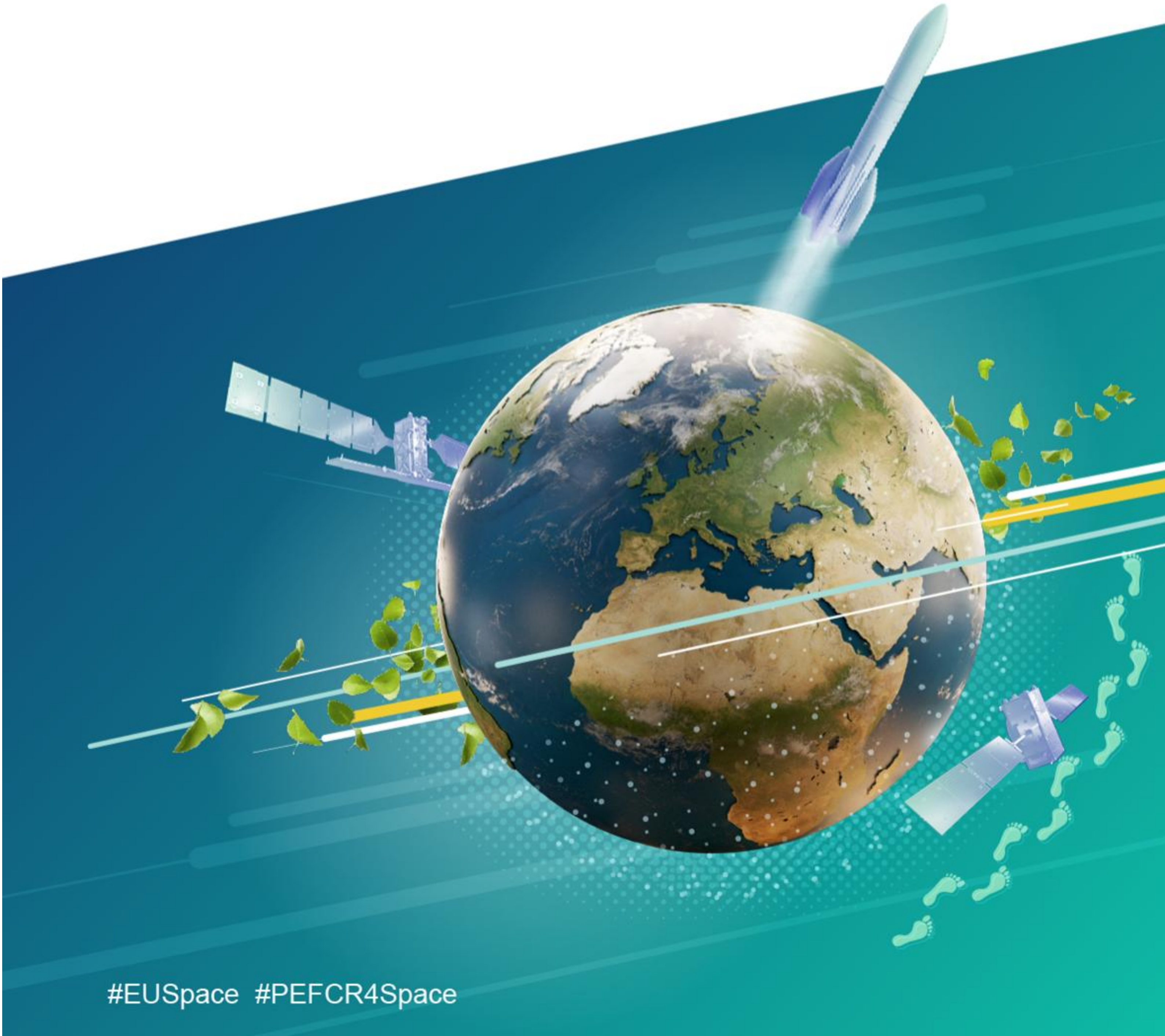
PEFCR
FOR THE SPACE SECTOR

First Draft Product Environmental Footprint Category Rules (PEFCR)

Space-based services delivered to EU stakeholders

Version for open consultation



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Comments	Grey normal text indicates those sections that will be filled in later. *Italic grey text between brackets [ ] is directly copy pasted from the PEFCR template as guidance or provides more information/questions to the reader.*

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Acronyms

[List in this section all the acronyms used in the PEFCR. Those already included in Annex I or the part A of Annex II shall be copied in their original form. The acronyms shall be provided in alphabetical order.]

