CRISTAL & LSTM
Life Cycle Assessment

ESA CSID 2024

DEFENCE AND SPACE

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Agenda

- CRISTAL mission
- LSTM missions
- Goal of the LCA study iaw ESA CPX SoW
- From Scope definition to LCA model: A step-by-step process to model all key activities within scope
- System Boundaries
- CRISTAL LCA results and environmental hotspot analysis
- LSTM environmental hotspot analysis
- Conclusions

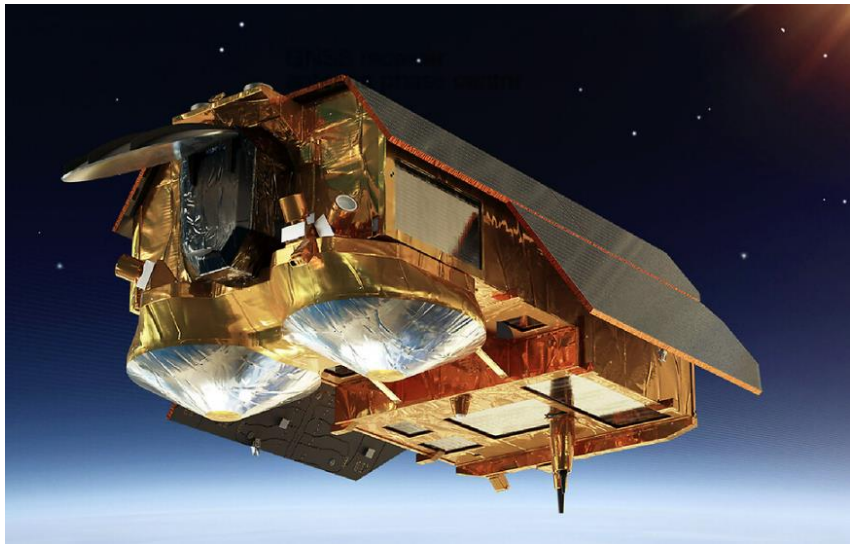
CRISTAL Mission

Main Objective:

- To measure and monitor the variability of Arctic and Southern Ocean **sea-ice thickness** and its **snow depth**.
- To measure and monitor the **surface elevation** and changes therein of glaciers, ice caps and the Antarctic and Greenland ice sheets.

Secondary Objectives:

- To contribute to the observation of **global ocean topography** as a continuum up to the poles.
- To support applications related to coastal and inland waters / **hydrological research**.
- To support applications related to **high latitude snow cover and permafrost**.



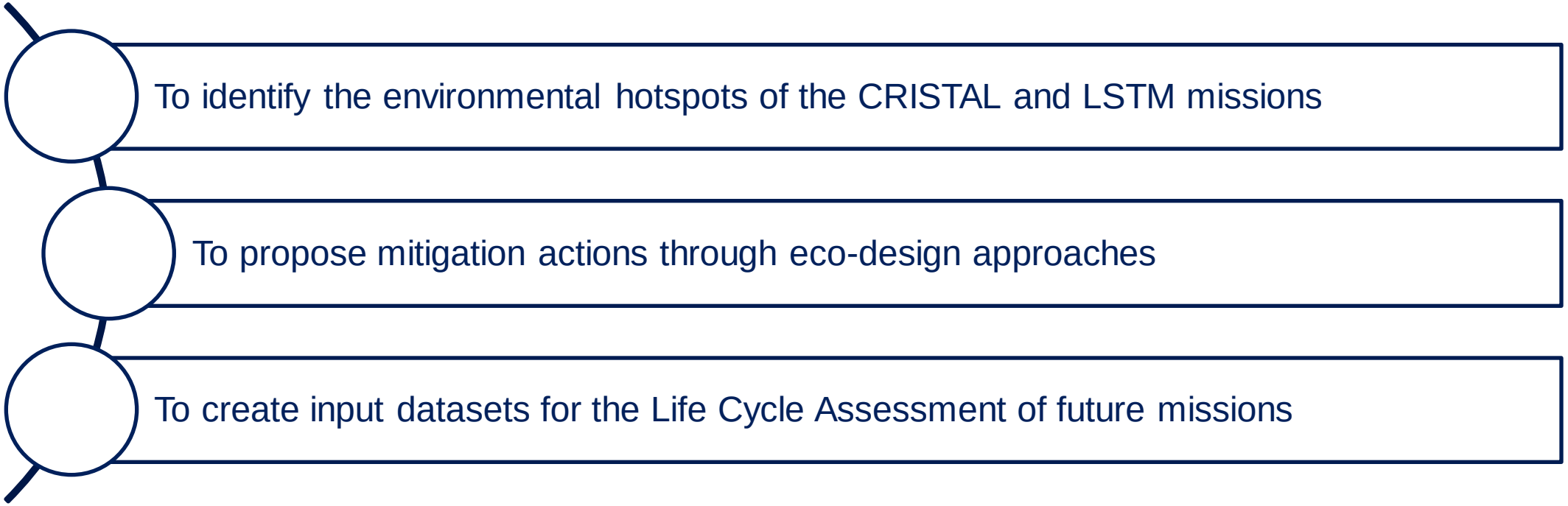
LSTM Mission (Land Surface Temperature Monitoring)

Measures **land temperature** and derived **evapotranspiration**.

Sustainable agriculture applications:

- Respond to climate variability
- Manage water resources
- Predict droughts
- Address land degradation
- High Temperature events (HTE)
- Natural hazards: volcanos, fires
- Coastal and inland water management
- Urban heat island issues.

