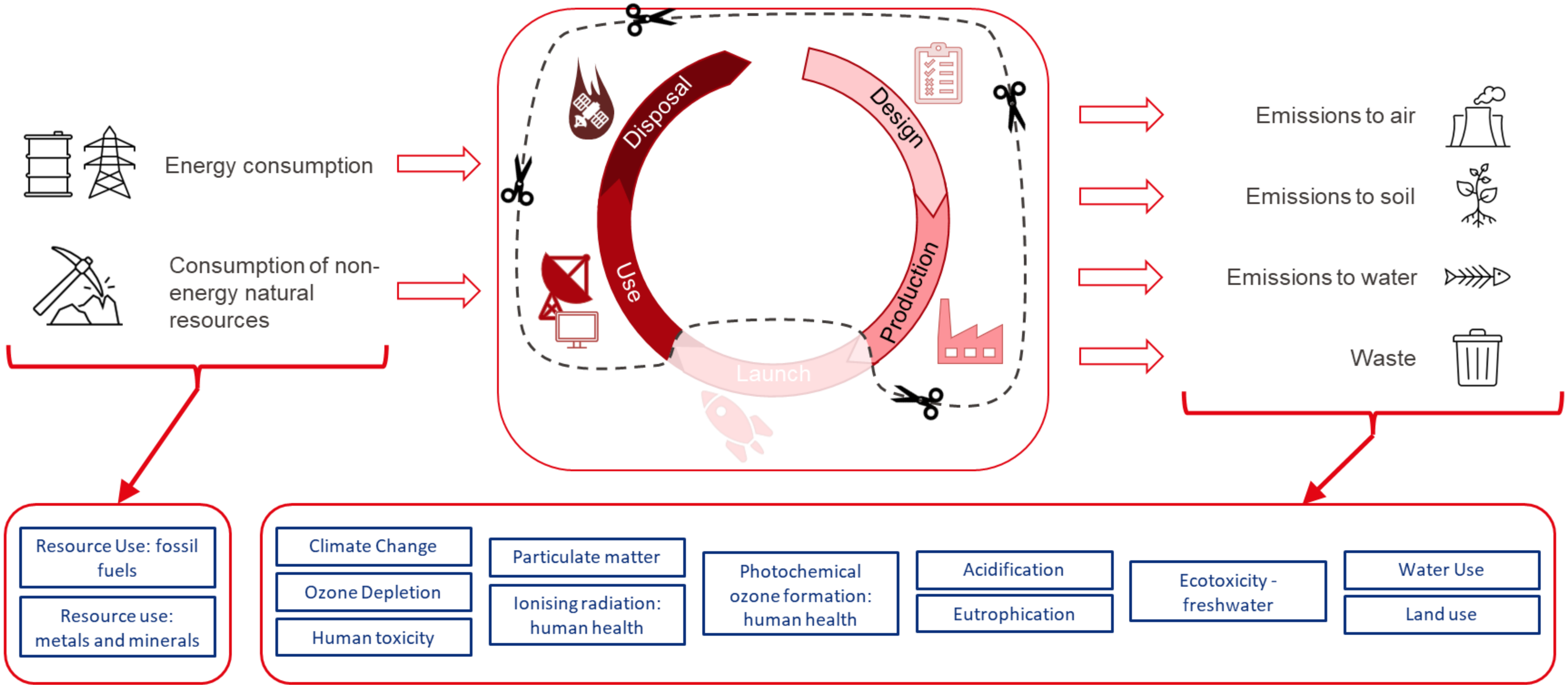
Marnix Verkammen

EPFL Space Center

Quick recap on LCA

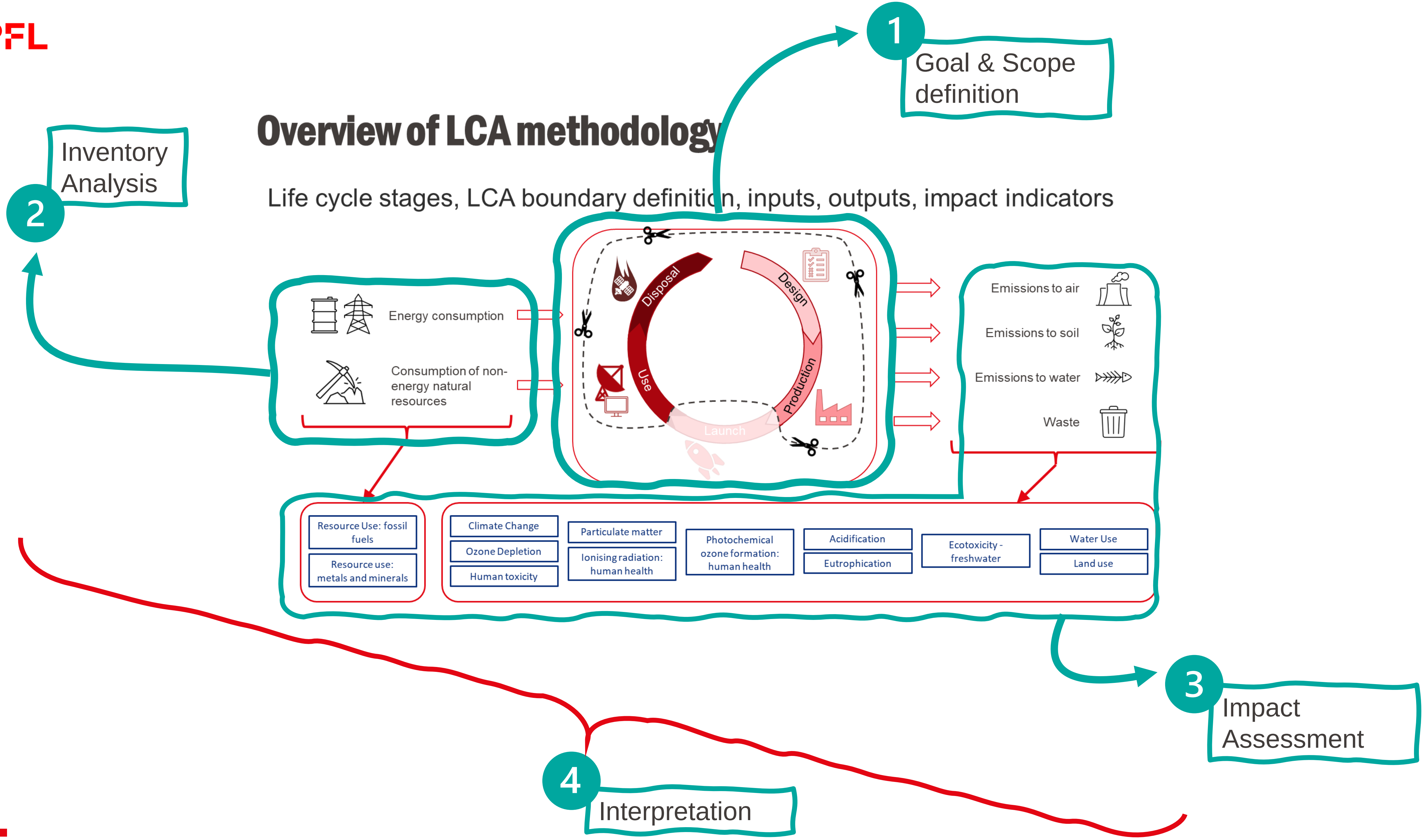
Overview of LCA methodology

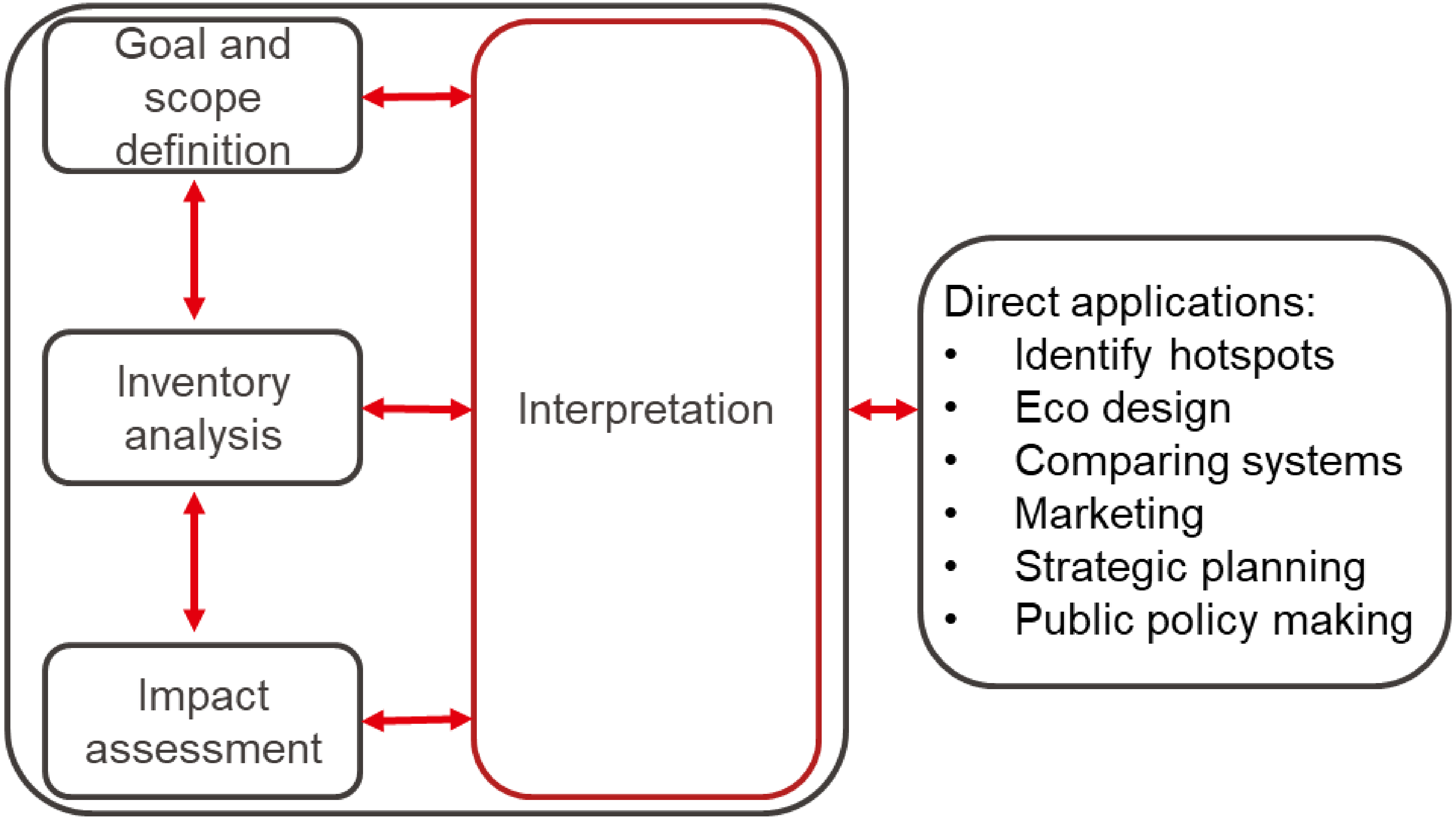
Life cycle stages, LCA boundary definition, inputs, outputs, impact indicators



Overview of LCA methodology

Life cycle stages, LCA boundary definition, inputs, outputs, impact indicators




Goal and scope definition
Inventory analysis
Impact assessment
Interpretation
Direct applications:
• Identify hotspots
• Eco design
• Comparing systems
• Marketing
• Strategic planning
• Public policy making