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie
AF	Allocation factor
Al	Aluminium
APN	Ammonium perchlorate
AR	Allocation ratio
B2B	Business to business
B2C	Business to consumer
BoC	Bill of components
BoM	Bill of materials
BP	Best practice
BSI	British Standards Institution
C-Band	Frequency band between 3 and 8 GHz
CF	Characterization factor
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
CH4	Methane
CPA	Classification of Products by Activity
DC	Distribution centre
DG DEFIS	Directorate-General for Defence Industry and Space
DMI	Dry matter intake
DNM	Data Needs Matrix
DQR	Data Quality Rating

DTH	Direct-To-Home
EEE	Electrical, Electronic and Electro-Mechanical (EEE) components
EC	European Commission
EF	Environmental footprint
EI	Environmental impact
EMAS	Eco-Management and Audit Scheme
EMC	Electromagnetic Compatibility
EMS	Environmental Management Systems
EoL	End of life
EO	Earth Observation
EPD	Environmental Product Declaration
FU	Functional unit
GCN	Ground Communication Network
GE	Gross energy intake
GEO	Geostationary Orbit
GHG	Greenhouse gas
GR	Geographical representativeness
GRI	Global Reporting Initiative
GWP	Global warming potential
HD	High Definition
HTP	High-test peroxide
HTPB	Hydroxyl-terminated polybutadiene
HTS	High Throughput Satellite
HTTP	Hydrogen Triphenyl
ILCD	International Reference Life Cycle Data System

ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	IPCC Intergovernmental Panel on Climate Change
IOS	In-Orbit Servicing
ISAM	In-Space Servicing, Assembly and Manufacturing
ISIC	International standard industrial classification
ISO	International Organisation for Standardisation
ISOS	In-Space Operations and Services
IST	In-Space Transport
ITU	International Telecommunication Union
IUCN	International Union for Conservation of Nature and Natural Resources
JRC	Joint Research Centre
Ku-Band	Frequency band between 12 and 18 GHz
LCA	Life cycle assessment
LCDN	Life Cycle Data Network
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LCS	Life cycle stage
LCT	Life cycle thinking
LEO	Low Earth Orbit
LH2	Liquid hydrogen
LNB	Low Noise Block down-converter
LOx	Liquid oxygen
LT	Lifetime
MAIT	Manufacturing, assembling, integration and testing
Mbps	Megabits per second

MEO	Medium Earth Orbit
MMH	Monomethylhydrazine
ms	Milisecond
N2O	Nitrous oxide
N2O4	Dinitrogen tetroxide
NACE	Nomenclature Générale des Activités Economiques dans les Communautés Européennes
NDA	Non-disclosure agreement
NGO	Non-governmental organisation
NMVOC	Non-methane volatile compounds
NTO	Dinitrogen tetroxide
OEFSR	Organization environmental footprint sectorial rules
OOS	On-Orbit Servicing
OTV	Orbital Transfer Vehicle
P	Precision
PAS	Publicly available specification
PCR	Product category rules
PDGS	Payload data ground segment
PEF	Product environmental footprint
PEFCR	Product environmental footprint category rules
PEF-RP PEF	Study of the representative product
PNT	Positioning, Navigation and Timing
RF	Radio Frequency
RP	Representative product
SB	System boundary
SCC/MCC	Spacecraft Control Centre/Mission Control Centre

SD	Standard Definition
SDS	Software Defined Satellites
SMRS	Sustainability measurement & reporting system
SS	Supporting study
STM	Space Traffic Management
TeR	Technological representativeness
TiR	Time representativeness
TS	Technical Secretariat
TVAC	Thermal Vacuum Chamber
UDMH	Unsymmetrical dimethylhydrazine
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
VHTS	Very High Yhroughput Satellite
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Definitions

[List in this section all the definitions that are relevant for the PEFCR. Those already included in Annex I or in part A of Annex II shall be copied in their original form. The definitions shall be provided in alphabetical order.]

All definitions are derived from the European Commission recommendations 2021/2779, except for those carrying a reference and added to improve the understanding of the report.

Activity data - information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains, which represent the activities of a process, are each multiplied by the corresponding activity data[1] and then combined to derive the environmental footprint associated with that process.

Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc.

Synonym of ‘non-elementary flow’.

Acidification – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Additional environmental information – environmental information outside the EF impact categories that is calculated and communicated alongside PEF results.

