Data Quality Rating for LCA in the space sector

Clean Space Days 2024

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Context

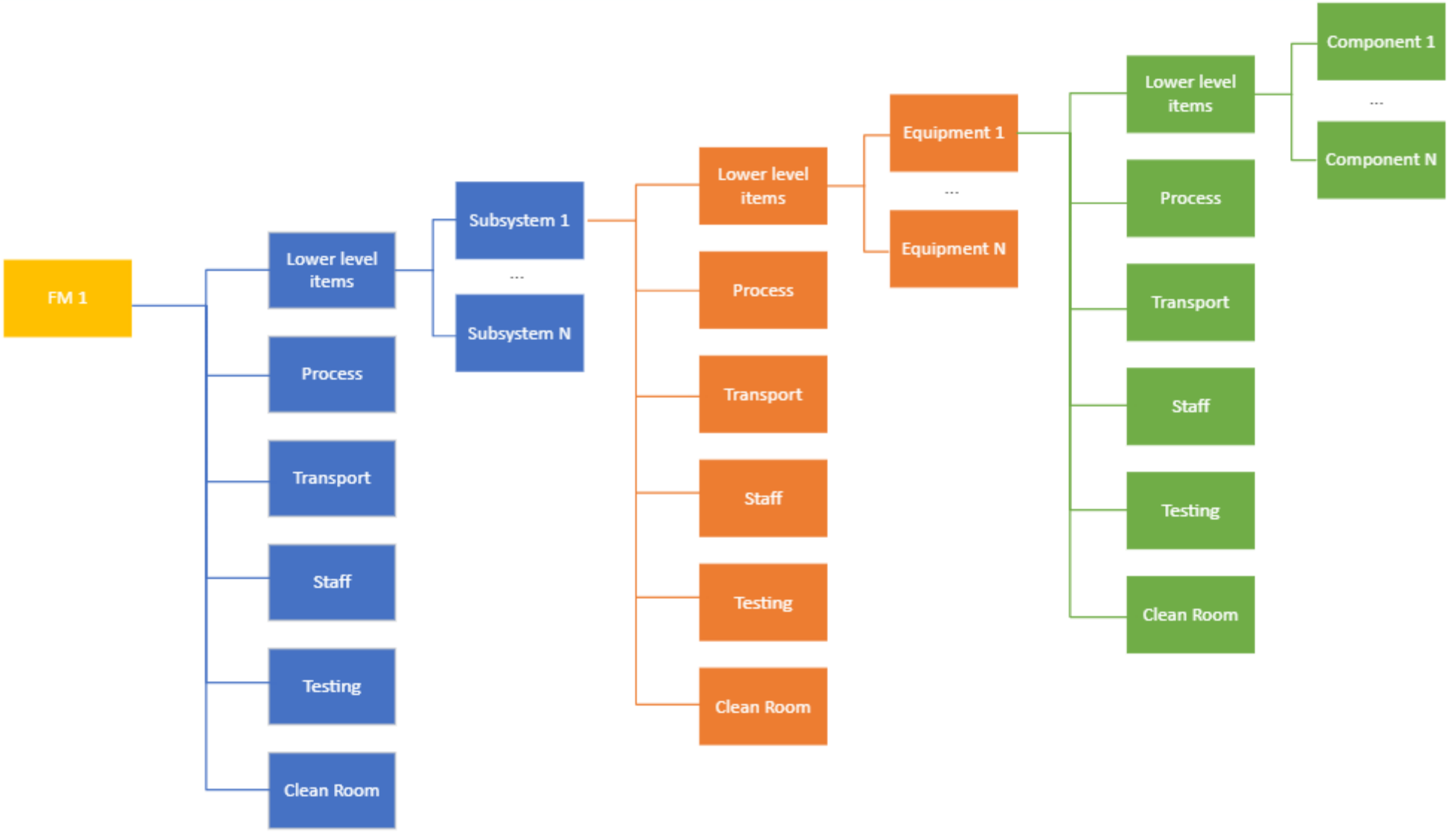
- **What is available today as methodology / guidelines ? What is applicable ?**
  - ESA Space system Life Cycle Assessment (LCA) guidelines (ESSB-HB-U-005), October 2016, update on-going
  - Tailoring documents for each Copernicus Mission
  - ESA Technical note on DQR (ESA-OPS-SC-TN-2023-002), March 2023

- **Why updating the Data Quality Rating (DQR) methodology ?**
  - DQR : **main requirement** to be achieved in the final iteration of LCA applied to projects.
  - Assesses the **maturity and validity** of the final assessment, allowing to know how trustable are the final results and allowing for fairer conclusions.
  - During intermediate iterations: allows to **identify and prioritise** the areas which need to be further investigated.
  - However, the return of experience shows that there are several different ways to interpret and calculate each of the data quality indicators

Harmonised and agreed definitions of each data quality criteria are needed

  - On-going update of ESSB-HB-U-005 : need to **update and align the DQR methodology**

New structure ESA LCA HB



Overview of proposed DQR methodology update

- **Applicability**
  - For LCA performed at **system/mission level**
  - To be used by **Prime together with LCA practionner**
- **Rating indicators**
  - Methodological appropriateness indicator removed
  - **Completeness** indicator becomes a **requirement**
  - Differentiate ratings between **primary (raw) data** from data collection and **LCI datasets modelling** – on-going
  - Update of pedigree matrix (see dedicated slides)
- **Computing DQR at different levels** (subsystem, system)
  - Start at equipment level
  - At each level: use the same structure, which is the one proposed in the update of the LCA HB. The DQR shall consider all these inputs.
  - Aggregation method slightly updated

New proposition: slightly deviate from the PEF method to better suit complex space use cases, while still following its key guidelines and principles.