Ecodesign

EPFL

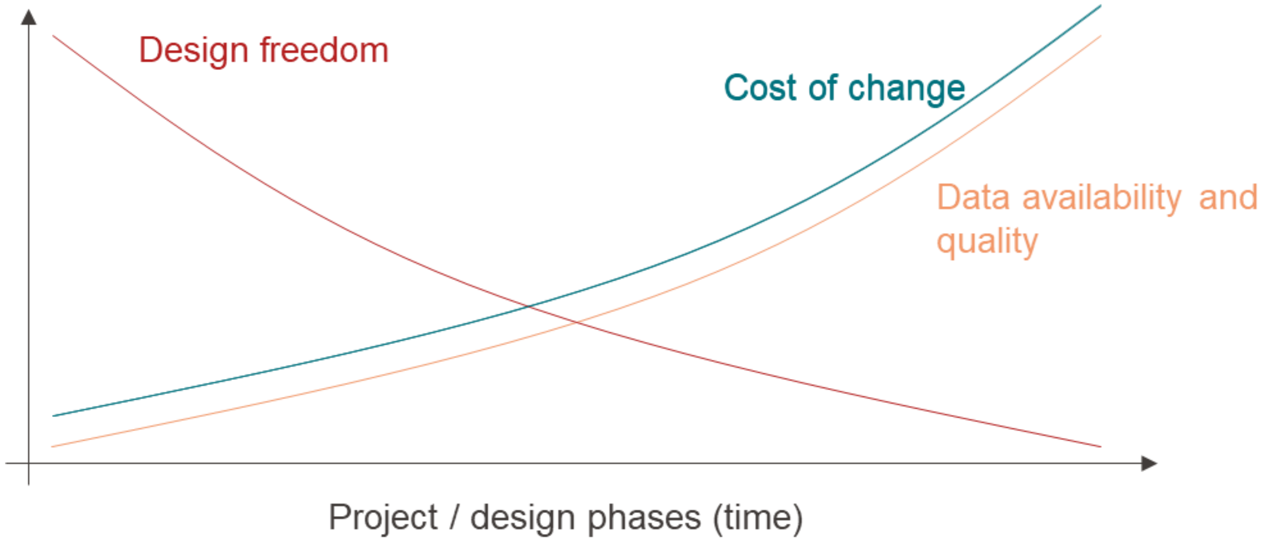
Ecodesign

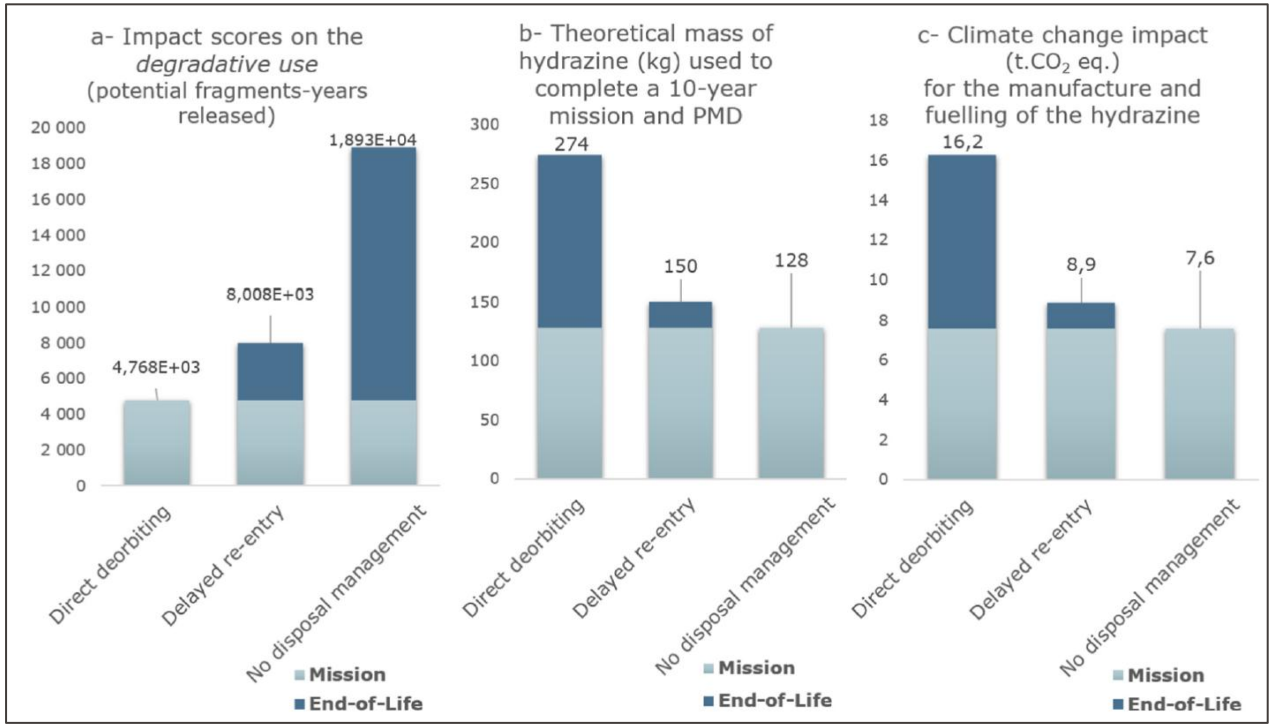
Done early in the design phase !

Iterative

- Perform LCA
- Identify hotspots
- Eco-design (with same performance)
- Re-assess