Additional technical information – non-environmental information that is calculated and communicated alongside PEF results.

Aggregated dataset - complete or partial life cycle of a product system that – next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) – itemises only the product(s) of the process as reference flow(s) in the input/output list, but no other goods or services.

Aggregated datasets are also called ‘LCI results' datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

[1] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011).

Allocation – an approach to solving multi-functionality problems. It refers to ‘partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems‘.

Application specific – generic aspect of the specific application in which a material is used. For example, the average recycling rate of PET in bottles.

Attributional – process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

Average Data – production-weighted average of specific data.

Background processes – refers to those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes.

Benchmark – a standard or point of reference against which any comparison may be made. In the context of PEF, the term ‘benchmark’ refers to the average environmental performance of the representative product sold in the EU market.

Bill of materials – a bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in scope of the PEF study. In some sectors it is equivalent to the bill of components.

Booster stage – Optional additional strap-on booster attached to the core stage

Business to business (B2B) – describes transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

Business to consumers (B2C) – describes transactions between business and consumers, such as between retailers and consumers.

Characterisation – calculation of the magnitude of the contribution of each classified input/output to their respective EF impact categories, and aggregation of contributions within each category.

This requires a linear multiplication of the inventory data with characterisation factors for each substance and EF impact category of concern. For example, with respect to the EF impact category ‘climate change‘, the reference substance is CO2 and the reference unit is kg CO2-equivalents.

Characterisation factor – factor derived from a characterisation model which is applied to convert an assigned life cycle inventory result to the common unit of the EF impact category indicator.

Classification – assigning the material/energy inputs and outputs tabulated in the life cycle inventory to EF impact categories, according to each substance's potential to contribute to each of the EF impact categories considered.

Climate change – EF impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes.

Co-function - any of two or more functions resulting from the same unit process or product system.

Commissioner of the EF study - organisation (or group of organisations), such as a commercial company or non-profit organisation, that finances the EF study in accordance with the PEF method and the relevant PEFCR, if available.

Company-specific data – refers to directly measured or collected data from one or more facilities (site-specific data) that are representative for the activities of the company (company is used as synonym of organisation). It is synonymous to 'primary data'. To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset – refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases.

Comparative assertion – an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category).

Comparison – a comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs.

Connectivity network - the terrestrial network, part of the ground communication network, that is used to interconnect different Earth stations sites with each other, with the antennas or with data centres.

Consumer – an individual member of the general public purchasing or using goods, property or services for private purposes.

Cooperative object – in the context of in-space transport this refers to a spacecraft, satellite, or any orbital asset that is designed or equipped to facilitate safe and effective interactions with other servicer spacecraft. Excludes non-functional, uncontrolled, or fragmented objects.

Co-product – any of two or more products resulting from the same unit process or product system.

Core stage – Main launcher stage that provides the initial thrust and carries the upper stages and payload.

Cradle to gate – a partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer’s ‘gate‘. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle to grave – a product’s life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Critical review – process intended to ensure consistency between a PEFCR and the principles and requirements of the PEF method.

Data quality – characteristics of data that relate to their ability to satisfy stated requirements. Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data quality rating (DQR) - semi-quantitative assessment of the quality criteria of a dataset, based on technological representativeness, geographical representativeness, time-related representativeness, and precision. The data quality shall be considered as the quality of the dataset as documented.

Delayed emissions – emissions that are released over time, e.g. through long use or final disposal stages, versus a single emission at time t.

Direct elementary flows (also named elementary flows) – all output emissions and input resource uses that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) – the transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Directly attributable – refers to a process, activity or impact occurring within the defined system boundary.

Disaggregation – the process that breaks down an aggregated dataset into smaller unit process datasets (horizontal or vertical). The disaggregation may help make data more specific. The process of disaggregation should never compromise or threaten to compromise the quality and consistency of the original aggregated dataset.

Downstream – occurring along a product supply chain after the point of referral.

Earth Station - a station located either on the Earth's surface or within the major portion of the Earth's atmosphere, excluding user terminal. It is intended for communication with one or more spacecrafts, or with one or more stations of the same kind by means of one or more reflecting satellites or other objects in space.

Ecotoxicity, freshwater – EF impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

Electricity tracking[2] – the process of assigning electricity generation attributes to electricity consumption.

Element – Combination of integrated equipment, components and parts (ECSS, 2023). Note: an element fulfils a major, self-contained, subset of a segment's objectives.