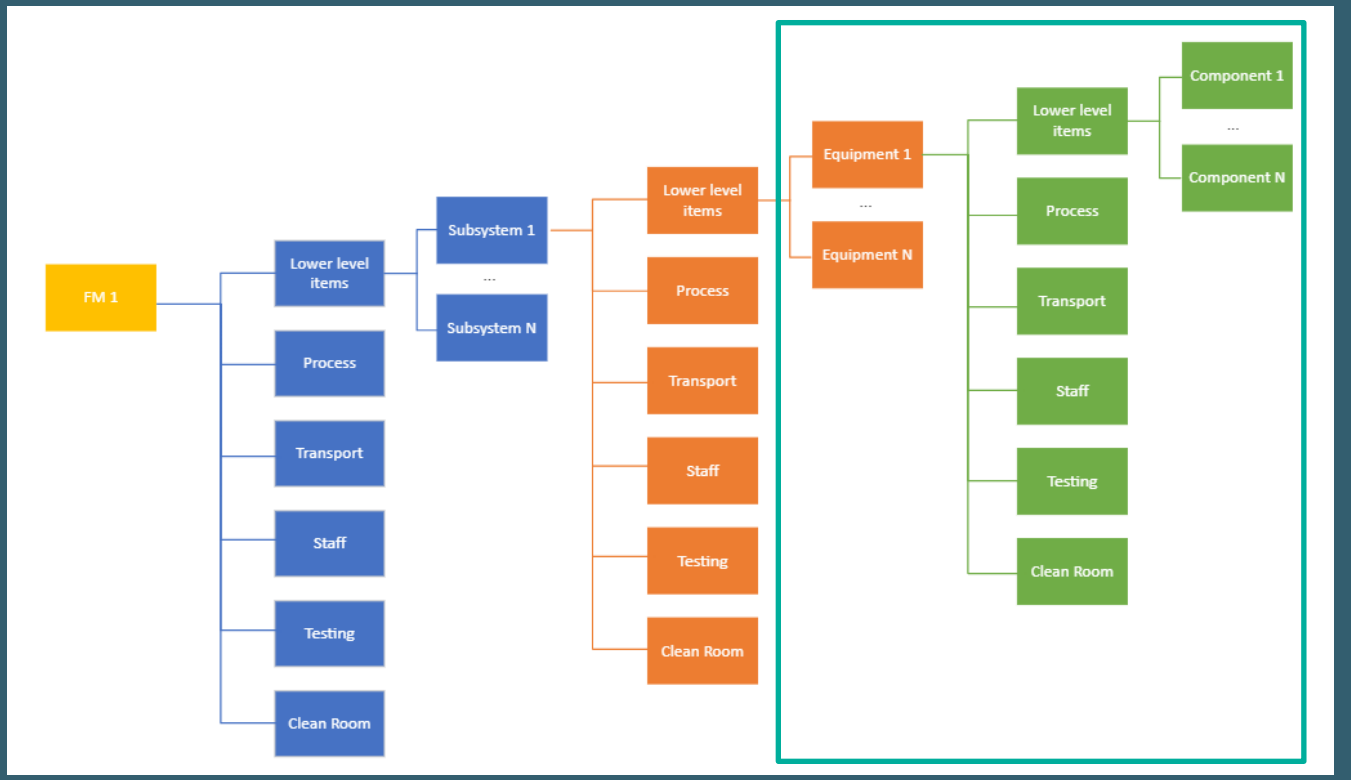
Proposed DQR methodology VS PEF

- Product Environmental Footprint (**PEF**) published by the **European Commission** is a **standardized methodology** for assessing the environmental impacts of products throughout their entire life cycle.

- **Differences wrt PEF:**
  - Methodological appropriateness and consistency criteria removed : relevant to full compliance with the PEF method. Based on LCA reports, ESA will still review the methods and consistency to ESA LCA Handbook.
  - Most relevant impact categories : 3 categories identified as mandatory + up to 80% of the total single score.
  - Different pedigree matrices depending on the type of element for which DQR is assessed (e.g. equipment/subsystem)
  - Direct assessment at equipment level, without assessing the data quality of each individual inputs at lower level
  - No use of Data needs matrix
  - Specific rating guidelines for ESA Database proxy

- **Commonalities wrt PEF:**
  - Criteria TeR, TiR, GeR, P are maintained
  - Completeness as requirement
  - Different method for DQR of secondary datasets (e.g. fitting of LCI datasets) – on-going work

