RINA Consulting
D-ORBIT RISE simplified LCA

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Introduction – Need and support

The need of D-Orbit

ESA asked D-Orbit to evaluate the environmental impacts of the RISE mission using Life Cycle Assessment methodology.

RINA support to D-Orbit

A simplified LCA of the RISE mission, using:

- ESA LCA Handbook
- ESA LCA DB
- SimaPro software
- RINA’s experience in conducting LCA Space studies since 2012 (missions, ground segment, space datasets)

Why RISE is important for ESA

RISE is a commercial in-orbit servicing mission that will demonstrate that it can safely rendezvous and dock to a geostationary client satellite. After verifying that it meets all the performance standards, D-Orbit will start commercial life extension services for geostationary satellites.

ESA's RISE mission marks a promising step towards enhancing in-orbit services and technologies, such as refuelling, refurbishment and assembling – all essential elements for creating a circular economy in space.

Extending life in orbit allows to keep Earth's orbits clean from **space debris**, as part of ESA's Zero Debris approach.

https://www.esa.int/Space_Safety/ESA_to_build_first_in-orbit_servicing_mission_with_D-Orbit

SPACE SAFETY

ESA to build first in-orbit servicing mission with D-Orbit

ESA / Space Safety

"In-orbit servicing is the logical continuation of **ESA's sustainable approach to space**. Extending the lifetime of satellites lets space operators generate **more data and revenue from existing space assets**, greatly improving both the sustainability and our competitiveness in space," says Josef Aschbacher, ESA Director General.

Life Cycle Assessment in space sector

Project stages

initial phases (A-B1; feasibility and preliminary definition)

later phases (B2/C/D; detailed definition + qualification and production)

Launch (E1)

Utilisation (E2)

Disposal (F)

Data availability

Low data availability (lack of primary data; use of databases and assumptions)

high data availability (use of primary data; use of databases for secondary data)

LCA level

simplified LCA (pinpoint key hotspots; address mitigation actions)

comprehensive LCA (thorough assessment of the mission's impacts; accurate evaluation of the potential benefits associated with specific design decisions)

As D-Orbit was in the early stages of the mission, a simplified LCA has been executed

LCA is an iterative process

Working together with D-Orbit – RINA tasks in RISE

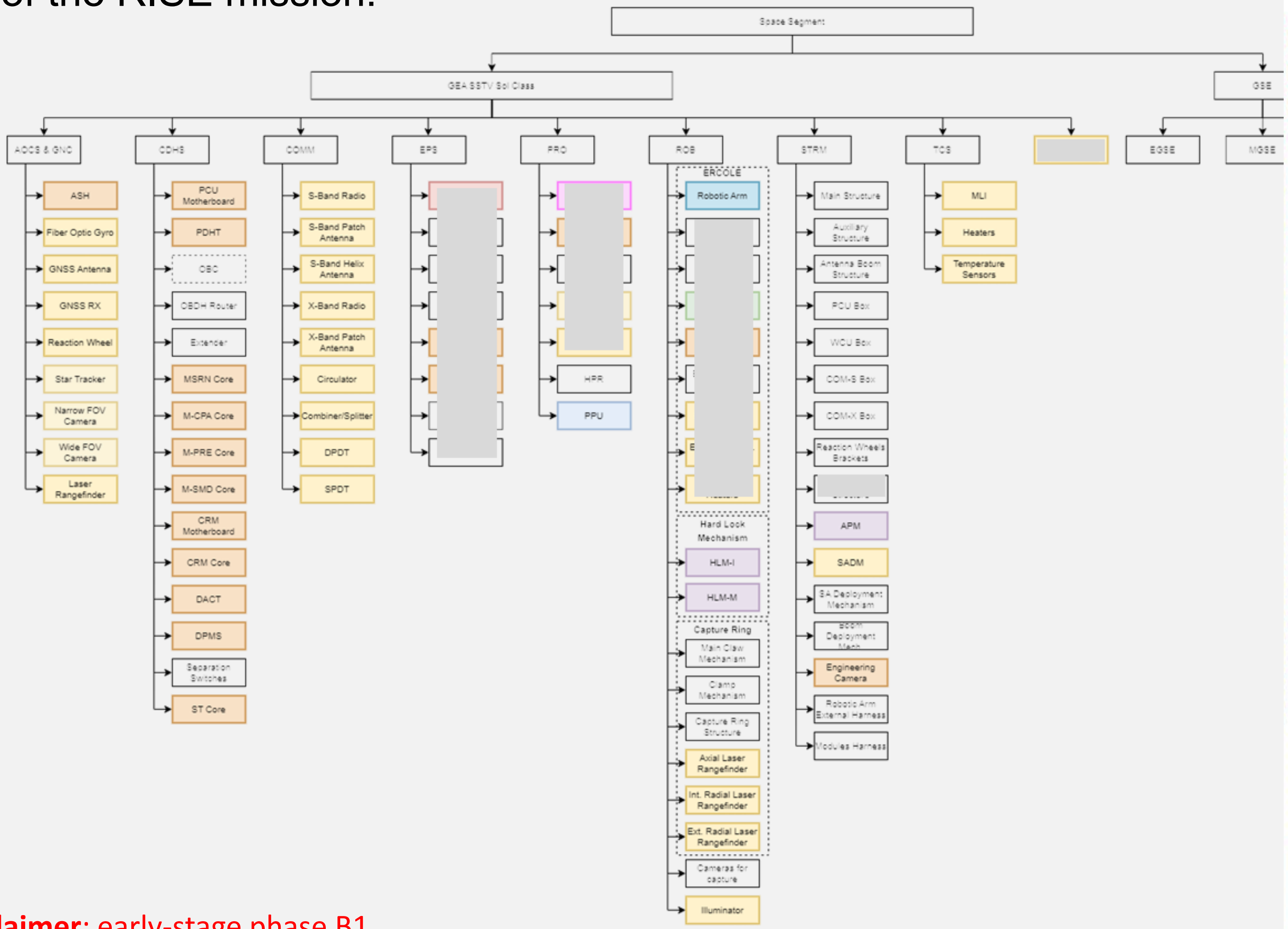
- Task 1: Goal and Scope Definition
- **Task 2: Inventory Analysis of the LCA Study**
- Task 3: Impact Assessment and Interpretation of the results
- Task 4: Support for implementing ESA requests for information