Goal of the LCA study iaw ESA CPX SoW



From Scope definition to LCA model

A step-by-step process to model all key activities within scope

Scope definition:

FU: "*The manufacturing, integration, qualification, testing and preparation for launch of the CRISTAL/LSTM space segment to fulfil its requirements".*

Impact indicators: PEF methodology (EF3.0) adapted by ESA

European Commission

Data collection:

- CPX proposal
- CPX product tree and mass budget
- CPX contracts
- CPX schedule and logistics plan
- CPX CRISTAL/LSTM supplier questionnaires
- CPX equipment DML
- Airbus facilities management
- ESA LCA Handbook and TNs
- Literature

Mapping of inventories

(Ecoinvent + ESA databases)

ecoinvent

esa

Modelling in LCA software

(Simapro software)

SimaPro

System Boundaries

Phases C + D – Detailed definition + Qualification and production

- Labour hours
- Staff travels by plane
- Equipment (Flight, EMs, EFM, GSE) material composition and manufacturing processes
- Transport of assembled equipment
- Testing at equipment and satellite level
- Propellant production

Phase E1 – Launch and commissioning, limited to spacecraft related activities

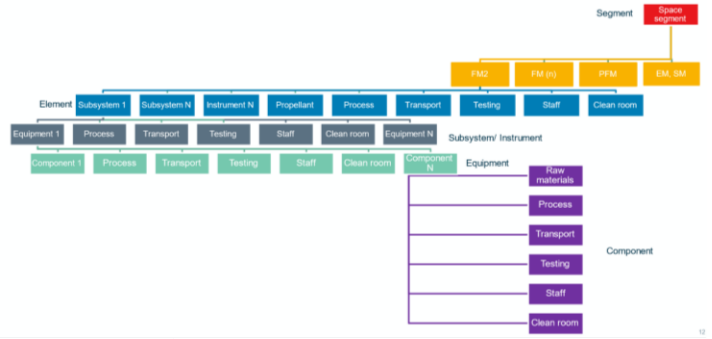
- Labour hours
- Staff travels
- Spacecraft Transport Container (STC) production
- Spacecraft and GSE transport to launch site

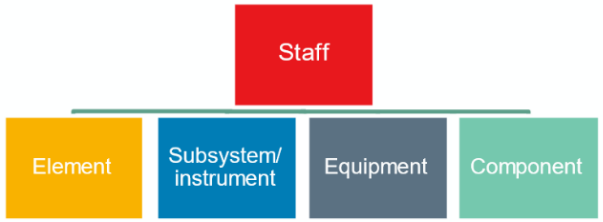
Phase F – Disposal (partially included)

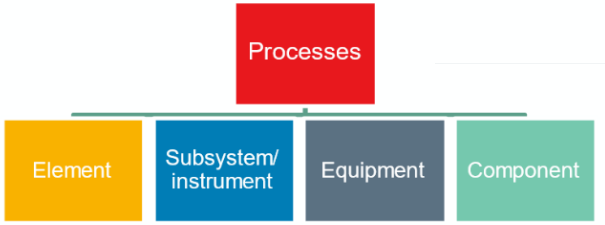
- Transport from launch site to Europe (GSE and containers)

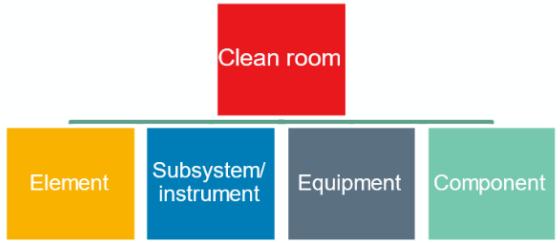
Thematic modelling strategies

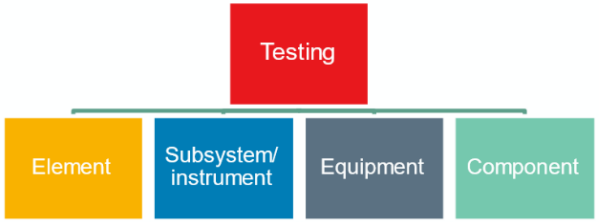
(ESA modelling guidelines)

