# Life Cycle Assessment of the European Launchers

Tiago Soares, Luisa Innocenti, Alessandro Cucci

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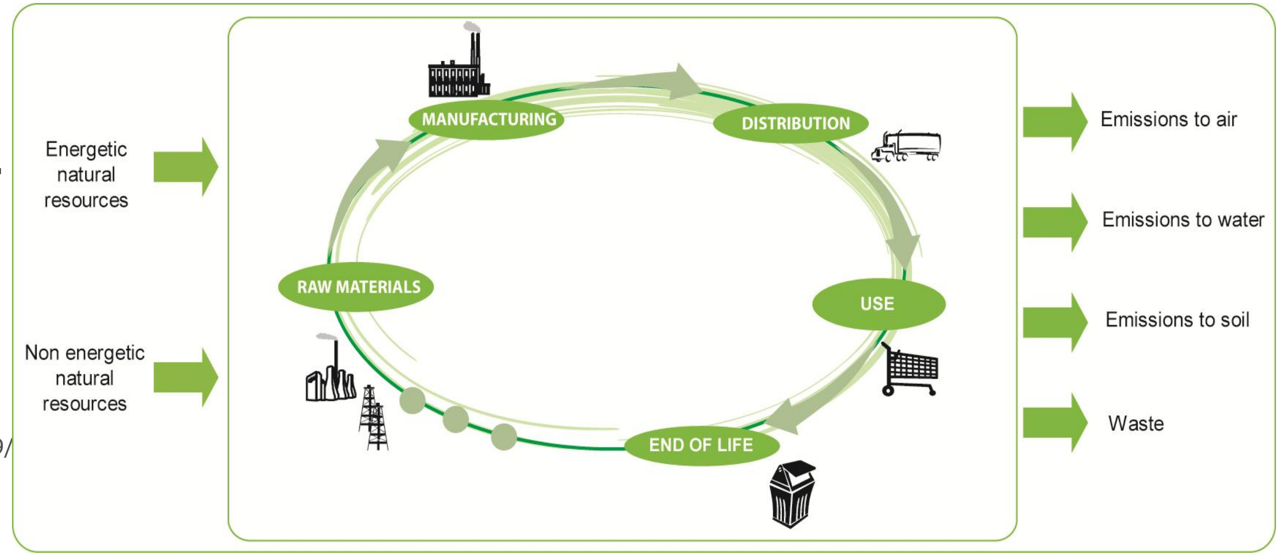
# Introduction

- Environment regulation is one of the fastest developing regulations (e.g. EU directives and regulations RoHS and REACh)
- There is a consensus that the most suitable tool to evaluate environmental impact of products and services is the Life Cycle Assessment (LCA).
- ESA has been a pioneer in applying the LCA methodology in the space sector, starting in 2009 with a preliminary system study called ECOSAT.
- ESA has carried out a **complete LCA of the European family of launchers**, to which most of the main industrials in the European launchers production have contributed.
- ESA aims to expand the use of LCA to the projects' design phases as a methodology to implement eco-design.

# LCA: methodology to quantify environmental impact of a product

- LCA is a standardised tool (ISO 14040 and 14044) existing for about 40 years.
- LCA results are **multi-criteria** (e.g. global warming potential, ozone depletion potential, human toxicity potential, metal depletion, etc.) and provide environmental impacts quantification at **different levels**, (system, subsystem, equipment, process, etc.) and at different **life cycle phases**.
- LCA does not provide a design methodology but provides the means to compare different design options and to perform technology trade-offs at equipment level.
- Life-cycle based approaches are used for all environmental regulations on products:
  - PAS 2050,
  - GHG Protocol scope 3,
  - French standard X30-323.



# Can LCA methodologies be applied to space projects?

- LCA is mostly used to model mass production products.
- ESA's experience shows that LCA opens a number of possibilities also for sectors where the production volume is relatively small. It allows to:
    - Have a better understanding and monitoring of the supply chain to avoid potential disruptions due to environmental legislation;
    - Identify environmental hot-spots in the products life-cycle and provide a basis for environmental impact mitigation;
    - Perform technology trade-offs, support to eco-design approaches and avoid burden shifting (e.g. from one life-cycle phase to another);
    - Support communication on environmental issues.
- There is a clear interest of the space sector in LCA methodology. European industry is actively contributing in ESA's activities on the subject.