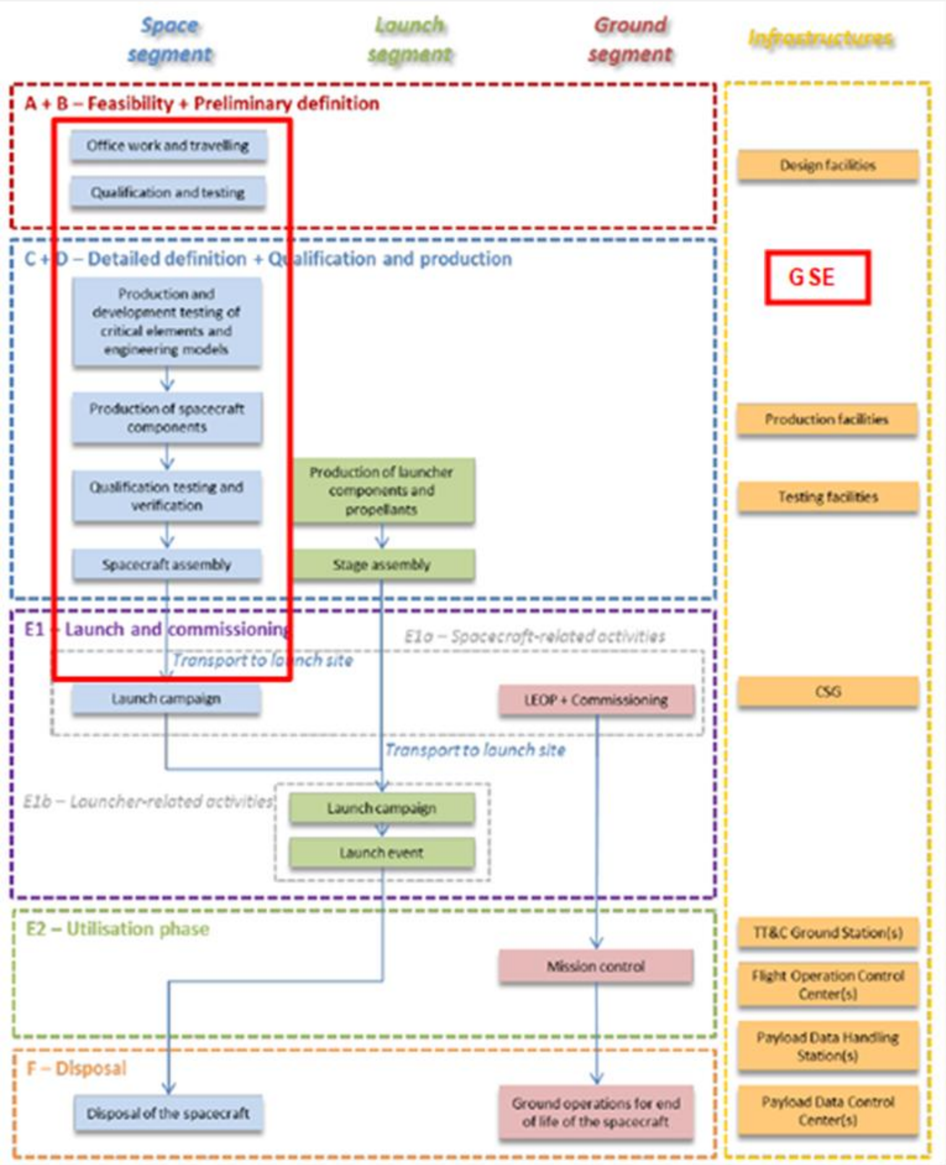
***In Task 2**, the effort for the client is fundamental for the execution of the whole activity.*