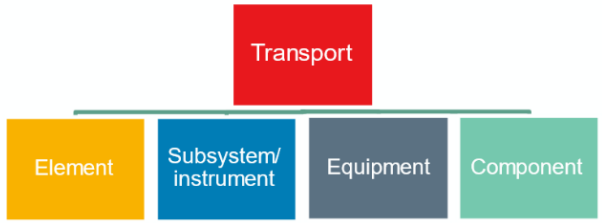












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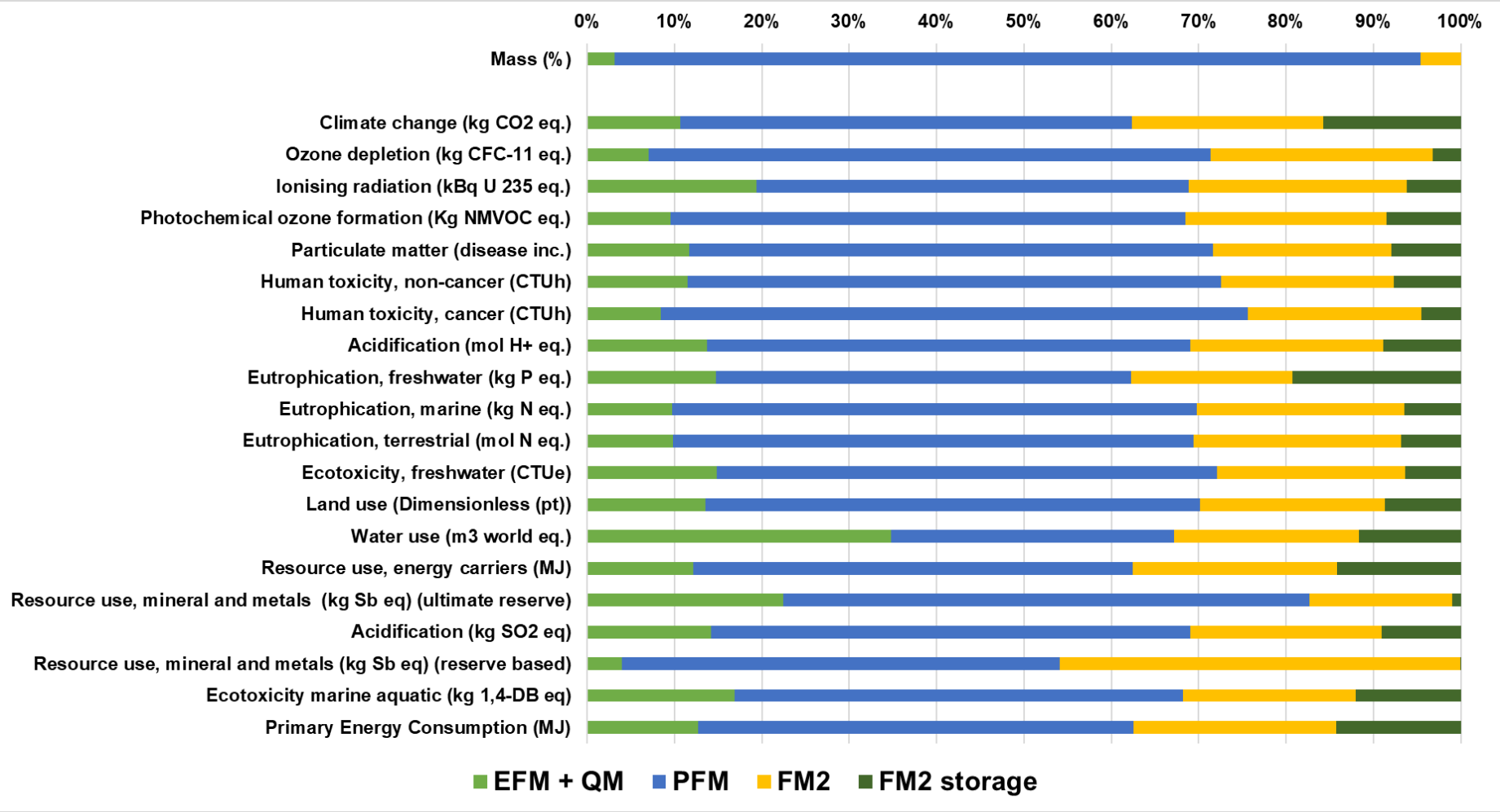
CRISTAL LCA results

LCA results: CRISTAL space segment breakdown



Note that PFM and FM2 satellites are identical. The PFM LCA category accounts for:

- the PFM dry mass
- the GSE, including the transport containers
- more demanding test sequences
- more staff hours and travels

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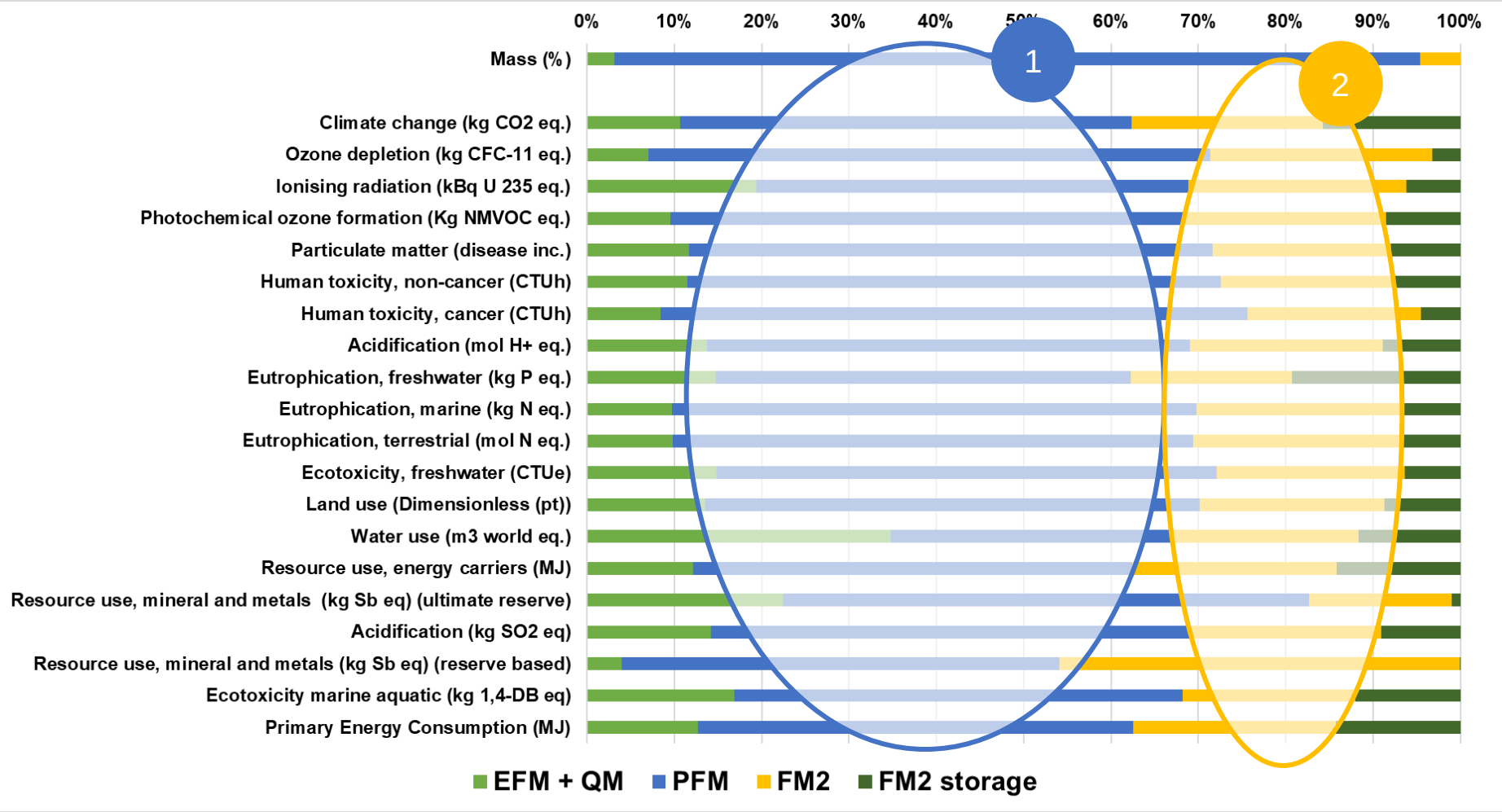
LCA results: CRISTAL space segment breakdown