# Why was LCA applied to Launchers?

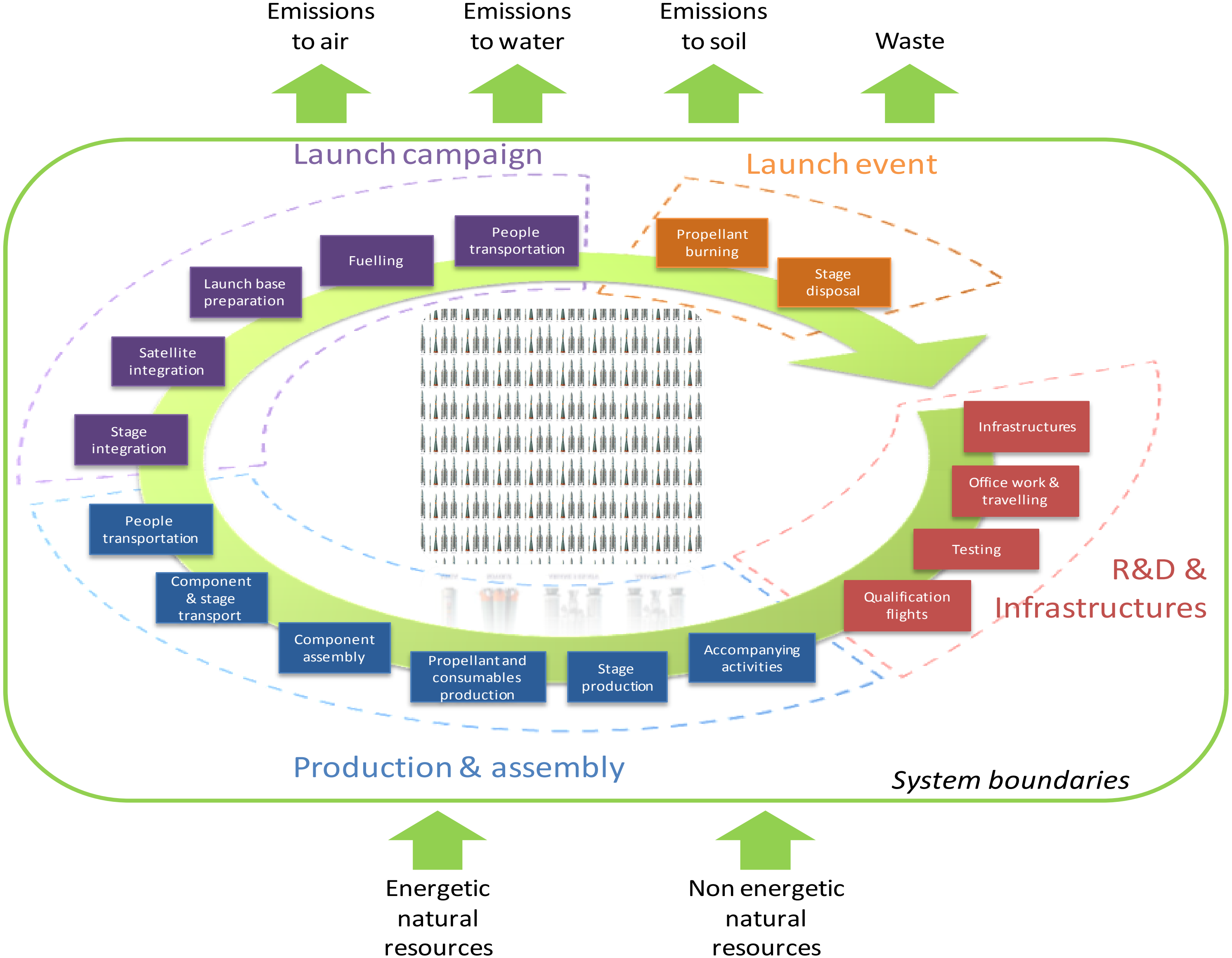
- Environmental concerns are in the forefront of public attention. There is a growing interest from customers, employees and stakeholders.