1. Equipment


FM 1
Lower level items
Process
Transport
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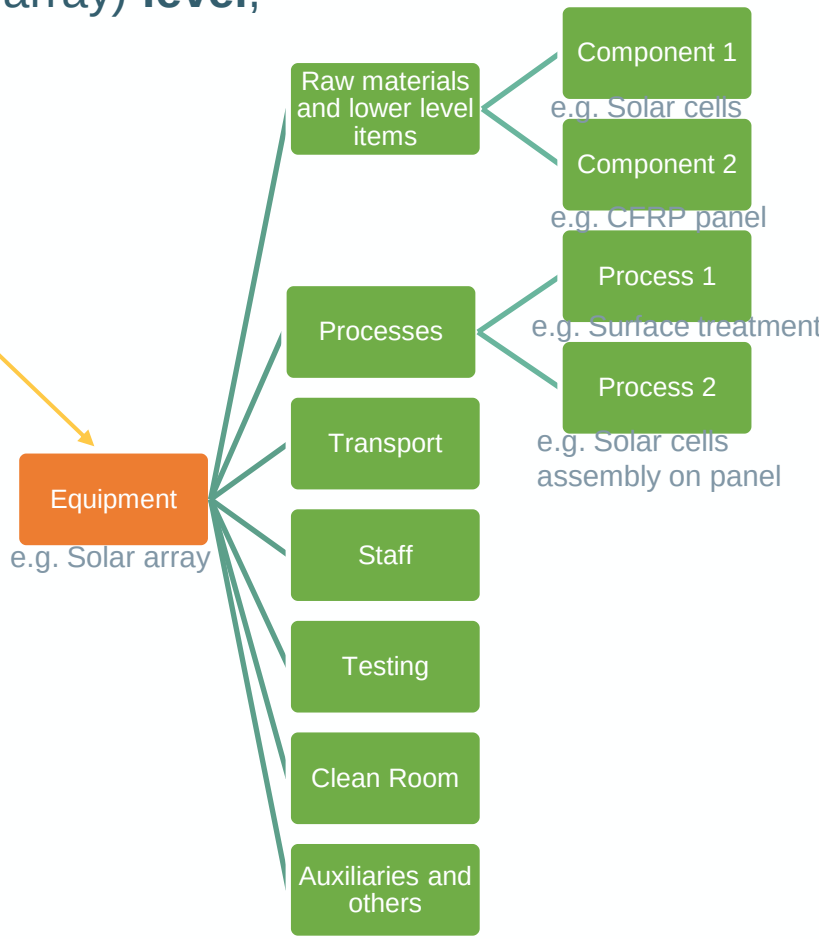
Component N

DQR evaluation at equipment level

- DQR shall be assessed for this complete data-set, **at equipment** (e.g. Solar array) **level**, not looking into the details of each input/ouputs

- List of indicators to be assessed, directly at equipment level :
  - **Ter, GR, TiR, P** : see matrices in the next slides
  - **Requirement for Completeness**



- If a proxy from the **ESA Database** is used to model the complete equipment (e.g. Solar Array from ESA DB) :
  - If the proxy is modified / adapted → DQR = 4 for all criteria
  - If the proxy is used as is → DQR = 5 for all criteria

Technological representativeness (TeR)

Technology aspects have been modelled using data from …

Rating	Data quality indicator for Technological Representativeness (TeR)	Example : Reference Equipment = RW 50 Nm, supplier 1
1	Data questionnaire (specific data from the supplier and technology under study)	RW 50 Nm supplier 1
2	Data questionnaire adapted from another equipment (another supplier or same supplier but other similar equipment)	RW 50 Nm supplier 2 + scaled or RW 30 Nm supplier 1 + scaled
3	No data questionnaire, based on DML & DPL inputs, together with design inputs (e.g. mass budget) and/or expert assumption. Assumptions on waste of materials and Buy-to-Flight ratio shall be included.	
4	No data questionnaire, using a generic proxy from ESA DB, modified	e.g. “Reaction Wheel” from ESA DB, modified to better fit the reference equipment
5	No data questionnaire, using a generic proxy from ESA DB, not modified Or based on assumption , using non-specific database (e.g. ecoinvent)	e.g. “Reaction Wheel” from ESA DB, as is

Completeness

- Similarly to what is proposed in the PEF 2021 : completeness becomes a requirement.

- Proposed requirement for completeness at equipment level
  - The life cycle inventory performed for an equipment shall include **all lower-level items and materials, processes, transport, staff, testing, and clean room activities**. Data shall represent each stage of production, from raw material extraction to final assembly and testing, including all relevant environmental impact. **Any data gaps shall be explicitly documented and justified**.
  - Note 1 : In case of data gaps identified, proxy data or assumptions shall be used. If no proxy data or assumptions are available, this shall be clearly reported.
  - Note 2 : Sensitivity analysis could be performed to assess the impact of incomplete data on the overall results.

- The compliance to this requirement shall be justified for each equipment.
- If NC, this shall be highlighted in the report.