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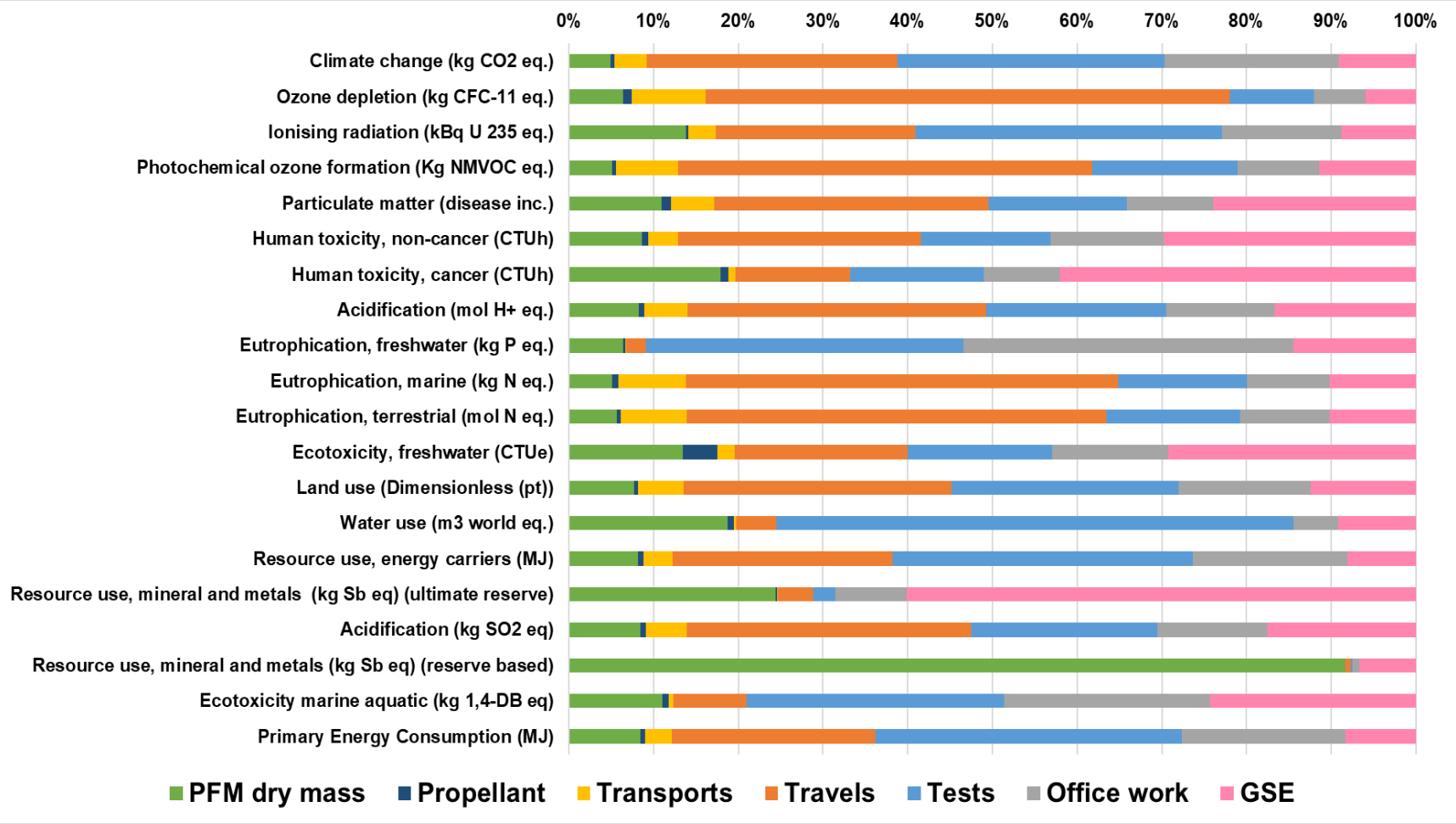
LCA results: CRISTAL PFM impact breakdown



"Travels" average contribution: 26% across impact categories.