*The overall activity timeline is strongly influenced by the **type of data** collected and by the **time needed for the client** to provide them to RINA.*
*RINA has assisted the client in the **data collection procedure**, guiding the client is identifying the **main data needs** and **proposing solutions** to address **specific data gaps**.*
All the collected information will be used to determine the Life Cycle Inventories, that will represent the basis for the modelling and the results calculation.

RISE mission – the boundaries of data collection

Global structure of the space segment of the RISE mission:





Disclaimer: early-stage phase B1

RISE mission

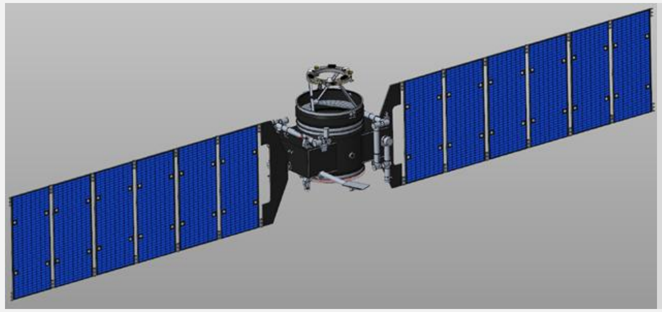
The **model philosophy** mainly includes:

A Proto-Flight Model (**PFM**)
A Structural and Thermal Model (**STM**)

→ for the most important pieces of equipment an Engineering Model (**EM**) and/or an Engineering Qualification Model (**EQM**) are prepared. Breadboard Models (**BBM**) can be made as mockup to test functionality (in preliminary phases).

The **General Support Equipment (GSE)** consist of:

- Mechanical Ground Support Equipment (MGSE)
- Electrical Ground Support Equipment (EGSE)
- Radio Frequency Ground Support Equipment (RFGSE)
- Fueling Ground Support Equipment (FGSE)
- Shipment Ground Support Equipment (SGSE)



SSTV Sol-Class is the spacecraft platform product line, designed to provide services to satellites in the GEO belt. **SSTV-001 Sol** is the actual spacecraft (sometimes referred to as *vessel*), **Proto-Flight Model (PFM)** of the *Sol-class*, that will fly the RISE mission and deliver the IOV of the service.

LCA study – What you can find in the report

Goal and scope

- Intended application(s)
- Methodological limitations
- Reasons for carrying out the study
- Target audience
- Commissioner of the study
- Unit of analysis (functional unit) and reference flow
- System Boundaries
- Assumptions, including justifications
- Data representativeness and appropriateness and types and sources of data
- Impact categories, models and indicators
- Treatment of multi-functionality

Life Cycle Inventories

- LCI data
- Cut-off criteria
- Data Quality
- Data collection procedures
- Sources of published literature
- Information on any use and end-of-life scenarios considered in downstream stages
- Calculation procedures
- Validation of data including allocation procedures
- Sensitivity analysis
- Modelling

Life Cycle Impact Assessment

- Calculations and results of the study
- Limitations and relationship with respect to goal and scope
- Additional environmental information, if any
- If included, normalisation factors and results

Interpretation

- Assessment of data quality
- Identification of environmental hotspots
- Uncertainty (at least qualitatively)
- Conclusions, recommendations (if any), limitations and improvement potentials

> REPORT IS CONFIDENTIAL <

Access allowed to ESA and D-Orbit only

LCA results reliability depends on data sources

Goal and scope	Life Cycle Inventories	Life Cycle Impact Assessment	Interpretation
• **Define the technical scenario (the business case object of LCA study)** • **Identify data sources (primary data from engineering department; databases, literature sources)** • **Identify key personel to be interviewed (company or suppliers or experts)**	•LCI data •Cut-off criteria •Data Quality •Data collection procedures •Data collection execution • End-of-life scenarios •Calculation procedures •Validation of data including allocation procedures •Sensitivity analysis •Modelling	• Calculations and results of the study • Limitations and relationship with respect to goal and scope • Additional environmental information, if any • If included, normalisation factors and results	• Assessment of data quality • Identification of environmental hotspots • Uncertainty (at least qualitatively) • Conclusions, recommendations (if any), limitations and improvement potentials

Data collection effort

10%	80%	5%	5%

How data are gathered - Life Cycle Inventory

Data collection procedures

Primary data and assumptions by D-Orbit have been collected via an LCI questionnaire.