- The LCA for launchers is a pro-active answer to the growing interest around the environmental impact of launchers – several articles have been published on the subject and information requests have been addressed to Arianespace.

**Objectives:**

- Quantitative assessment of the environmental impacts.
- Identify actions of impact mitigation.
- Define a methodological framework.
- LCA model to be progressively enhanced.
- Provide guidelines for communication.

# Modeling life-cycle of launchers

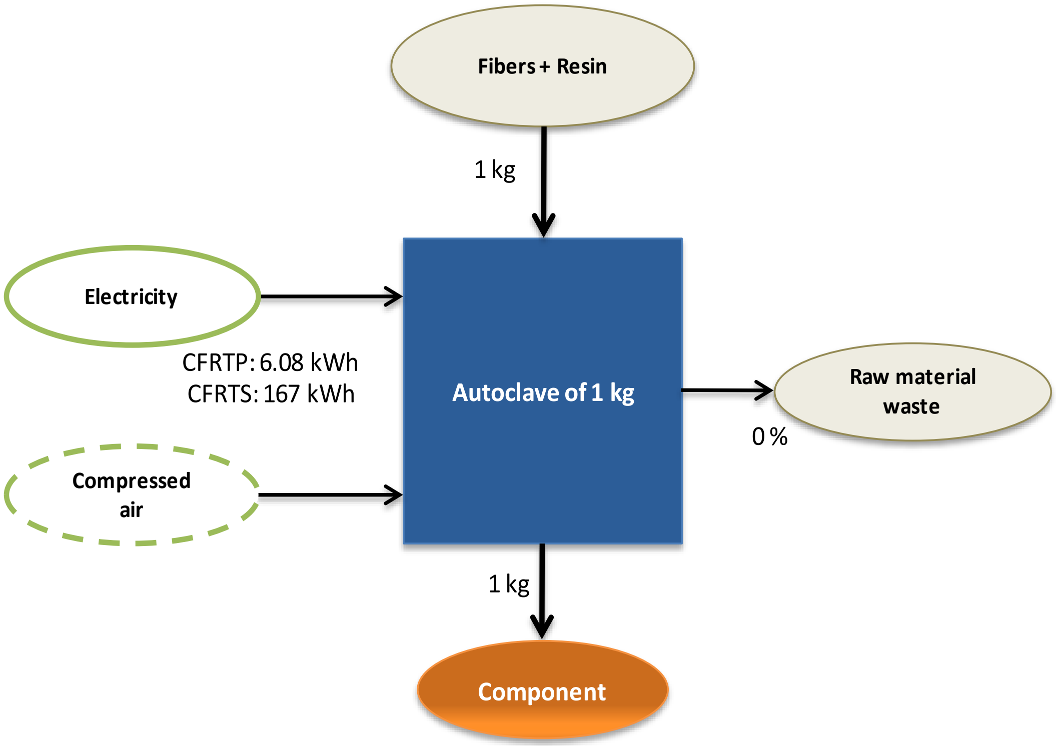


# R&D and Infrastructures

- Including the R&D activities in the LCA presents several difficulties:
  - Allocation of these impacts to one launch.
  - Heritage i.e. how to define how much of a launcher design is inherited from previous launcher designs and R&D.
  - Data collection i.e. R&D activities take place over a long time frame. The level of uncertainty is much higher than for the other phases.
- A **high level** assessment of the R&D was performed in parallel for reflections on the relative weight of the environmental footprint of these activities.

# Production & Assembly and Launch Campaign

- Production & assembly and Launch campaign modelled following the standard LCA approach.
- The Launchers dry mass and propellants have been divided into their elementary parts and modelled according to LCA standards.
- Each industrial process was characterized in terms of inputs and outputs.
- Specific processes and materials were characterized based on industrial data, literature research or extrapolation from known processes.