Aggregation

- Once all equipment DQR have been assessed → aggregation to a **single DQR** for the "lower-level items" (≠ subsystem), for each data quality indicator (TeR, GR, TiR, P), for each impact category

$$DQR_{System_{i_j}} = \frac{\sum_k RI_{k_j} * DQR_{k_i}}{\sum_k RI_{k_j}}$$

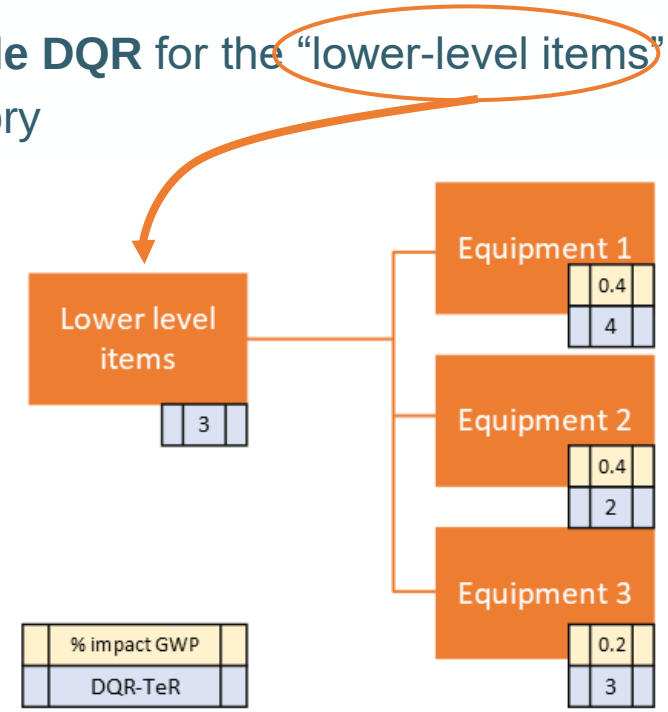
Where:

$i\ refers\ to\ the\ data\ quality\ indicator\ i$

$j\ refers\ to\ the\ impact\ category\ j$

$k\ refers\ to\ the\ item\ k\ from\ the\ System$

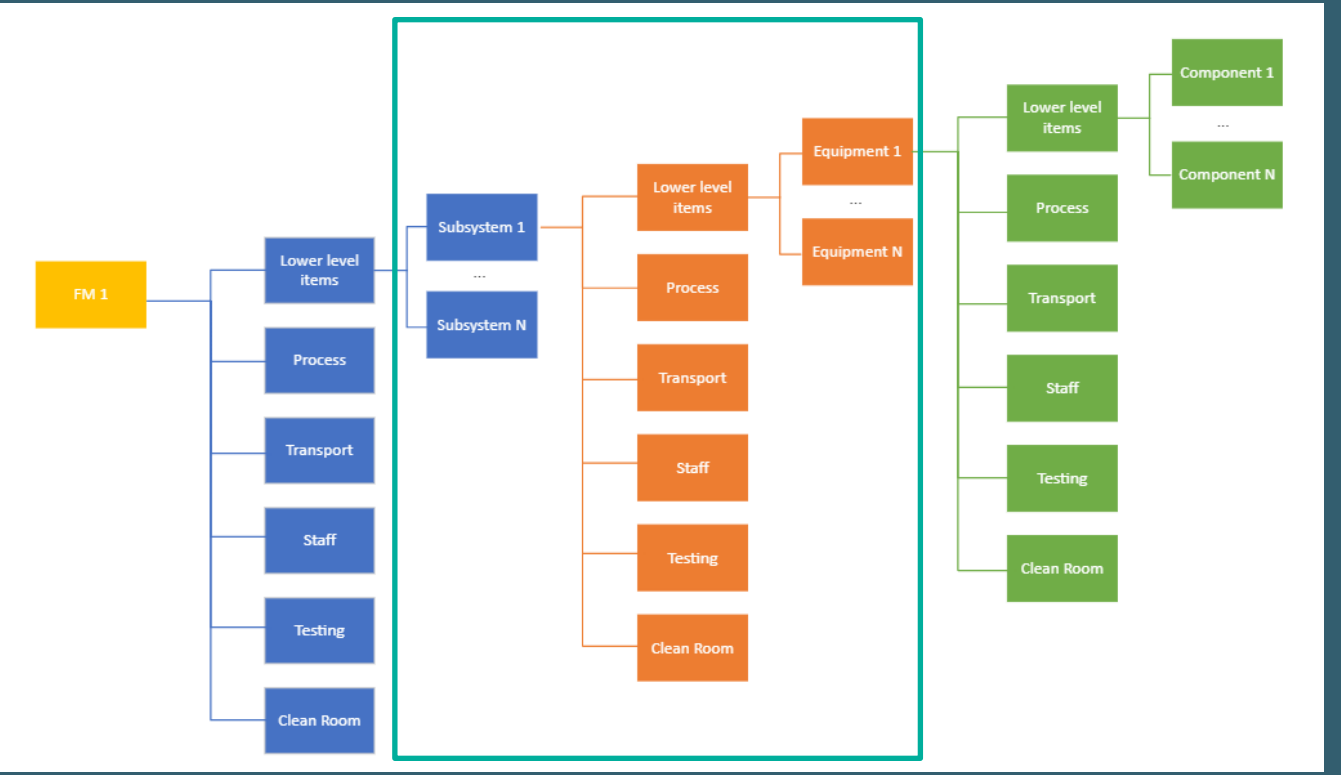
$RI_{k_j}\ refers\ to\ the\ relative\ impacts\ of\ each\ item\ of\ the\ system\ for\ each\ category\ j, in\ percentage$