The questionnaire was precompiled based on the mass budget provided by D-Orbit in December 2024 and was structured to include staff hours, staff travel (by plane), manufacturing (raw materials and processing), transport and testing hours for each item.

							FLIGHT MODEL														
					riority for compilatio									Inputs and waste					Output (Subcomponent subdivi		
ESA Space segment phases	Sub-system (Source)	Item	Physical allocation	Localisati on	Weight (top 10)	Make	Unitary mass [kg]	Unitary volume [m3]	Qty	Margin [%]	Margined mass [kg]	Provider	Flow type	Flow	Amount	Margined mass [kg] of 1 item	Unit	% w/w		Qty	Ui
A+B - Feasibility + Preliminary definition- phase AB1	Whole Satellite, dry mass	NA	NA	NA			NA	NA	NA	NA	NA	NA	Staff	Office work			Hours				
A+B - Feasibility + Preliminary definition- phase AB1	Whole Satellite, dry mass												Staff	Travel (by plane)			man*km				
A+B - Feasibility + Preliminary definition- phase B2	Whole Satellite, dry mass	NA	NA	NA			NA	NA	NA	NA	NA	NA	Staff	Office work			hours				
A+B - Feasibility + Preliminary definition- phase B2	Whole Satellite, dry mass												Staff	Travel (by plane)			man*km				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA	[if known, needed to calculate transport distances]			0.42		2	5%	0.44	Baseline: Auricam - sodern ARIANEGROUP [insert here notes too, e.g. fixed, TBD...]	Staff	Office work			person-hours				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Staff	Travel (by plane)			man*km				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Manufacturing	Material flow 1 [specify]			kg		Sub-component 1 [keep in correspondance with the		
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Manufacturing	Material flow 2							
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Manufacturing	Material flow 3					Sub-component 2		
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Manufacturing	Material flow 4							
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Manufacturing	Energy consumption for assembly			kWh				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Waste	Waste from manufacturing - flow 1 [insert material and end of li			kg				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Testing	Energy consumption for testing [specify type of testing]			kWh				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Testing	Time necessary for testing [specify type of testing]			h				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Testing	Energy consumption for clean room			kWh				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Testing	Time necessary for clean room			h				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Testing	Material flow 5			kg				
C+D - Detailed definition + Qualification and production	AOCS	NFoV Camera (Narrow Field of View Camera)	M-CPA										Transport	(specify mode, e.g., truck EURO 5, plane)			kg				