# Data Collection

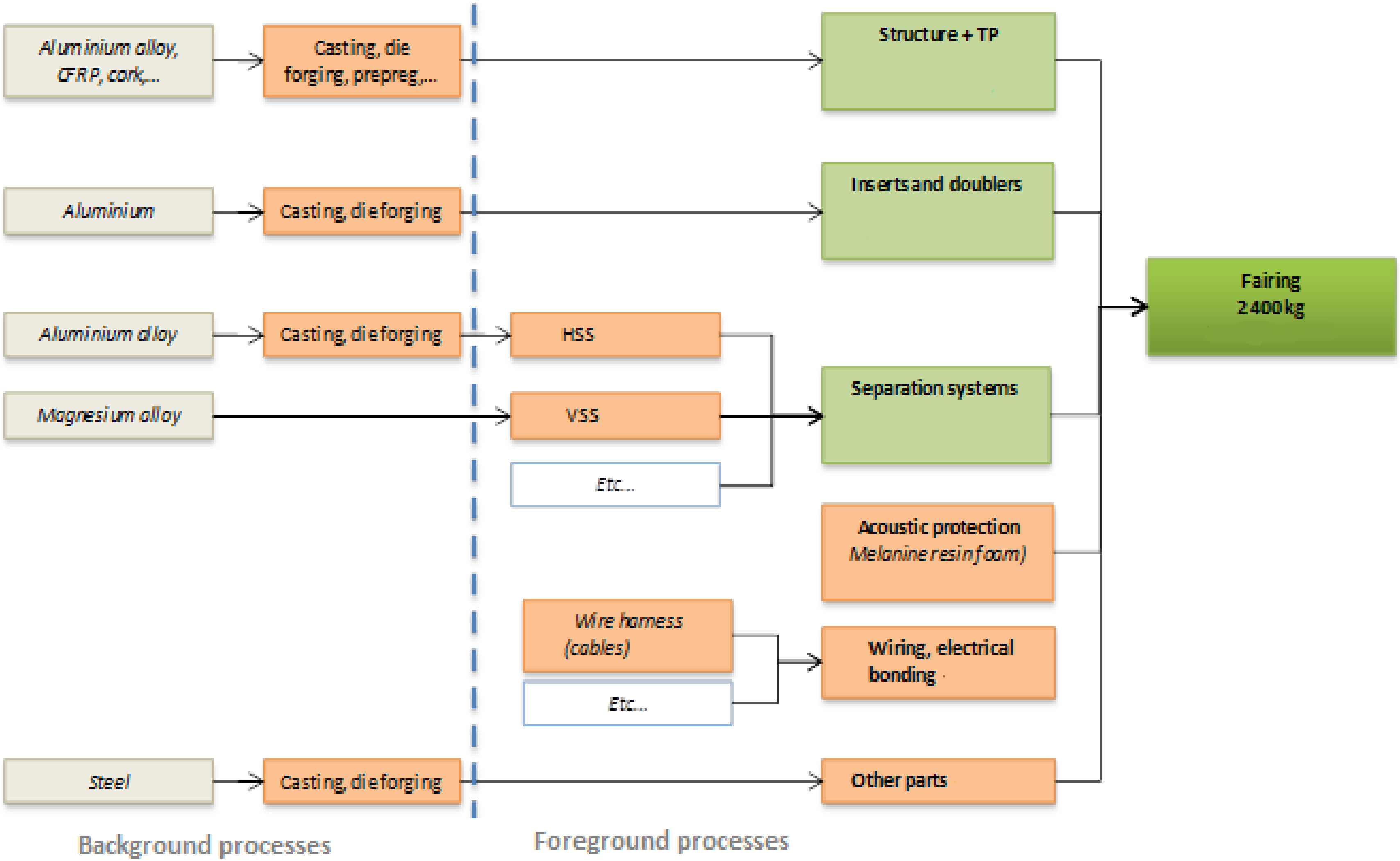
- Launchers are very complex systems with a wide international supply-chain.
- A **primary data collection** process was performed.
  - **3 steps:**

  I. Industrial workshop with all companies in supply-chain of Ariane 5 and Vega.

  II. A preliminary questionnaire was sent to all industrials.

  III. Detailed and customized questionnaires to collect quantitative data.
- This process was complemented by **secondary data collection**
  - ESA has provided detailed data:
    - full detailed documentation of Ariane 5 and Vega;
    - mass budget, cost budget, internal studies, etc..
  - Extensive complementary literature review of more than 100 sources.