- The impact categories to be used are only the **most relevant impact categories**
  - i.e. all categories contributing to at least 80% of the total single score
  - 3 as a minimum : Human Toxicity Potential, Global Warming Potential, Abiotic resource Depletion Potential (*)

(*) If launch is included in the system boundaries, Ozone Depletion potential category shall be included

2. Subsystem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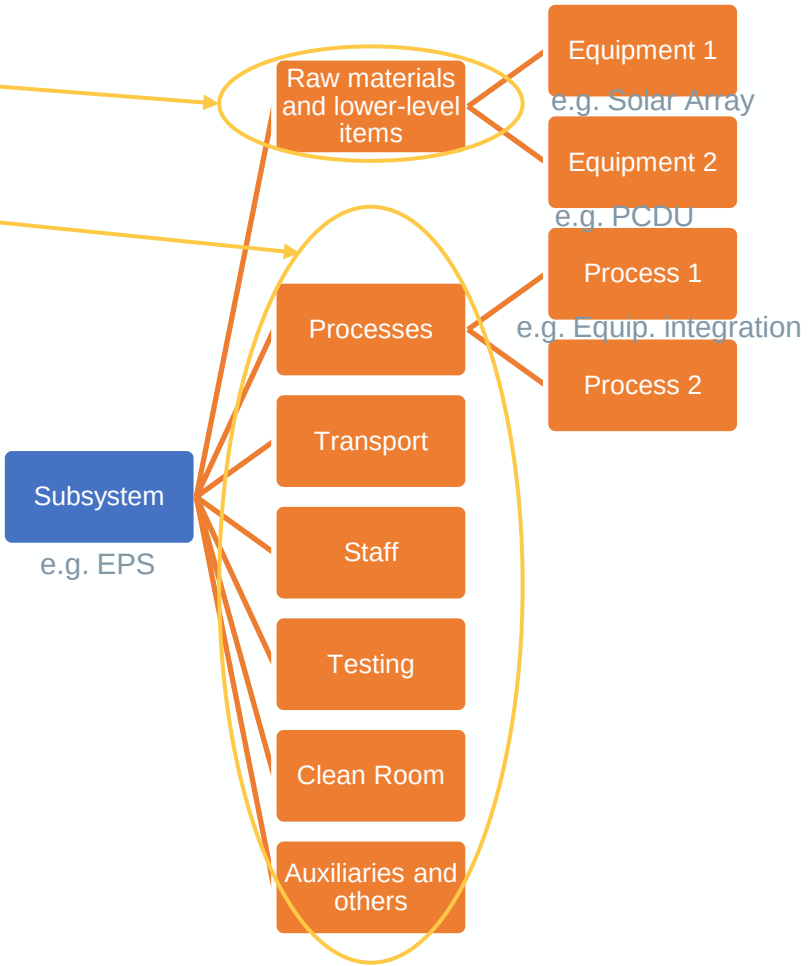
DQR evaluation at subsystem level

- DQR for lower-level items is known (see previous slides)
- DQR shall be assessed for **other types of inputs**:
  - for all 4 indicators : TeR, GR, TiR, P (see next slides)
  - for each process (e.g. Process 1, Process 2, etc.)
  - Aggregated to get a DQR per category (processes, transport, etc.)
- **Requirement for Completeness** at subsystem level
- If proxies from the **ESA Database** (e.g. Clean room usage) are used :
  - If the proxy is modified / adapted → DQR = 4 for all criteria
  - If the proxy is used as is → DQR = 5 for all criteria



Processes – Pedigree matrix

	TeR	GR	TiR	P
1	Process is run by the company providing the data	The process modelled takes place in the site the dataset is valid for	Process data is less than 3 years old	Specific data based on measures
2	Process is not run by the company providing the data, but this company has access to specific information	The process modelled takes place in the region the dataset is valid for	Process data is between 3 and 6 years old	Specific data estimated by specific calculations, using proprietary information (e.g. Company based)
3	Process is not run by the company providing the data, but process is modelled and justified with expert assumption	The process modelled takes place in the country the dataset is valid for	Process data is between 6 and 10 years old	Average data estimated with proprietary information (e.g. Company based) assumption
4	Process is not run by the company providing the data and ESA database is used with adaptations to the process under study	The process modelled takes place in the continent the dataset is valid for	Process data is between 10 and 15 years old	Average data estimated with justified assumption
5	Process is not run by the company providing the data and ESA database is used as is	The process modelled takes place in a different country/continent than the one the dataset is valid for Or unknown	Process data is more than 15 years old, or age unknown	Average data with assumptions unknown