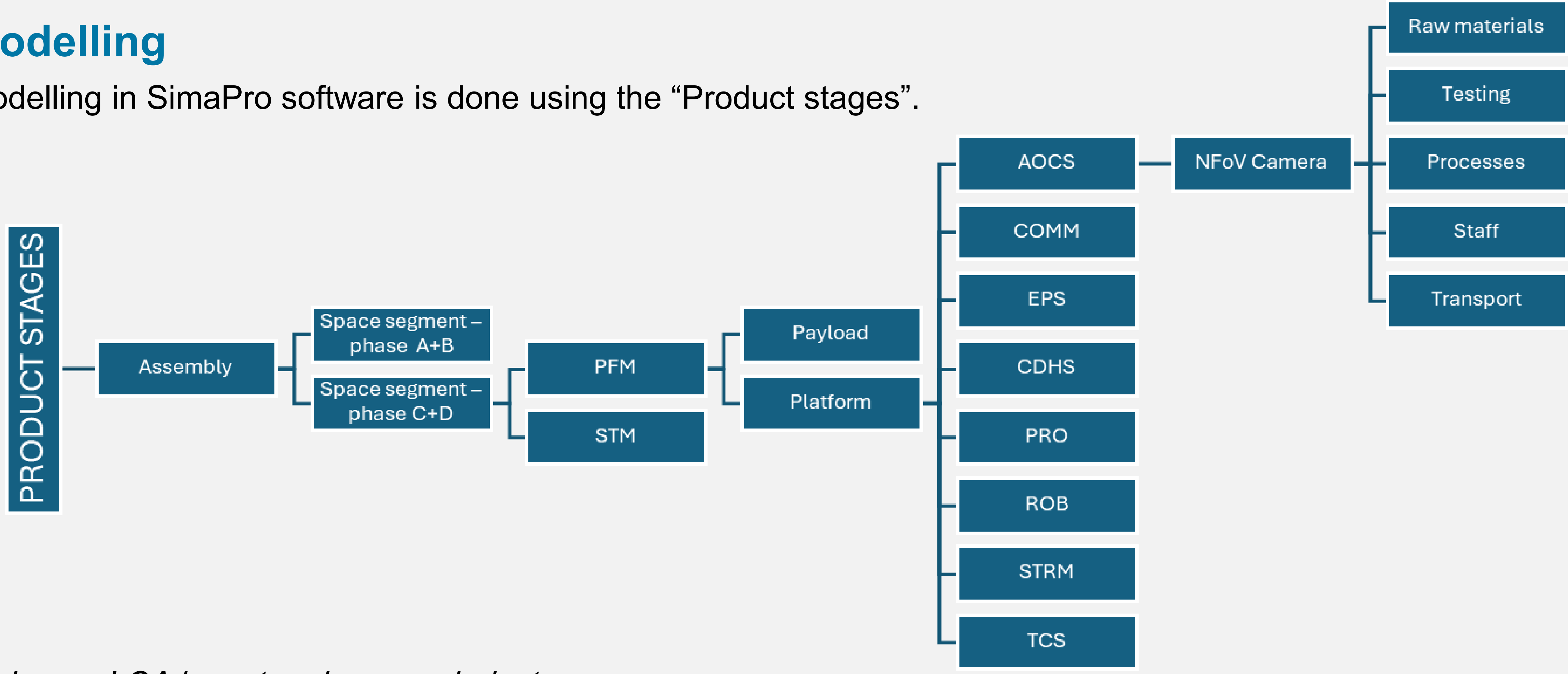
Sources of published literature

Some data gaps have been addressed by using **information from literature** as proxies. Additionally, **technical datasheets and commercial brochures** provide data for modeling certain equipment. The sources of this information are cited within the study.