# Production & Assembly and Launch Campaign – Fairing model



# Launch Event

**Propellant burning**

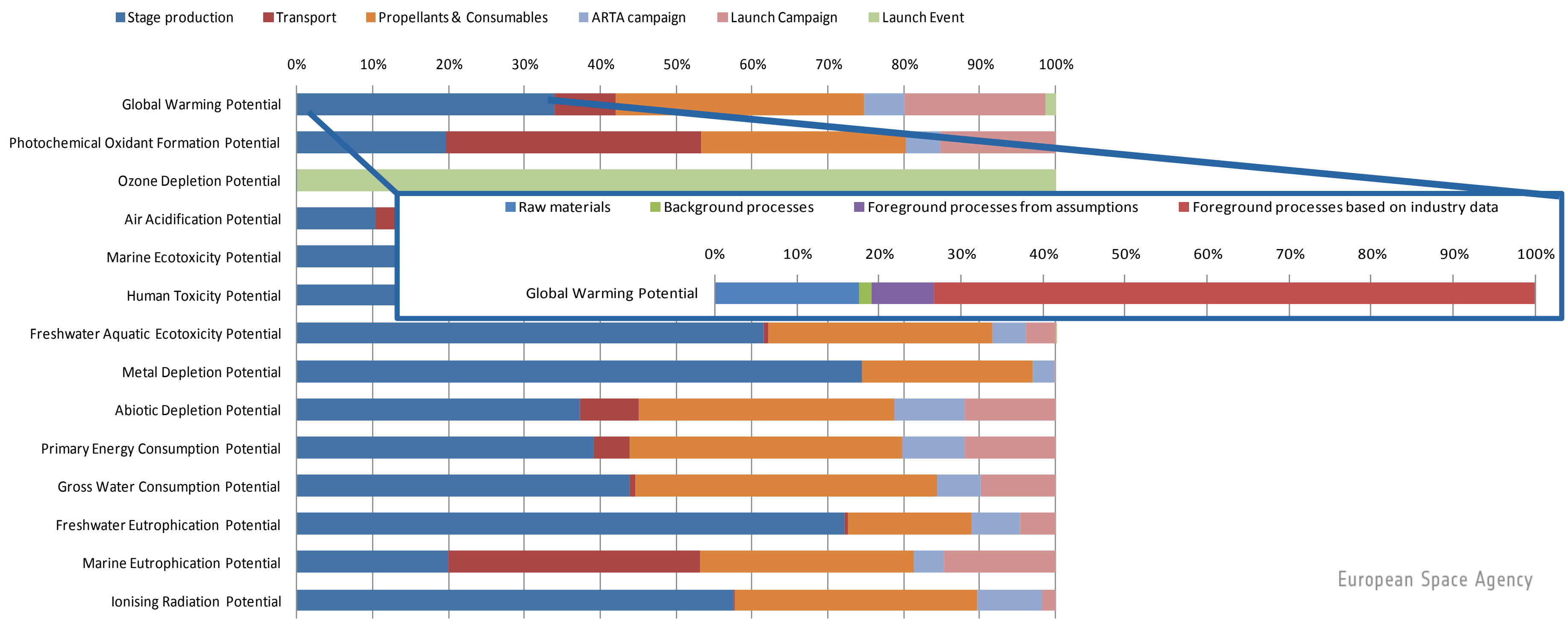
- 2-D global atmospheric model was used to evaluate impacts on ozone depletion and global warming.
- The launch phase presents special challenges to the climate models and even to the environmental metrics (e.g. ODP metrics).
- A Specific study to address this issue has been kicked-off in 2012.

**Stage disposal**

- After stage separation, lower stages and fairing fall in the ocean.
- Very conservative approach: it has been assumed that all metals falling in the ocean were converted in their corresponding ions.
- Residual solid propellant combustion continues in the ocean (no need for additional oxygen).
    - Only combustion exhausts remain, which based on the current knowledge were not considered toxic for the marine fauna & flora.