Avoid burden shifting !
- By phase
- By indicator
- By (sub)system

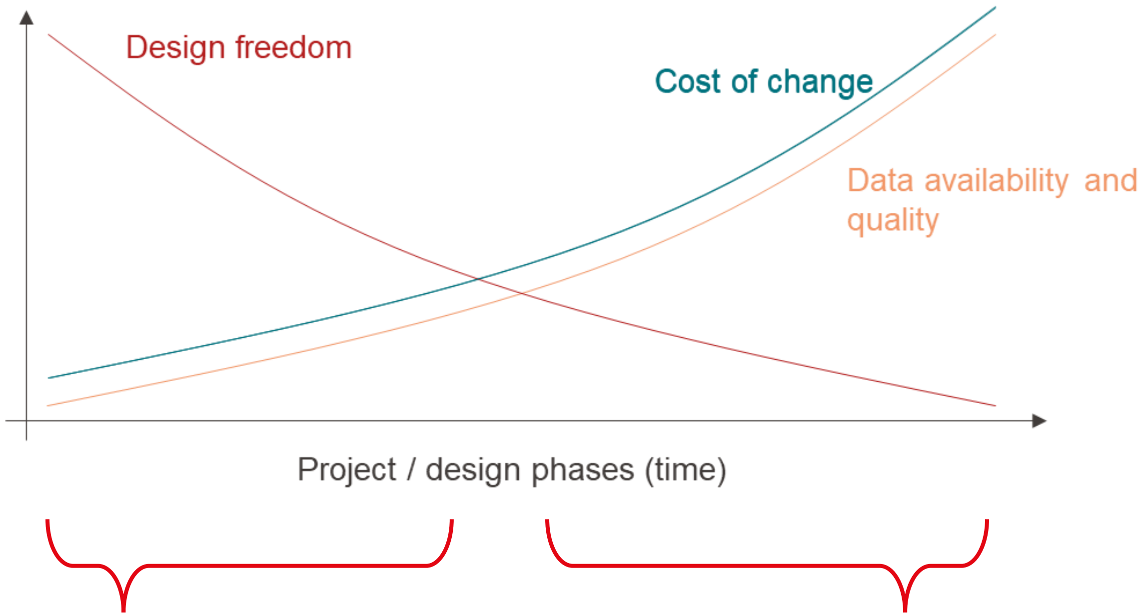




Example from T. Maury et al., “Assessing the impact of space debris on orbital resource in life cycle assessment: A proposed method and case study”, Science of the Total Environment 667 (2019) 780–791

When to Ecodesign

Ecodesign can be applied at any time... but with varying degree of effectiveness



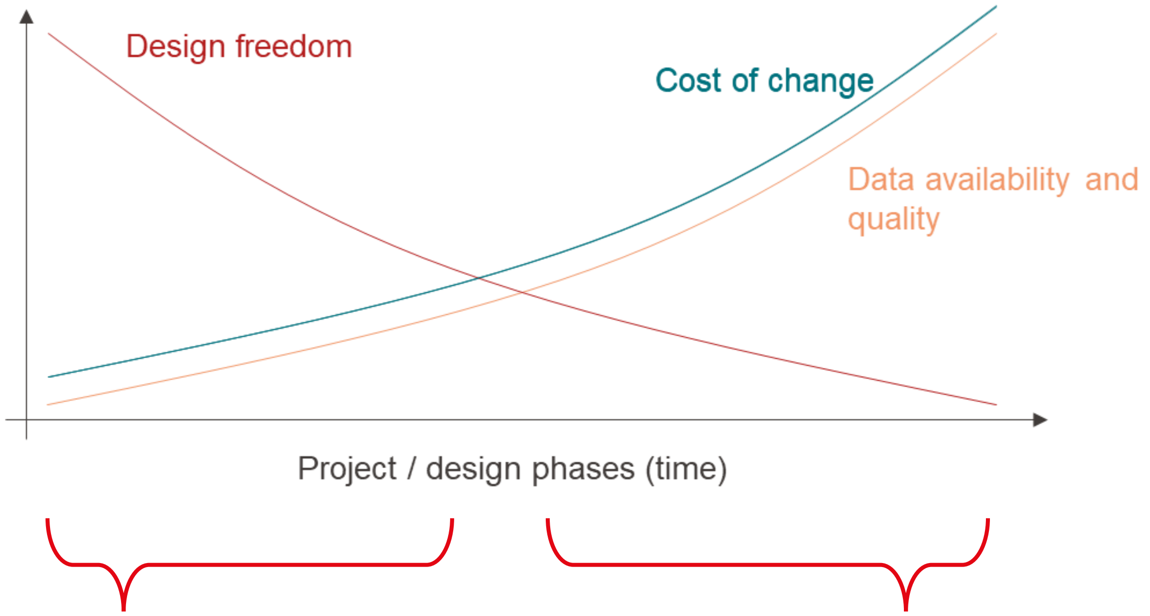
Greatest effect on overall environmental impacts

But, lowest certainty on impact changes (limited available info)

Diminishing effect on overall environmental impacts

But, highest certainty on impact changes (limited available info)

Levels of Ecodesign



- Mission architecture
  - Nr. of launches and S/C,
  - Size of S/C,
  - Ground operations...
- High-level design choices
  - Use or not of COTS* systems,
  - Need for specific testing facilities...
- (Sub-) System level changes
  - Type of materials used,
  - Choice of specific subsystem...
- Low-level design choices
  - Optimization of ground segment procedures,
  - Choice of specific component...