Elementary flows – in the life cycle inventory, elementary flows include 'material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation'.

Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the EF impact categories.

End user – the individual using the actual service provided

Engine – propulsion system to generate thrust

Environmental aspect – element of an organisation's activities or products or services that interacts or can interact with the environment.

Environmental footprint (EF) communication vehicles – all the possible ways that may be used to communicate the results of the EF study to the stakeholders (e.g. labels, environmental product declarations, green claims, websites, infographics, etc.).

Environmental footprint (EF)- compliant dataset – dataset developed in compliance with the EF requirements, regularly updated by DG JRC[3].

Environmental footprint (EF) impact assessment – phase of the PEF analysis aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. The impact assessment methods provide impact characterisation factors for

[2] https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii
[3] https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf

elementary flows, to aggregate the impact so as to obtain a limited number of midpoint indicators.

Environmental footprint (EF) impact assessment method – protocol for converting life cycle inventory data into quantitative contributions to an environmental impact of concern.

Environmental footprint (EF) impact category – class of resource use or environmental impact to which the life cycle inventory data are related.

Environmental footprint (EF) impact category indicator – quantifiable representation of an EF impact category.

Environmental impact – any change to the environment, whether adverse or beneficial, that wholly or partially results from an organisation's activities, products or services.

Environmental mechanism – system of physical, chemical and biological processes for a given EF impact category linking the life cycle inventory results to EF category indicators.

Equipment (of a spacecraft or launcher) – refers to the physical devices, tools, instruments installed on the spacecraft/launcher that enable it to perform its specific function or mission. They are categorized into different subsystems. Equipment can include both hardware and software components.

EU space programme - Umbrella for the different space programmes which the EU is responsible for. Examples of components of the EU space programme are Copernicus, Galileo and EGNOS (DG DEFIS, 2024).

Eutrophication – EF impact category related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland that accelerate the growth of algae and other vegetation in water.

The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass.

To assess the impacts due to eutrophication, three EF impact categories are used: eutrophication, terrestrial; eutrophication, freshwater; eutrophication, marine.

External communication – communication to any interested party other than the commissioner or the practitioner of the study.

Extrapolated data – data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.

Flow diagram – schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Foreground elementary flows - direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground processes – those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e.g. goods transport, head-office services, etc.).

Functional unit – defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions 'what?', 'how much?', 'how well?', and 'for how long?'.

Gate to gate – a partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate to grave – a partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Global warming potential (GWP) – An index measuring the radiative forcing of a unit mass of a given substance accumulated over a chosen time horizon. It is expressed in terms of a reference substance (for example, CO2-equivalent units) and specified time horizon (e.g. GWP 20, GWP 100, GWP 500 – for 20, 100 and 500 years respectively).

By combining information on both radiative forcing (the energy flux caused by emission of the substance) and on the time it remains in the atmosphere, GWP gives a measure of a substance's capacity to influence the global average surface-air temperature and therefore subsequently influence various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

Ground segment - Part of a space system, located on ground, which monitors and controls space segment element(s) (ECSS, 2023). It consists of all the ground-based elements of a space-based system required to operate the satellite(s) and distribute the payload(s) data among interested parties on the ground, via a dedicated network.

Within this PEFCR also named „**Ground infrastructure**".

Ground segment element - Element within a ground segment.

Note: a ground segment element can be composed of several ground segment elements, e.g. a ground station network is a ground segment element that can be composed of a set of ground stations and a communication network (ECSS, 2023).

Examples, Annex B.2 (ECSS, 2023): payload/instrument control centre, ground station network, ground station, ground communications network.

Horizontal averaging – the action of aggregating multiple unit process datasets or aggregated process datasets in which each provides the same reference flow, to create a new process dataset.

Horizonal rules – Modelling rules that are common to all products in scope of the PEFCR. Horizontal rules prevail over the vertical ones; however, specific derogations from this principle may be allowed if properly justified in the PEFCR (Extracted from the main text of the EC recommendation 2021/2279, Section A.3.1).

Human toxicity – cancer – EF impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to cancer.

Human toxicity - non cancer – EF impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.

Independent external expert – competent person, not employed in a full-time or part-time role by the commissioner of the EF study or the user of the EF method, and not involved in defining the scope or conducting the EF study.

Indirect land use change (iLUC) – this occurs when a demand for a certain land use leads to changes, outside the system boundary, i.e. in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

Input flows – product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products.