# How to use the results

- **Absolute results** have always to be normalised to provide tangible information.
- **Relative results** allow to identify processes of the life-cycle where eco-friendly alternatives can have a greater impact.
- Mitigation measures do not mean necessarily a change in the final product (e.g. adopt alternative industrial process, modify infrastructure of production site, etc.).



# Model validation

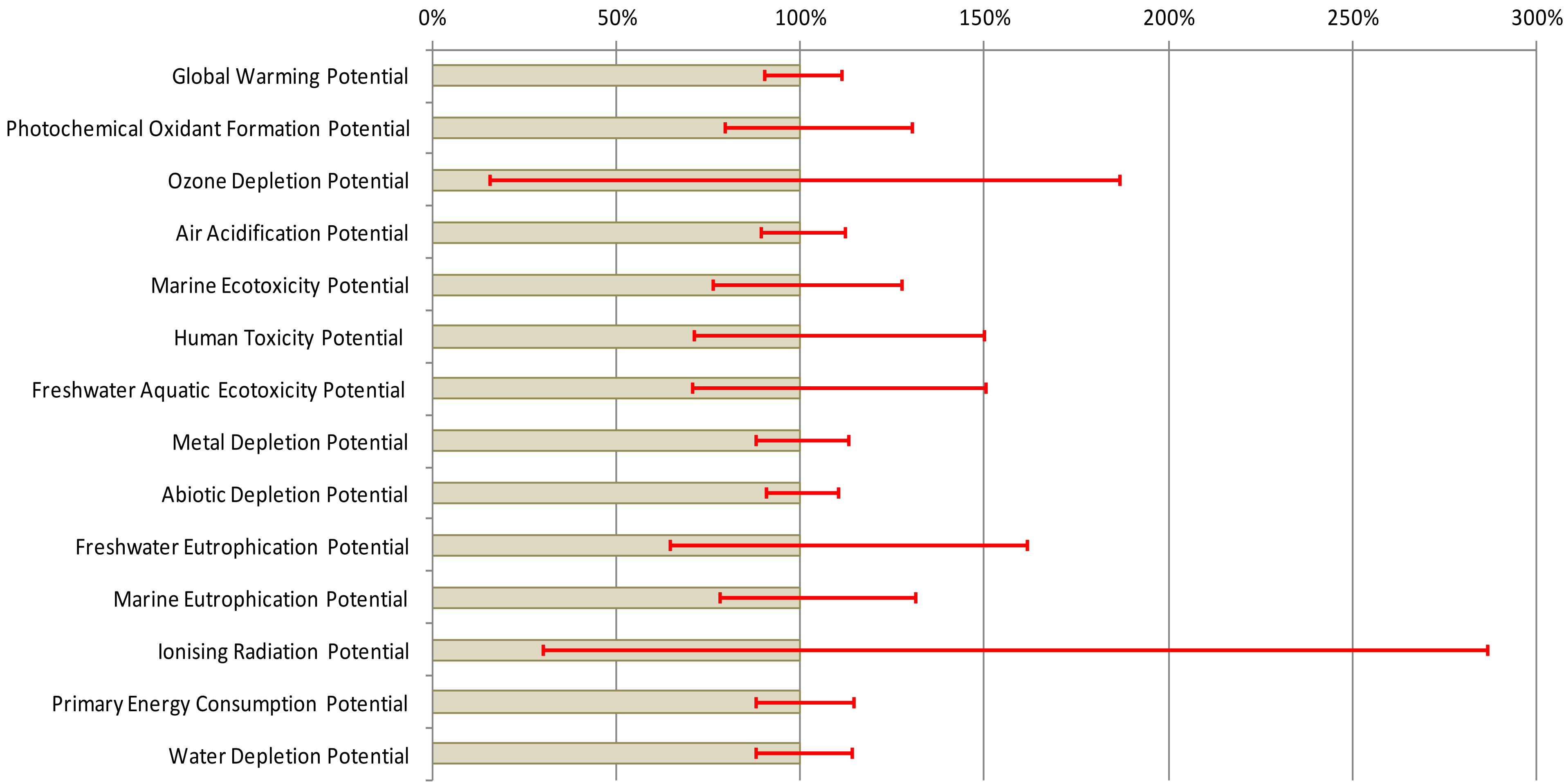
## Uncertainty analysis

- The uncertainty analysis was carried out based on Monte-Carlo simulations.
- Each raw data has been modelled as a normally distributed probability function with the following characteristics:
  - Mean value: equal to the value retained for the deterministic calculation.
  - Uncertainty: estimated based on the source of the data as well as its robustness.
- LCA databases data is already modelled taking into account uncertainty.
- The sensitivity of the results to changes in input parameters has been checked.