"Tests" average contribution: 23% across impact categories, dominated by the environmental testing (avg: 43%) and by the time spent in the cleanroom (avg: 41%) *at satellite level.*

Resource use, minerals and metals *(Ultimate reserve)* is dominated by the GSE dry mass, in particular the content in electronic components.

Resource use, minerals and metals *(Reserve based)* is dominated by the PFM dry mass, in particular the power sub-system.

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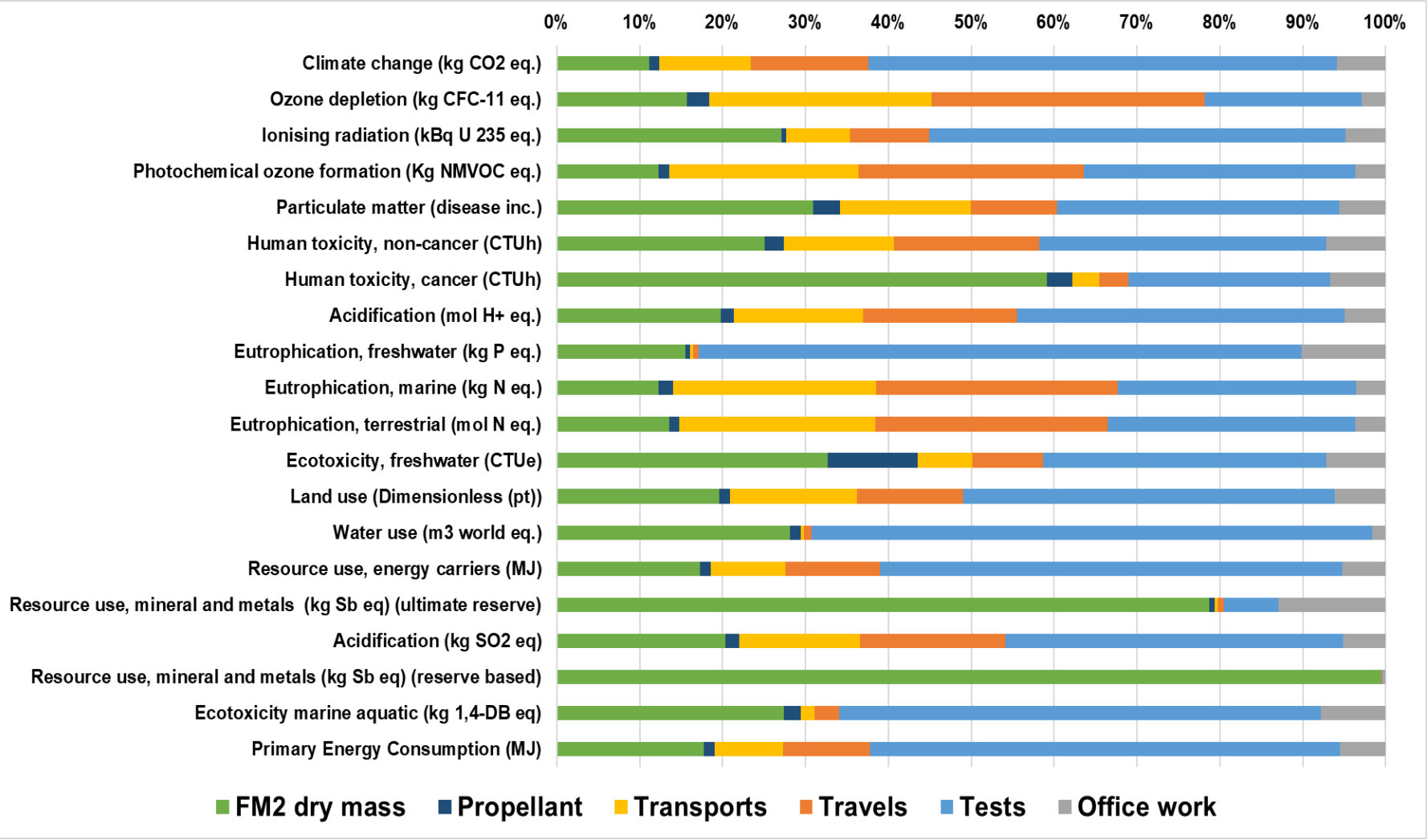
LCA results: CRISTAL FM2 impact breakdown