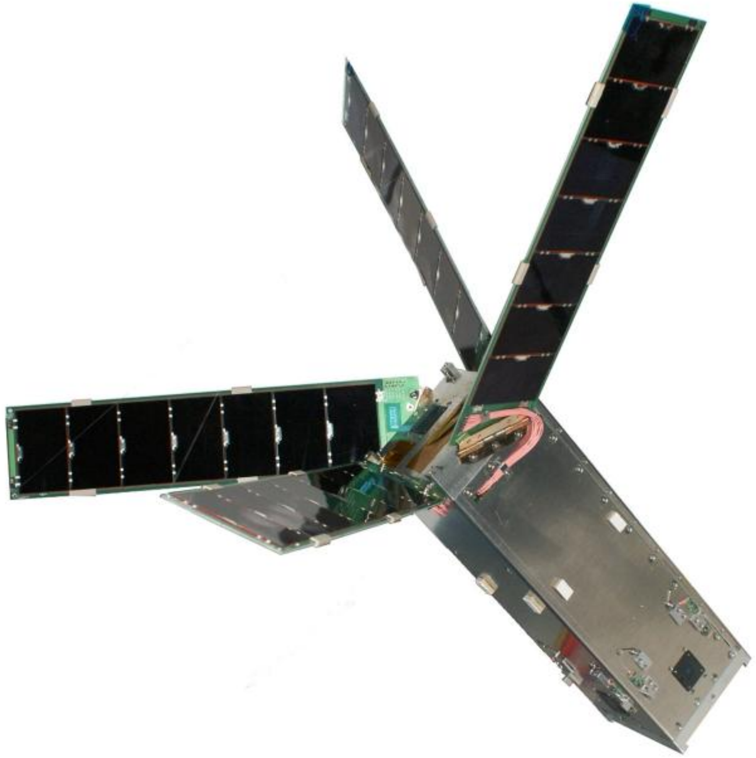
* COTS = Commercially Off The Shelves

Ecodesign Example

Delfi-n3Xt : TU Delft's second Cubesat

Key characteristics

- 3U-Cubesat (100x100x300mm)
- Mass: 3kg
- Launch date: 2013
- Operational for 2 months
- Loss of contact until a brief revival in 2021



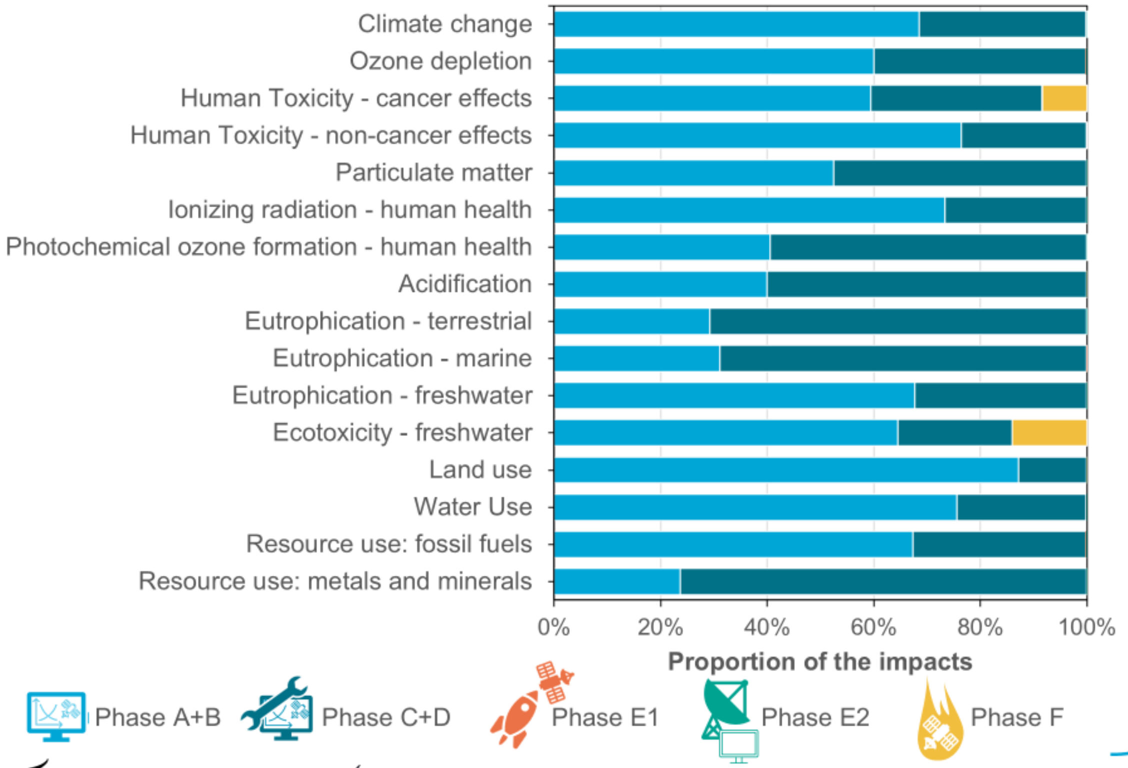
TU Delft eSpace SPACE SUSTAINABILITY RATING