How data are ordered - Life Cycle Inventory

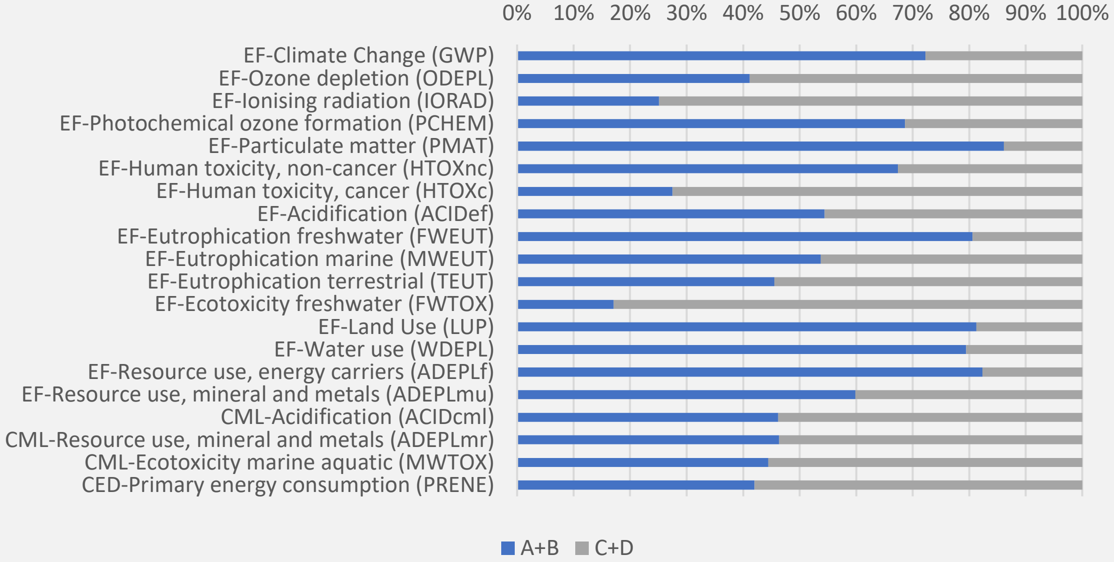
Modelling

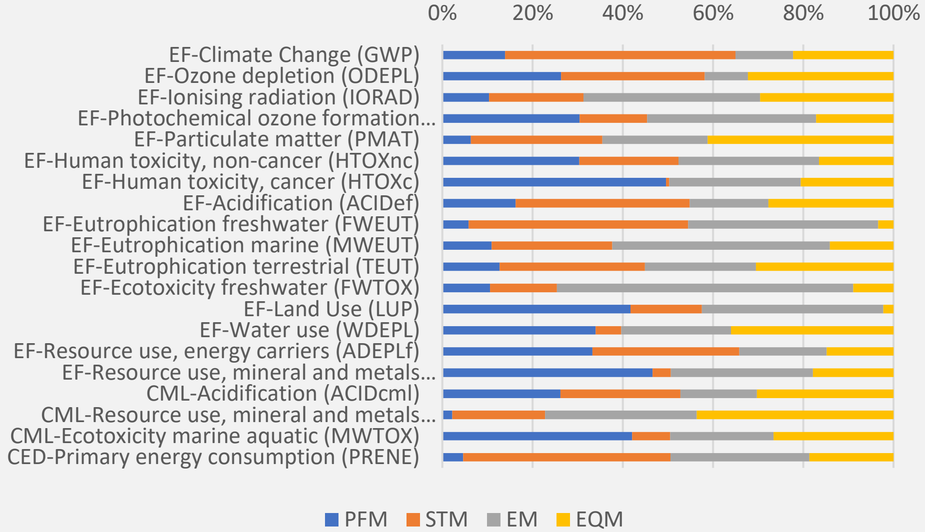
The modelling in SimaPro software is done using the “Product stages”.



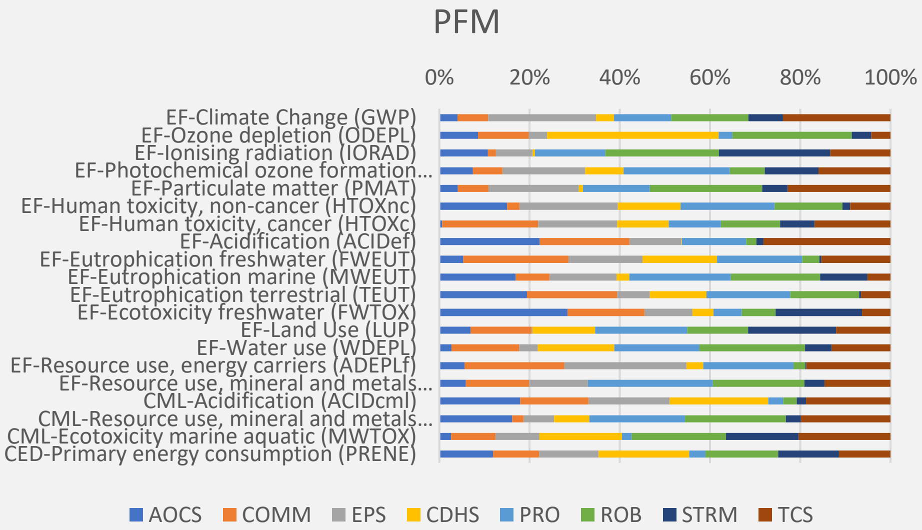
“Performing an LCA inventory in space industry means build up a satellite, a space craft or launcher” (G. Urbano)

Data are generating impacts – Life Cycle Impact Assessment





Possible examples of results visualization *(random values)*



What about uncertainty, Missing data, Assumptions, Impacts

RINA APPROACH: We take the overall picture (from the top), defining the structure, fill the gaps, drive data collection (with the Client). <u>All datasets in the model shall be filled with data</u>. Inserted data can have different sources: primary data, secondary data, assumptions

We are engineers, we make assumptions.

Assumptions shall be realistic, credible, data based (at least overall weight of the component, using top-down approach), tracked and described.

Assumptions will be discussed with Clients and LCA engineers, confirmed by literature or database like Ecoinvent® (EMPA)(when data are available).

IMPACT OF ASSUMPTIONS:

<u>Disclaimer: All datasets in the model shall be filled with data</u>.

Use of assumptions in dataset creation of a system: i) The overall weight; ii) The materials; iii) The processes to build the system (energy).

The impact generated:

too high impact (check the outliers in the graphs of impact), then check your assumption in input data.

too low impact: you can’t notice, but you know this is an assumption. Then, next steps try to find out primary data.

Primary data are gold, secondary data are silver, assumptions are bronze

Methodology – Strategy for data gaps

RINA EXPERTS SAY: Preferred option is to develop specific LCI and datasets for equipment and materials, collecting primary data from the Client and the involved suppliers.

When data are missing: (in order of priority)

- ✓ First pick: model equipment based on specific technical datasheets from specific suppliers or from other suppliers of similar equipment
- ✓ Second pick: use generic datasets from the ESA LCA database for the same equipment or materials
- ✓ Last chance: select proxy datasets from the ESA LCA database or Ecoinvent© databases that are representative of a similar equipment or material

When data were missing – How we solved it

RINA faced several times data missing. Here are some examples:

Model equipment based on specific technical datasheets from specific suppliers or from other suppliers of similar equipment

Star tracker and gyroscope: technical data sheets from D-Orbit and other similar suppliers

Use generic datasets from the ESA LCA database for the same equipment or materials

solar panels : proxy (ESA LCA DB): **Solar Array, power supply {RER} | production | Cut-off, U**