"Tests" average contribution: 39% across impact categories

"FM2 dry mass" average contribution: 29% across impact categories

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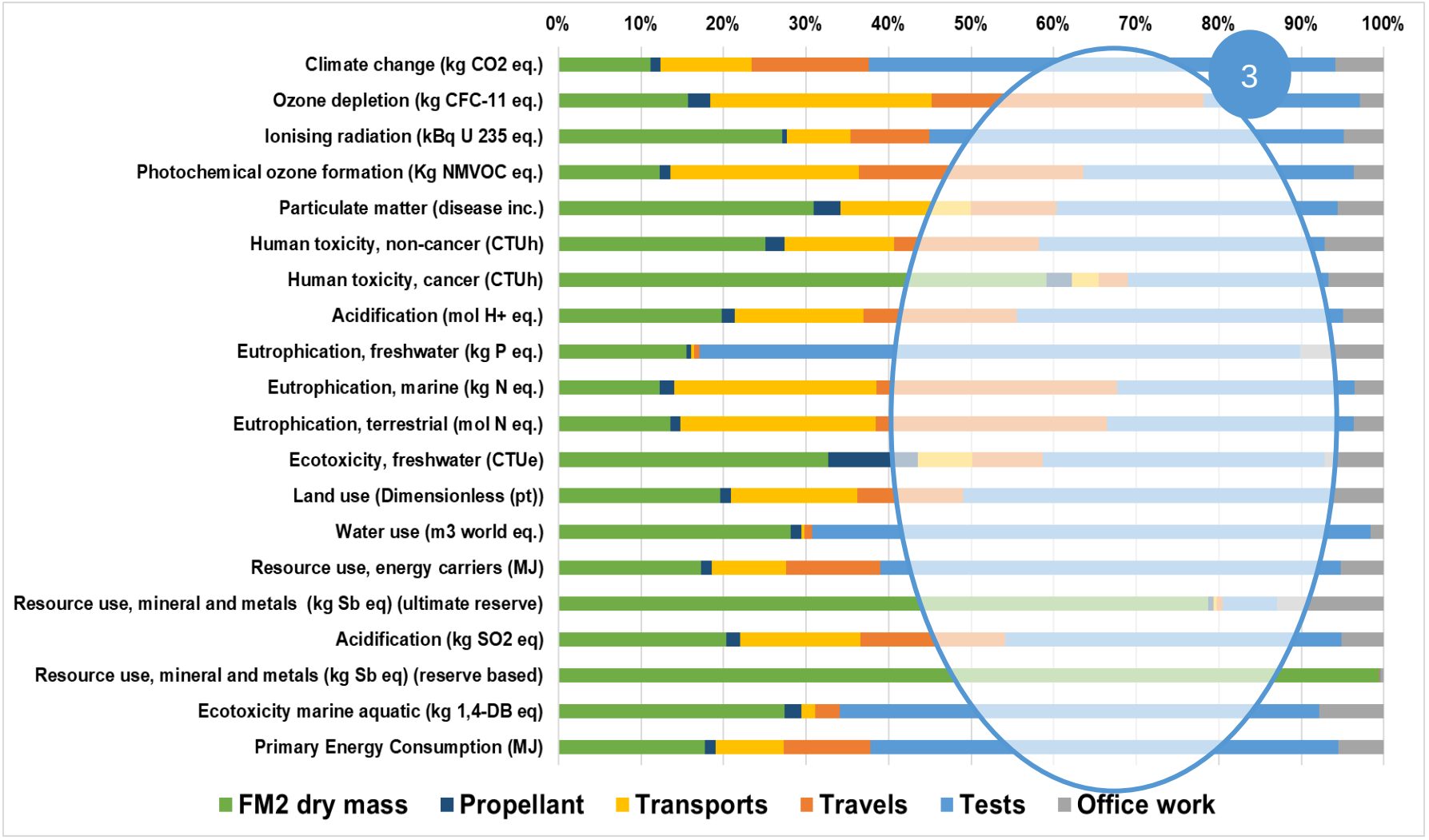
LCA results: CRISTAL FM2 impact breakdown



"Tests" average contribution: 39% across impact categories

"FM2 dry mass" average contribution: 29% across impact categories

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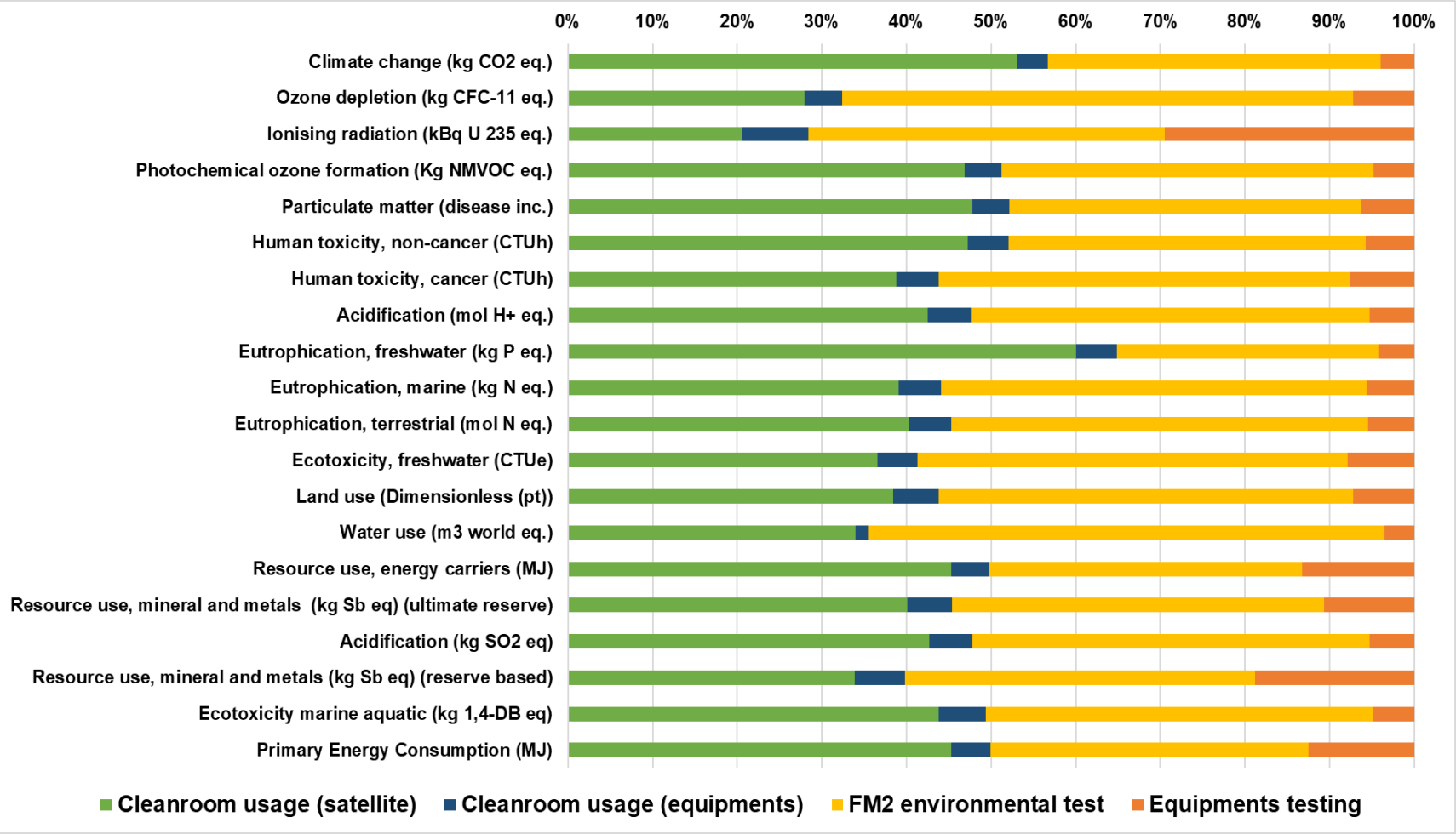
LCA results: CRISTAL FM2 AIT impact breakdown