24

M. Verkammen, *Consensus-based single-score life cycle assessment for space missions*, MSc Thesis, TU Delft, 2023. http://resolver.tudelft.nl/uuid:fe91662b-6885-41d4-85ee-3f303febded5

Ecodesign Example

LCA results of Delfi-n3Xt



1. **Normalisation** through the Environmental Footprint (EF) per person globally
2. Application of the **recommended weighting factors**

Weighting factors used	Single-score
Recommended ones	**14.30**
ESA's	20.17
PEF's	16.00

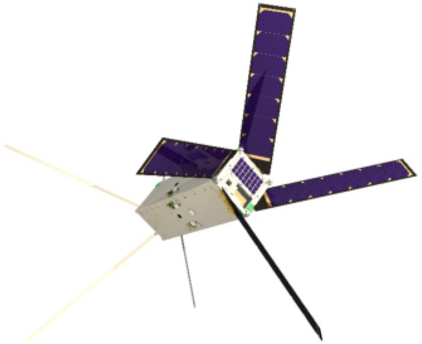
TU Delft eSpace SPACE SUSTAINABILITY RATING

Source for the Environmental Footprint (EF) normalisation factors: S. Sala, et al, "*Global normalisation factors for the Environmental Footprint and Life Cycle Assessment*," Publications Office of the European Union: Luxembourg, 2017. doi: 10.2760/88930
Source for ESA's weighting factors: E. Tormena, "*Internship ESA Clean Space - Final Report*," ISAE-SUPAERO, 2022
Source for PEF's weighting factors: S. Sala, et al., "*Development of a weighting approach for the Environmental Footprint*," Publications Office of the European Union: Luxembourg, 2018

M. Verkammen, *Consensus-based single-score life cycle assessment for space missions*, MSc Thesis, TU Delft, 2023. http://resolver.tudelft.nl/uuid:fe91662b-6885-41d4-85ee-3f303febded5

Ecodesign Example

Use of single-score in Ecodesign



- Changing Li-ion battery into hypothetical NiMH battery
- Keeping the same masses (due to time constraints)

Old single score	New single-score
14.30	15.97

- The **new score is "worse"** (i.e. higher) than the old one.
- NiMH is therefore a "worse" design decision
- Coincidently, it was not chosen (but for different reasons)

The single-score could have been useful during the design.

TU Delft eSpace SPACE SUSTAINABILITY RATING

M. Verkammen, *Consensus-based single-score life cycle assessment for space missions*, MSc Thesis, TU Delft, 2023. http://resolver.tudelft.nl/uuid:fe91662b-6885-41d4-85ee-3f303febded5

Other examples

Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 72 (2023) 2917–2935
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr
ELSEVIER

Life cycle engineering of space systems: Preliminary findings

Andrew Ross Wilson *, Massimiliano Vasile

Aerospace Centre of Excellence, Department of Mechanical & Aerospace Engineering, University of Strathclyde, 75 Montrose Street, Glasgow G1 1XJ, UK

Received 25 March 2022; received in revised form 8 December 2022; accepted 10 January 2023
Available online 18 January 2023

Abstract

The application of Life Cycle Engineering (LCE) within the concurrent engineering process presents a viable method for assessing environmental, social and economic impacts of space missions. Despite this, the novelty of the concept within space mission design has meant that the approach has not yet been widely implemented. This paper successfully demonstrates this technique for the first time and presents LCE results of three SmallSat missions designed at the University of Strathclyde using the concurrent engineering approach. The Strathclyde Space Systems Database (SSSD) was deployed to calculate the total life cycle impacts of each mission, including the identification of common design hotspots. A novel technique called Multi-Criteria Decision Analysis (MCDA) was also trialled, whereby several impact categories were converted into single scores as a test case to reduce the learning curve for engineers. Overall, the LCE results indicate that the manufacturing & production of the launcher dominate the majority of impact categories. Other common hotspots were found to relate to the use of germanium as a substrate as well as the launch event. As an additional observation, in terms of the behavioural aspects, it was clear that study participants were more open to the concept of LCE with each new concurrent engineering session, evidenced by increasing levels of interaction amongst study participants. These findings are intended to provide industrial stakeholders with a preliminary benchmark relating to the general sustainability footprint of SmallSats, whilst demonstrating the viability of integrating LCE within the concurrent engineering process of space missions.