In-Space Operations and Services (ISOS) – activities carried out in space (on orbit and in outer space), with a view to provide a range of services on the assets of the space-based segment and which include the performance of tasks such as inspection, rendezvous, docking, repair, refuel, reconfiguration, manufacturing, assembling and disassembling, re-use, recycling, removal and transport of operational, non-operational and defect objects (incl. debris, platforms and larger structures) in space with servicer spacecraft with a high degree of autonomy. ISOS = ISAM (In-Space Servicing, Assembly and Manufacturing) + transportation in space (space-to-space transportation). In-Orbit Servicing (IOS) or On-Orbit Servicing (OOS) are the same and belong to ISAM (DG DEFIS, 2024).

Intermediate product – output form of a unit process that in turn is input to other unit processes which require further transformation within the system. An intermediate product is a product that requires further processing before it is saleable to the final consumer.

Ionising radiation, human health – EF impact category that accounts for the adverse health effects on human health caused by radioactive releases.

Land use – EF impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc.

Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in soil quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in soil quality multiplied by the area).

Launch segment - Part of a space system which is used to transport space segment element(s) into space. A launch segment is composed of the integrated launcher and the facilities needed for manufacturing, testing and delivering the launcher elements. Launch segments elements are for example engine and upper part (ECSS, 2023).

Launcher – Rocket-propelled vehicle used to transport a payload (spacecraft, satellites, supplies, etc) from Earth to space.

Lead verifier – person taking part in a verification team with additional responsibilities, compared to the other verifiers in the team.

Life cycle – consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle approach – takes into consideration the spectrum of resource flows and environmental interventions associated with a product from a supply-chain perspective, including all stages from raw material acquisition through processing, distribution, use, and end of life processes, and all relevant related environmental impacts (instead of focusing on a single issue).

Life cycle assessment (LCA) – compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle impact assessment (LCIA) – phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts for a system throughout the life cycle.

The LCIA methods used provide impact characterisation factors for elementary flows to aggregate the impact, to obtain a limited number of midpoint and/or damage indicators.

Life cycle inventory (LCI) - the combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle inventory (LCI) dataset - a document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. A LCI dataset could be a unit process dataset, partially aggregated, or an aggregated dataset.

Loading rate – ratio of actual load to the full load or capacity (e.g. mass or volume) that a vehicle carries per trip.

LEO PNT - LEO PNT systems are globally operating satellite systems in Low Earth Orbit (<2,000 km) that provide Positioning, Navigation, and Timing signals, either as standalone solutions or as complements to other GNSS. By operating closer to Earth, they offer stronger signals, faster transmission times, and improved resilience in challenging environments such as urban canyons or indoors.

Material-specific – a generic aspect of a material. For example, the recycling rate of polyethylene terephthalate (PET).

Multi-functionality – if a process or facility provides more than one function, i.e. it delivers several goods and/or services ('co-products'), then it is 'multifunctional'. In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products, according to clearly stated procedures.

Non-elementary (or complex) flows – in the life cycle inventory, non-elementary flows include all the inputs (e.g. electricity, materials, transport processes) and outputs (e.g. waste, by-products) in a system that need further modelling efforts to be transformed into elementary flows. Synonym of 'activity data'.

Normalisation – after the characterisation step, normalisation is the step in which the life cycle impact assessment results are divided by normalisation factors that represent the overall inventory of a reference unit (e.g. a whole country or an average citizen).

Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system, in terms of the total contributions to each impact category per reference unit.

Displaying the normalised life cycle impact assessment results for the different impact topics next to each other shows which impact categories are affected most and least by the analysed system.

Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

Operator - 'operator of space infrastructure' means a public or private entity that is authorised to carry out space activities in accordance with Member State law, or is an entity which operates space infrastructure, by carrying out at least any of the following services related to space activities (DG DEFIS, 2024):operation, control and monitoring of the launch process of a space object;

1. operation, control and maintenance of the ground-based segment of the space infrastructure, including facilities used for the launch process;
2. carrying out ISOS.

Organisation Environmental Footprint Sectorial Rules (OEFSRs) - sector specific, life-cycle based rules that complement general methodological guidance for OEF studies by providing further specification at the level of a specific sector.

OEFSRs help to shift the focus of the OEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the OEF method. Only the OEFSRs developed by or in cooperation with the European Commission, or adopted by the European Commission or as EU acts are recognised as in line with this method.