## Review process

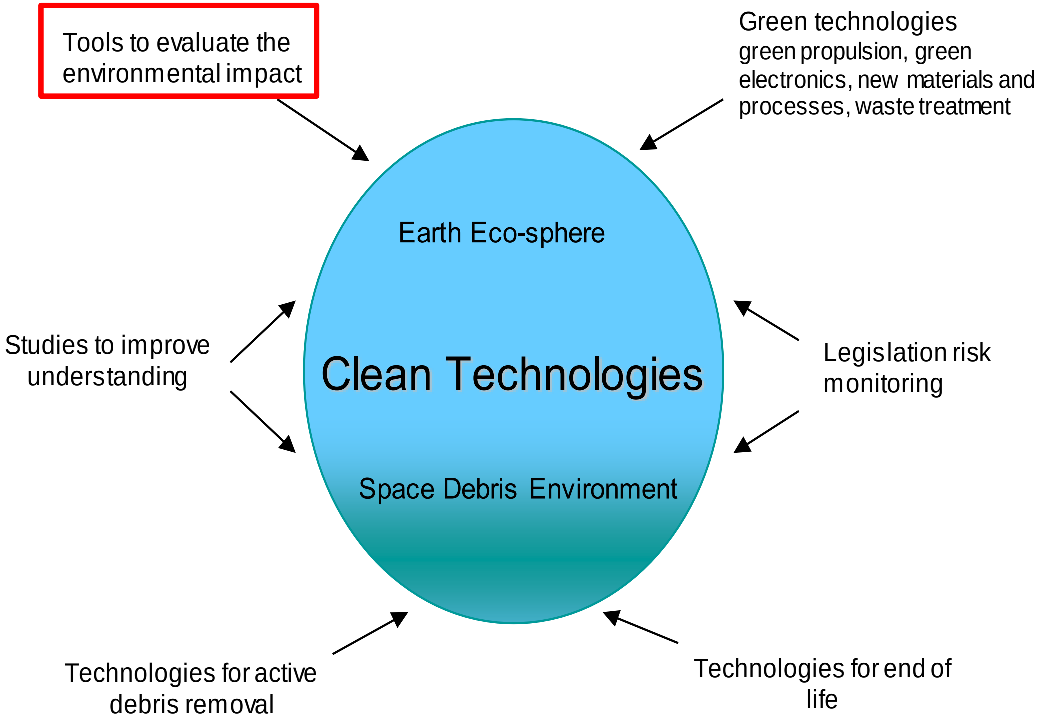
- Independent review by consultancy firm specialised in the LCA field to validate the approach, methodologies and outcome.
- Internal ESA review involving 10 Launchers specialists to validate assumptions done to model the European Launchers life-cycle.

# Model validation



# Future applications of LCA at ESA

- Substantial work is still required to adapt the methodologies, databases and tools to the specificities of space materials and processes.
- Through the **Clean Space initiative** ESA is proposing a roadmap for the development of a framework of environmental impact assessment for space.



# Conclusions

- Life Cycle Assessment is a **structured and internationally standardised methodology** for environmental impact assessment.
- ESA has been a pioneer in applying the LCA methodology to space systems. An LCA of the European launcher family has been carried out.
- Launchers are very complex systems with **specific impacts that are not shared by any other anthropogenic activity**.
- An extra effort to model new processes/materials and complementary tools were needed to model specific impacts, e.g. atmospheric impact of the launch.
- This activity has shown the **relevance of LCA to assess the environmental footprint of Launchers** and has instigated discussions on mitigation actions.
- **ESA's Clean Space initiative proposes a roadmap to establish a common eco-design framework** available for European space organisations.