Environmental testing at satellite level average contribution: 45% across impact categories

Time spent in the cleanroom at satellite level average contribution: 41% across impact categories

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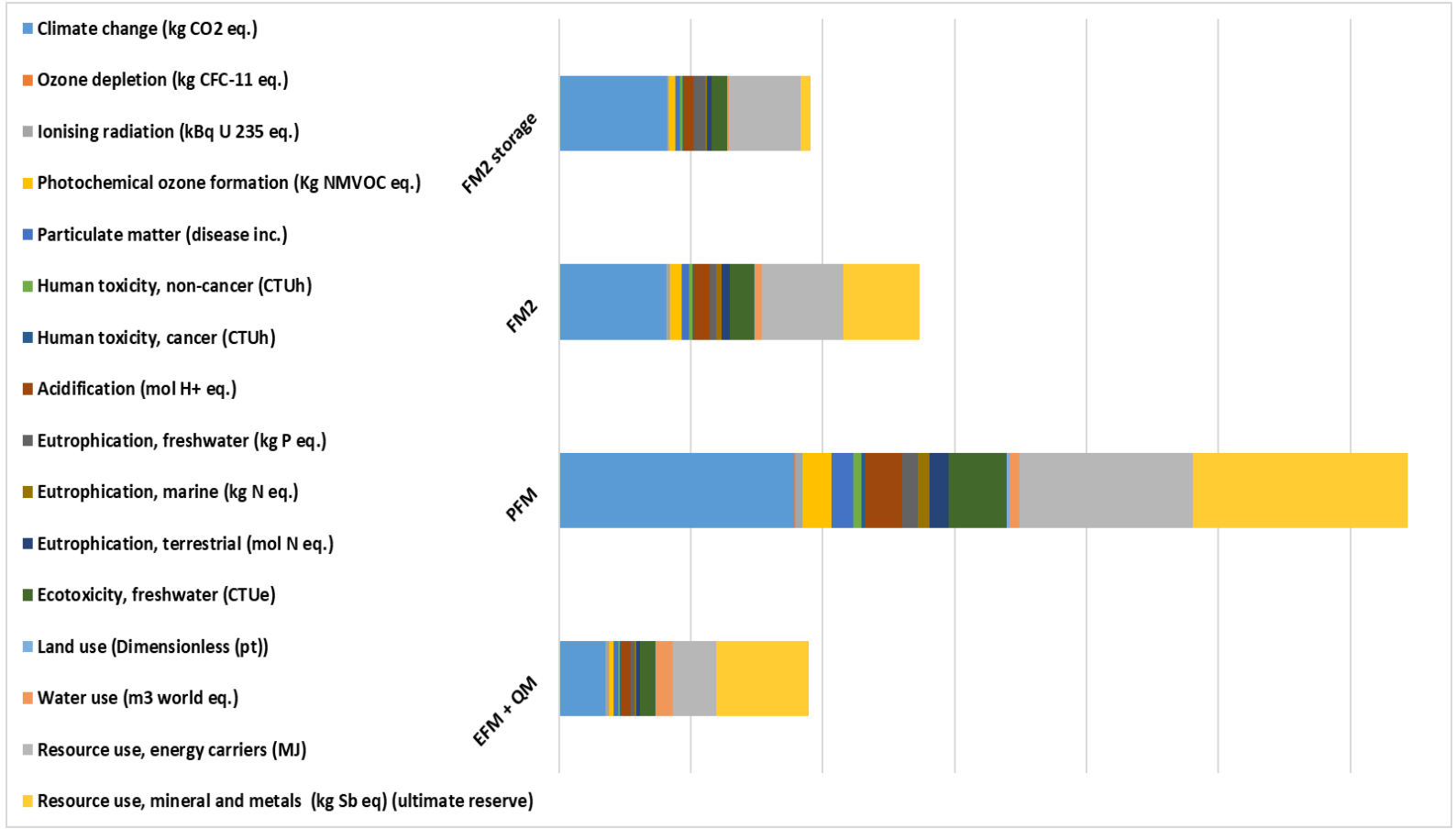
CRISTAL LCA results: Single score



PEF single score – ESA adpatation [ ]

Environmental hotspots

- ***Climate Change + Resource use, energy carriers*** – Travels and energy consumption originating mainly from AIT.
- ***Resource use, minerals and metals*** – extraction of the metals used as primary materials in electronic components.