https://doi.org/10.1016/j.asr.2023.01.023

75th International Astronautical Congress (IAC) - Milan, Italy, 14-18 October 2024.

IAC-24,D2,9-D6.2,6,x85483

Streamlining Life Cycle Assessment Framework for Space Missions at Early Design Stages: Insights from the CHESS Cubesat Mission

Angelina Frolova[a1]*, Antonio Zecchin[a2], Lina Kuhlmann[a3], and Marnix Verkammen[b]*

[a] *Ecole Polytechnique Fédérale de Lausanne (EPFL), Route Cantonale, 1015 Lausanne, Switzerland*
[1] angelina.frolova@epfl.ch
[2] antonio.zecchin@epfl.ch
[3] lina.kuhlmann@gmx.ch
[b] *EPFL Space Centre (eSpace), Ecole Polytechnique Fédérale de Lausanne, PPH 335 Station 13, CH-1015 Lausanne, Lausanne, Switzerland,* marnix.verkammen@epfl.ch
*Corresponding Authors

Abstract

With the rate of satellite launches skyrocketing, so does the environmental impact of the space sector. This tendency emphasizes the need to simplify the impact assessment for early phase design, where the potential for mitigating ecological damage is greatest. Indeed, whilst the Life Cycle Assessment (LCA) methodology provides an essential framework for the calculation of the environmental impact of a space mission (e.g. space transportation vehicles and CubeSat missions), the various impact categories it outputs may cause confusion for engineers, managers and other stakeholders involved in decision-making. That may result in them cherry-picking and favoring few commonly known indicators (e.g. climate change or land use), while failing to consider a broader image due to its apparent complexity. Past work has been performed to define a methodology to reduce the LCA results into a single-score, making LCA more intuitive during preliminary design stages. However, these methodologies are still in development, requiring more LCA studies to be performed.

To that end, this paper presents the LCA and the single-score methodology applied to the CHESS mission (Constellation of High-performance Exosphere Science Satellites), a 3U student-led CubeSat mission conducted by the EPFL Spacecraft Team jointly with University of Bern (UNIBE) and Federal Institute of Technology Zurich (ETHZ). Variations on the design are made, including extrapolating CHESS's design to CubeSats of different sizes, in order to investigate the effectiveness of the single-score method during early design stages. Moreover, this paper introduces preliminary ideas for an eco-design tool featuring an intuitive, streamlined graphical user interface, and integrated machine learning capabilities. A web-based application would facilitate recommendations for optimizing CubeSat mission design to minimize their environmental externalities without requiring users to have in-depth knowledge of LCA methodologies, thus enhancing accessibility to sustainable space solutions within the LCA domain. Beyond CubeSats, this approach holds potential applicability to Space Transportation Vehicles and other satellite types, highlighting the versatility and relevance of the single-score LCA methodology in early-stage eco-design initiatives.

http://dx.doi.org/10.52202/078377-0017

https://www.researchgate.net/publication/388571355_Streamlining_Life_Cycle_Assessment_Framework_for_Space_Missions_at_Early_Design_Stages_Insights_from_the_CHESS_Cubesat_Mission

Your turn

To do Today

- Perform a simplified LCA of your space mission
  - Use the Excel provided on Moodle
  - Fill in each tab, following an LCA procedure
  - Look at the values and the results
  - Note that only 7 of the 15 impact indicators are shown in the LCI tab, as these are considered the most important ones. Nevertheless, you could also look at the other indicators

- Make modifications to the space mission design to find ecodesign options
  - Duplicate tabs to make modifications whilst preserving the original

Preparation for next lecture

- Answer to questions in preparation to next lecture
  - What is your first impression when browsing the report? ➜ Does it feel transparent and educational, or more like a marketing/communication tool?
  - Is the company driven by voluntary engagement, or does it mainly act to comply with regulatory requirements ?
  - When comparing these companies, which one appears the most mature in terms of CSR? Why?

- Post your answers as a group on the forum.
  - See the newly created forum.