Output flows – product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases. Output flows are also considered to cover elementary flows.

Ozone depletion – EF impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g. chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons).

Partially disaggregated dataset - a dataset with an LCI that contains elementary flows and activity data, and that yields a complete aggregated LCI data set when combined with its complementing underlying datasets.

Partially disaggregated dataset at level-1 - a partially disaggregated dataset at level-1 contains elementary flows and activity data for one level down in the supply chain, while all complementing underlying datasets are in their aggregated form.

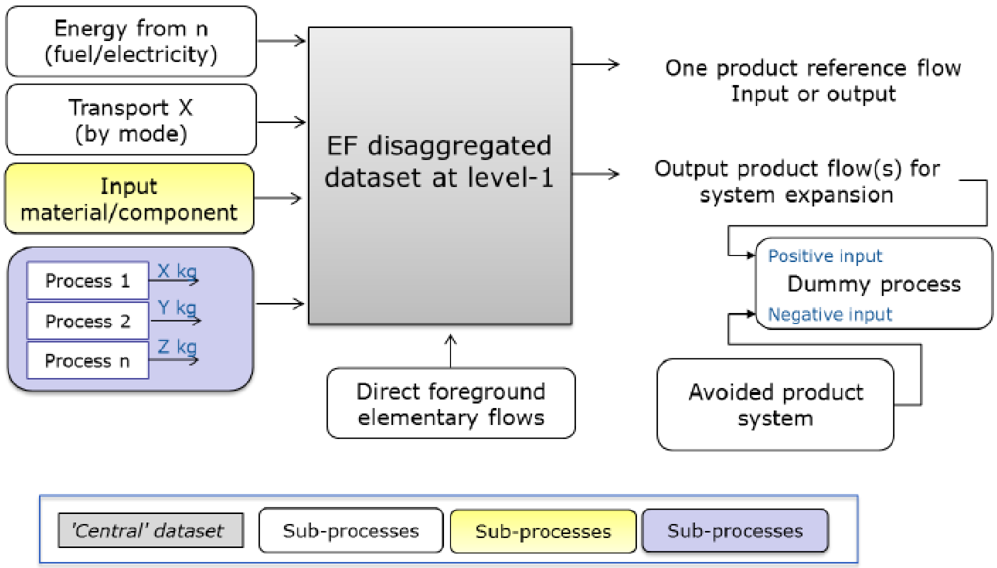

Figure 1: Example of dataset partially disaggregated at Level-1

Particulate matter – EF impact category that accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH3).

Payload – this term refers to the add-on item being transported, also named cargo. The payload of a launcher refers to the satellite(s) that are being transported / delivered to orbit, while the payload of a spacecraft refers to the instrument(s) on board such as the equipment, or systems that are designed to perform specific functions or tasks.

Payload section – Structure above the upper stage of a launcher to protect, transport and release of the payload

PEFCR supporting study – PEF study based on a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

PEF profile – The quantified results of a PEF study. It includes the quantification of the impacts for the various impact categories and the additional environmental information considered necessary to report.

PEF recommendation - "Commission recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisation" (EC, 2021/2279).

PEF study report – Document that summarizes the results of the PEF study.

PEF study of the representative product (PEF-RP) – PEF study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and any other major requirements needed for to define the benchmark for the product category/ sub-categories in scope of the PEFCR.

PEF study – term used to identify all the actions needed to calculate the PEF results. It includes the modelling, data collection and analysis of the results. PEF study results are the basis for drafting PEF reports.

Photochemical ozone formation – EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight.

High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials, by reacting with organic materials.

Population - any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study.

Primary data – data from specific processes within the supply chain of the user of the PEF method or user of the PEFCR.

Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the user of the PEF method or user of the PEFCR.

In the PEF method, primary data is a synonym of 'company-specific data' or 'supply chain specific data'.

Product – any good or service.

Product category – group of products (or services) that can fulfil equivalent functions.

Product category rules (PCRs) – set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

Product environmental footprint category rules (PEFCRs) – product category-specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification for a specific product category.

PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter most, and hence increase the relevance, reproducibility and consistency of the results by reducing costs, compared to a study based on the comprehensive requirements of the PEF method.

Only PEFCRs developed by or in cooperation with the European Commission, or adopted by the Commission or as EU acts, are recognized as being in line with this method.

Product flow – products entering from or leaving to another product system.