Aggregation

For each data quality indicator (TeR, GR, TiR, P) and for each impact category :

- Aggregation for all inputs category (Process, Transport, etc.) → completeness = requirement
- Aggregation for a given Subsystem

Once all subsystem DQR have been assessed → aggregation to a single DQR for the "lower-level" items (≠ system)

$$DQR_{System_{i_j}} = \frac{\sum_k RI_{k_j} * DQR_{k_i}}{\sum_k RI_{k_j}}$$

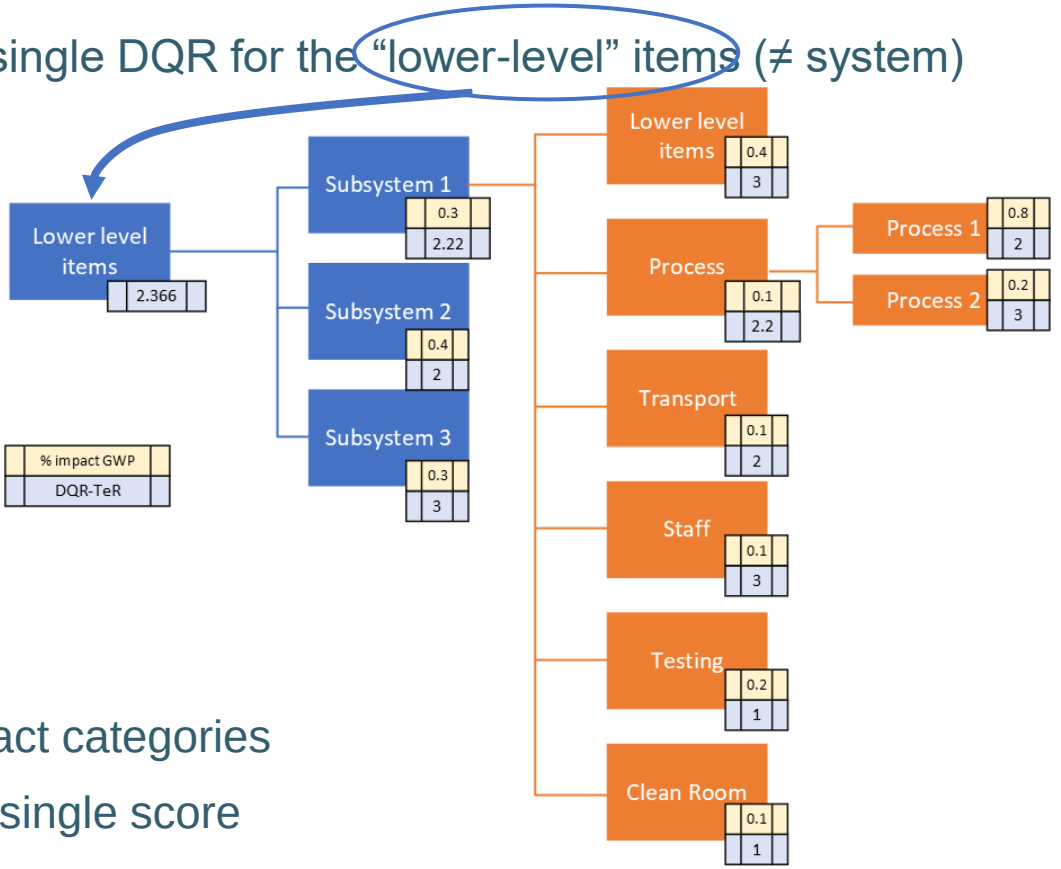
Where:

i refers to the data quality indicator i

j refers to the impact category j

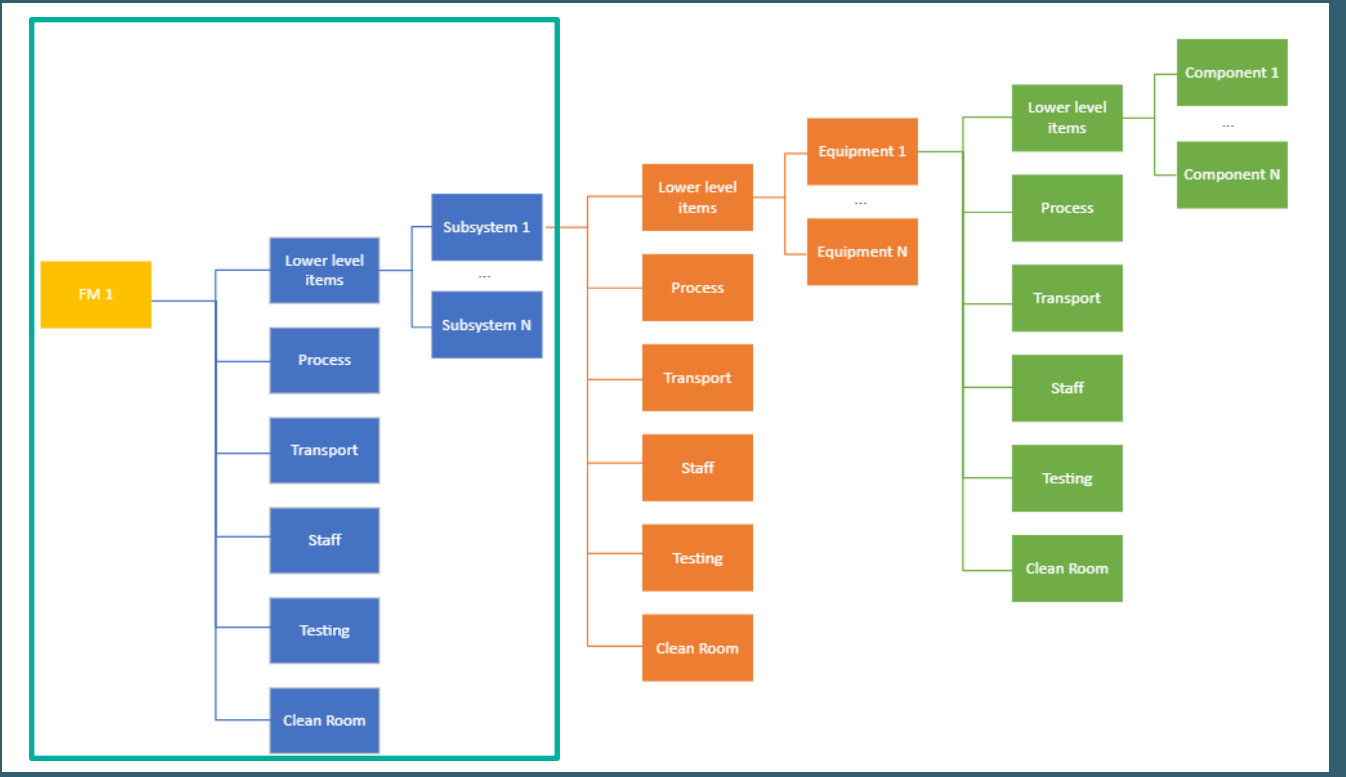
k refers to the item k from the System

RI_{k_j} refers to the relative impacts of each item of the system for each category j, in percentage



- The impact categories to be used are only the most relevant impact categories
  - i.e. all categories contributing to at least 80% of the total single score
  - 3 as a minimum : HTP, GWP, ADP

3. System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DQR evaluation at system level

- DQR for lower-level items is known (see previous slides)
- DQR shall be assessed for **other types of inputs**:
  - for all 4 indicators : TeR, GR, TiR, P (same matrices as subsystem)
  - for each process (e.g. Process 1, Process 2, etc.)
  - Aggregated to get a DQR per category (processes, transport, etc.)
- **Requirement for Completeness** at system level
- If proxies from the **ESA Database** (e.g. Clean room usage) are used :
  - If the proxy is modified / adapted → DQR = 4 for all criteria
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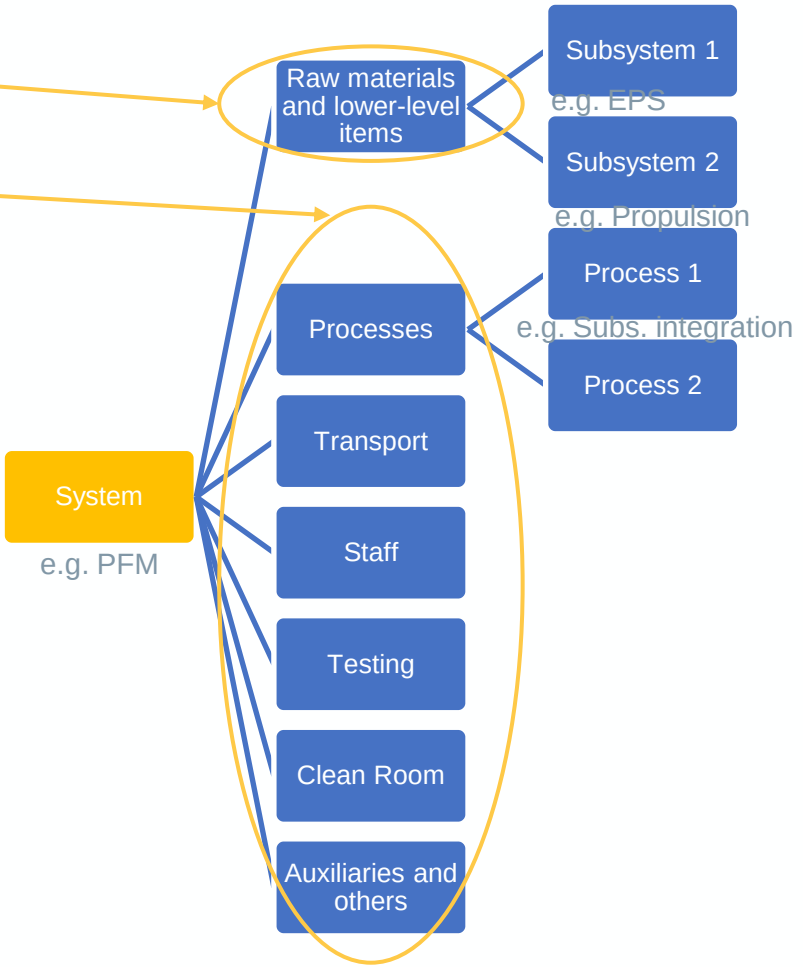