PPU (Electric Propulsion Power Processing Unit): proxy **Power supply unit, at plant {CN} | production | Cut-off**

Select proxy datasets from the ESA LCA database or Ecoinvent© databases that are representative of a similar equipment or material

representative of similar equipment: **PCB (PCB (rPBA) [mass] {DE}| Production | Cut-off, S: from ESA LCA DB)**

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electronic components (Electronic component, passive & active, unspecified (proxy) {GLO}| Production | Cut-off, U: from 2 ecoinvent datasets)

Lesson learned from RISE LCA study

Regarding **modeling in early-stage**, like the experience with D-orbit:

- ✓ Need to simplify the architecture of the model on SimaPro, avoiding the dataset or fluxes not yet object of implementation (e.g. staff travel, staff office work, etc.)
- ✓ Need to simplify the modeling of auxiliary models of the philosophy (e.g. SQM, EM etc.) where “dummies” are present: consider only aggregated values by total mass per each sub-system, without need to go deeper at equipment level
- ✓ critically review ESA datasets for testing (e.g. TVAC, clean room) since some doubts arose (e.g. N_2 flux values out of range)

General comment: review planning and delivery of activities as a function of REAL effort that practitioners spend on the entire project (from data collection, through modeling and FR delivery): schedule is often too tight and quality could be affected too (LCA is not a one-man-show).

What's next – 2nd iteration of LCA is coming

RINA performed the 1st iteration LCA of RISE.

Next step is approaching; 2nd step will investigate equipment of RISE suppliers.

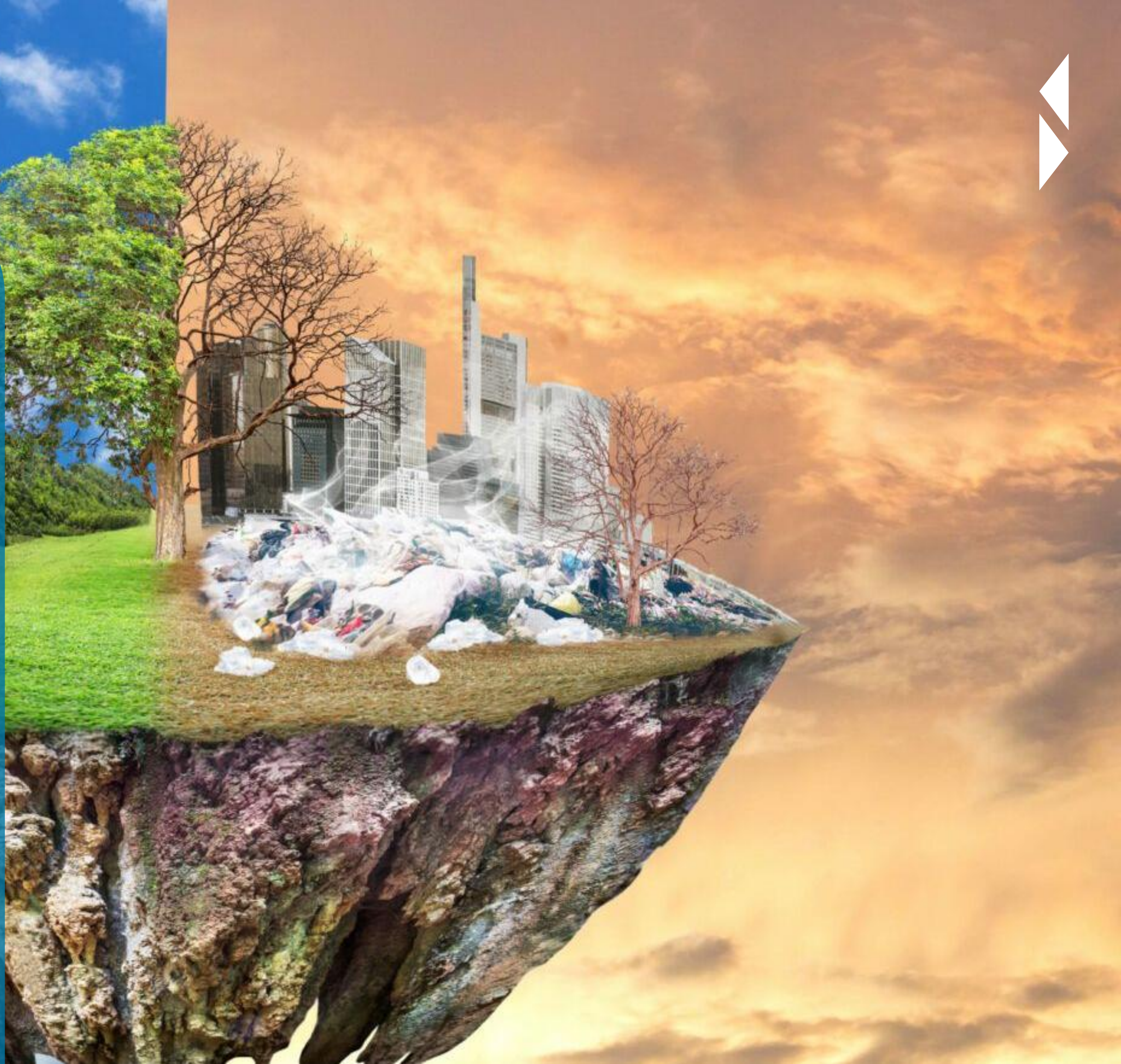
- ✓ Vendors will be involved in data collection.
- ✓ They will be asked to contribute providing primary data and technical data sheet.
- ✓ D-orbit engineering will feed primary data to Consultancy company.