FM2 vs PFM

The FM2 LCI differs from the PFM LCI in the following aspects:

- GSE allocated to PFM
- Test sequences less demanding
- Less labour hours
- Less travels

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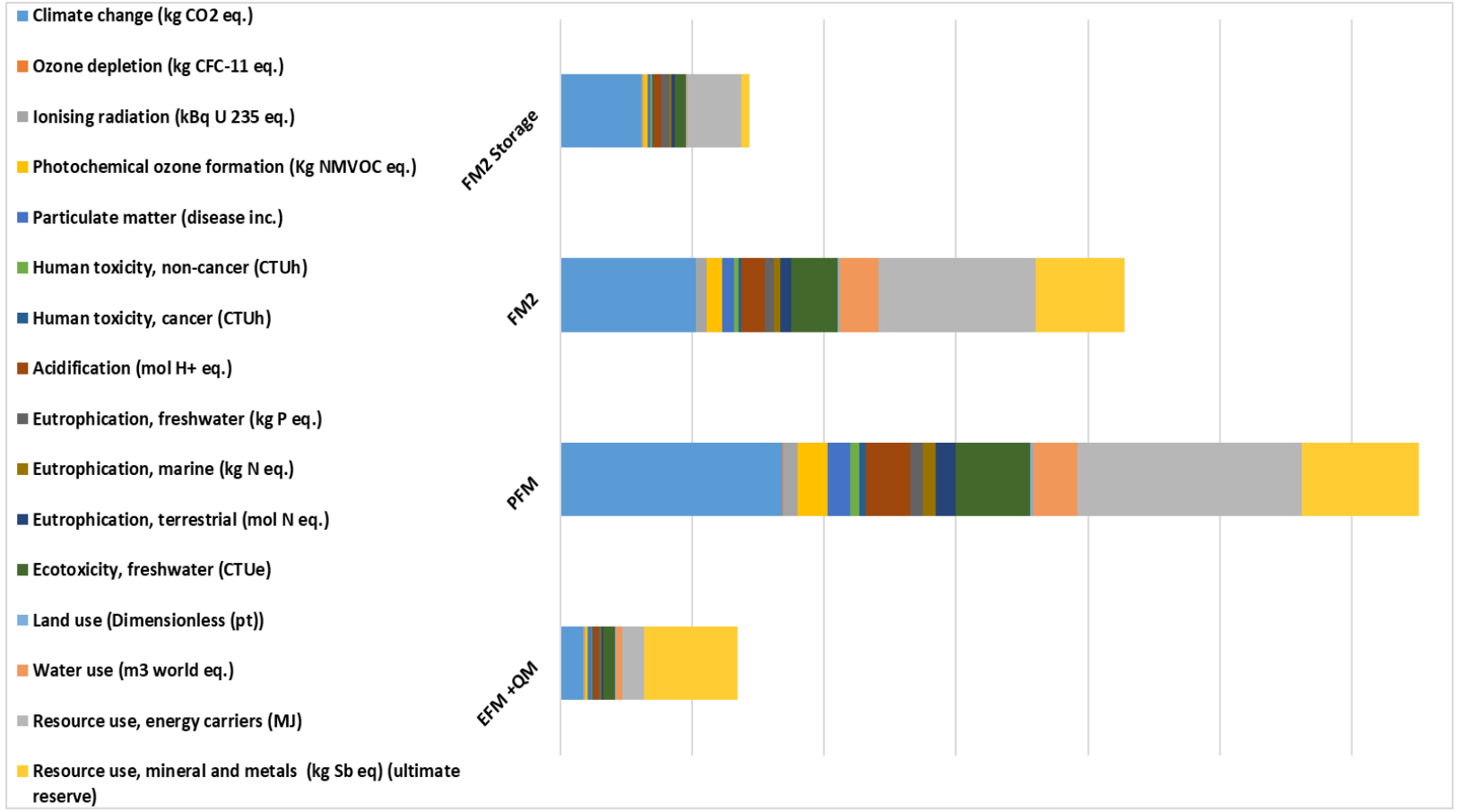
LSTM LCA results

LSTM LCA results: Single score



PEF single score – ESA adpatation [ ]

Environmental hotspots

- ***Climate Change + Resource use, energy carriers*** – Travels and energy consumption originating mainly from AIT (*very demanding test sequence at instrument level*)
- ***Resource use, minerals and metals*** – extraction of the metals used as primary materials in electronic components.

FM2 vs PFM

The FM2 LCI differs from the PFM LCI in the following aspects:

- GSE allocated to PFM
- Test sequences less demanding
- Less labour hours
- Less travels

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Main methodological challenges

- Modelling of electronic equipment
  - Results are very sensitive to the content of electronic components
  - GSE are mainly COTS items – feasible and representative approach is the use of very generic proxies
- Calculating the DQR
  - Methodology is to some extend subjective and as is does not distinguish between quality of primary data and fitness of the LCA database processes to describe the primary data.
  - Methods performed for data collection are often unknown to the LCA practitioner.

Common Conclusions and Improvement Potentials

- The PFM (satellite + GSE) is the main contributor to all impacts (cumulated average share of impacts of 55%).
- The FM2 represents about 5% of the total mass but cumulates over 20-30% of all impacts of each mission.
- The environmental profile is dominated by the ***AIT phase, Travels and Equipment manufacturing phase (including GSE).***.
- The most critical environmental hotspots are the categories “Climate Change” and “Resource use, energy carriers”.

Methodological improvements
• Focus the data collection of primary data on mission specific elements. • Simplify/tailor and provide better guidelines for LCA supplier questionnaires. • Evolve the ECSS documentation standards to be harmonized with inputs requested for LCA.

Thank you