Aggregation

For each data quality indicator (TeR, GR, TiR, P) and for each impact category :

- Aggregation for all inputs category (Process, Transport, etc.)
- Aggregation for a given system

Once all system DQR have been assessed → aggregation to a single DQR for the "mission DQR"

$$DQR_{System_{i_j}} = \frac{\sum_k RI_{k_j} * DQR_{k_i}}{\sum_k RI_{k_j}}$$

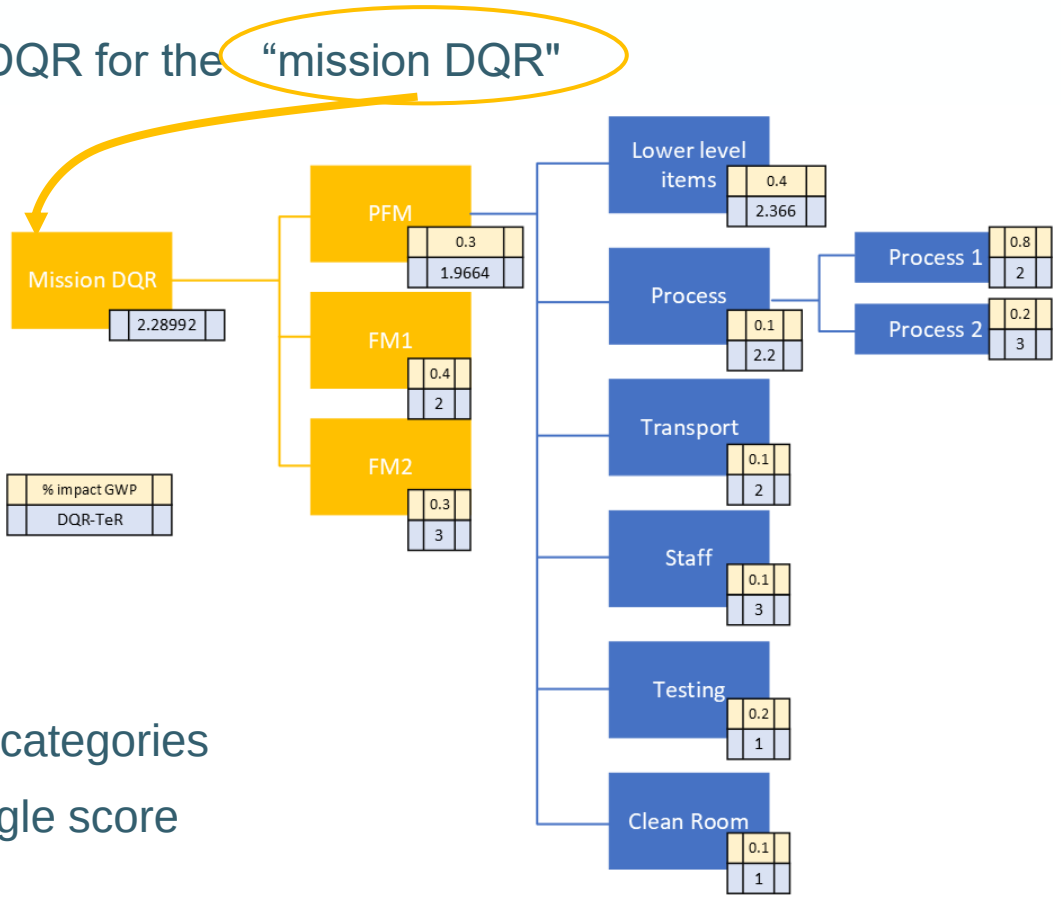
Where:

i refers to the data quality indicator i

j refers to the impact category j

k refers to the item k from the System

RI_{k_j} refers to the relative impacts of each item of the system for each category j, in percentage



- The impact categories to be used are only the most relevant impact categories
  - i.e. all categories contributing to at least 80% of the total single score
  - 3 as a minimum : HTP, GWP, ADP

"Mission" in the example here is referring only to the Space Segment

Conclusions & Way forwards

Conclusions

- Proposed method enables applicability at **multiple levels**, with guidelines for **aggregation** and **new pedigree matrices**
- For early phases, DQR may be limited (e.g. not better than 4) & non-compliance with the completeness requirement

→ Objective is to improve DQR in the next iterations, especially focusing on the items that are expected to have a higher environmental impact, with more precise and representative data and datasets

Next steps

- **Finalize key points**
  - Investigate pedigree matrices for each category (Processes, Transport, etc.) at subsystem/system level
  - Refine rating for Raw data vs LCI datasets modelling
  - Validate the three mandatory impact categories (from previous LCA performed)
- **Stakeholder Consultation**
  - Review and approve the method with stakeholders, adjusting, as necessary.
- **Application**
  - Implement the method in a full mission case study (this will require additional time).