Dataset will be opened again, one by one, updating material and energy flows figures and adding datasets if new ones shall be added.

This is the reason why RINA suggests to "*simplify the architecture of the model on SimaPro, avoiding the datasets or fluxes not yet object of implementation*".

Sustainability in RINA

Working together with our Clients



ESG services for products

Life Cycle Thinking

Life Cycle Assessment - LCA (ISO 14040 & 14044), **Life Cycle Costing - LCC** (ISO 14040 & 14044, Setac Guidelines, **Social Life Cycle Assessment S-LCA** (UNEP SETAC, 2009)

Water Footprint

Evaluation of **water footprint** in accordance with **ISO 14046**, helping organizations assess and manage their water consumption and impact

Carbon Footprint

Carbon footprint of products in compliance with ISO **14067** to help businesses enhance sustainability, meet regulatory requirements, and achieve carbon neutrality goals while improving environmental responsibility

Eco-design assessment

As-is analysis and identification of **circular economy actions** to be implemented; evaluation of the environmental benefits deriving from the actions; CFD/CAD analysis, numerical modeling to develop new products

Assessment on specific ESG parameters

Assessment of other ESG parameters related to the life cycle of products or services, such as the recyclability or the circularity

Environmental labels

Support in preparing the preparatory documentation for achieving the **Environmental Product Declaration**, (ISO 14025), ISCC, and Remade in Italy on the recycled content of the product, LEED, BREEAM, etc.

Digital Product Passport

Consultancy activity supporting businesses in implementing Digital Product Passports (DPPs) to enhance transparency, traceability, and compliance with sustainability regulations

Digital environmental tool

Development of **digital tools** for calculating and communicating the ESG performances of products

ESG services for organizations

GHG Accounting

GHG Accounting & Reporting, GHG Emissions Inventories (ISO 14064 and GHG protocol); support for companies in joining Climate Change or other environmental initiatives, such as **SBTi** (Science Based Targets initiative), **CDP**, **Ecovadis**, etc.

Decarbonization Roadmap

Decarbonization Roadmap to reduce the organization's GHG emissions and support companies in achieving their **decarbonization targets**, following **ISO 14068** and **PAS 2060** standards.

ESG reporting and scoring

Creating of the Sustainability Report for companies, in line with ESRS standards (CSRD); ESG scoring scheme definition and ESG KPI quantification and monitoring, including e.g. circularity assessment according to UNI/TS 11820

EU Taxonomy Regulation alignment

Assessment of **EU Taxonomy** Regulation alignment and **DNSH** (Do No Significant Harm) analysis. **Climate Risk Vulnerability Assessment** (CRVA)

Green Procurement and resource optimization

Supply chain analysis and **resource(energy and material) optimization**, consultancy for **ISO 20400**, **scouting** of suppliers and technologies, **ESG KPI definition and monitoring** for **supply chain**

Due diligence

Technical due diligence, **ESG** due diligence, **Technical & Business** Due Diligence (T&BDD), **Lenders Market Advisor** (MDD), **Operational** DD

ESG Management Systems

ISO 14001:2015, ISO 50001:2018, ecc.

SA8000:2014, ISO 30415:2021, UNI Pdr 125:2022, ISO 45001:2018, ecc.

ISO 90001:2015, ISO/IEC 27001:2013, ecc.

Alignment to ESG directives

Support to companies to be compliance with the ESG directives such as CSRD, CSDDD, CBAM, NIS2, Deforestation, EU Taxonomy etc.

Funding schemes

Scouting of funding schemes, preparing the complete documentation for applying to and finalization of the concept and creation of the project (Innovation Fund, PNRR, CEF, IPCEI, etc)

For more info:

Thank you for your attention

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