Product system – collection of unit processes with elementary and product flows, performing one or more defined functions, which model the life cycle of a product.

Product tree - Hierarchical representation of the product into successive levels of detail (ECSS, 2023). Note that this is not the same as the “product tree” as usually defined in LCA because the latter includes the full value chain e.g. to produce the different elements.

Raw material – primary or secondary material used to produce a product.

Reference flow – measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Refurbishment – the process of restoring components to a functional and/or satisfactory state compared to the original specification (providing the same function), using methods such as resurfacing, repainting, etc. Refurbished products may have been tested and verified to function properly.

Releases – emissions to air and discharges to water and soil.

Representative product (model) – this may be a real or virtual (non-existing) product. The virtual product should be calculated based on average European market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category.

Other weighting sets may be used, if justified – for example weighted average based on mass (tonne of material) or weighted average based on product units (pieces).

Representative sample – a representative sample with respect to one or more variables is a sample in which the distribution of these variables is exactly the same (or similar) as in the population of which the sample is a subset.

Resource use, fossil – EF impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

Resource use, minerals and metals – EF impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

Review – procedure intended to ensure that the process of developing or revising a PEFCR has been carried out in accordance with the requirements provided in the PEF method and part A of Annex II.

Review report - a documentation of the review process that includes the review statement, all relevant information about the review process, the detailed comments from the reviewer(s) and the corresponding responses, and the outcome. The document shall carry the electronic or handwritten signature of the reviewer (or the lead reviewer, if a reviewer panel is involved)

Review panel – team of experts (reviewers) who will review the PEFCR

Reviewer – independent external expert conducting the review of the PEFCR and possibly taking part in a reviewer panel.

Satellite - Satellites are composed of a platform (also called bus) and one or several payloads. The payload(s) is/are really tailored to the mission(s) of the system. A satellite (or a set of satellites for constellation) can have different existing designs. Satellites can operate in different orbits and be part of different constellation concepts (Technical Secretariat of the Space PEFCR, 2025).

Sample – a subset containing the characteristics of a larger population. Samples are used in statistical testing when population sizes are too large for the test to include all possible members or observations. A sample should represent the whole population and not reflect bias toward a specific attribute.

Service Availability - The service availability represents the design yearly availability of the end-to-end service delivery calculated from link margin under clear sky conditions along with International Telecommunication Union (ITU) rain model. The inclusion of elements depends on the service delivered.

Software-defined Satellite - satellites that use software to dynamically reconfigure their functions and operations after launch via reprogrammable software.

Secondary data – data that is not from a specific process within the supply-chain of the company performing a PEF study.

This refers to data that is not directly collected, measured or estimated by the company, but rather sourced from a third party LCI database or other sources.

Secondary data includes industry average data (e.g., from published production data, government statistics and industry associations), literature studies, engineering studies and patents) and may also be based on financial data, and contain proxy and other generic data.

Primary data that go through a horizontal aggregation step are considered to be secondary data.

Segment (also referred to as "space mission segment") - Set of elements or combination of systems that fulfils a major, self-contained, subset of the space mission objectives (ECSS, 2023).

Sensitivity analysis – systematic procedures for estimating the effects of the choices made regarding methods and data on the results of a PEF study.

Site-specific data – directly measured or collected data from one facility (production site).

A synonym of ‘primary data’.

Single overall score – sum of the weighted EF results of all environmental impact categories.

Space Activities - Activities performed in the context of a space mission, throughout a space mission’s life cycle. More specifically, in this report, space activities refer to space missions in general (Technical Secretariat of the Space PEFCR, 2025).

Space based services – A service delivered to stakeholders through activities (partially) taking place in space, meaning above the Kármán line (100 km altitude).

Space Mission - User-defined needs to be achieved by a space system (ECSS, 2023). A space mission corresponds to all activities from design, manufacturing, launch, operations to end of life.

Examples: Cryosat (ESA’s ice mission), Swarm (ESA’s magnetic field mission), Copernicus Sentinel and Copernicus expansion missions e.g. CO2M, ROSE-L, etc.

Space Mission Type - Group of space missions providing similar types of services (Technical Secretariat of the Space PEFCR, 2025). The main space mission types considered in this PEFCR are: Earth Observation, Navigation, Telecommunications, in orbit services and Launch services.

Space Programme - Set of related space missions managed in a coordinated way to contribute to an overall objective (ECSS, 2023). A space programme may consist of several space missions.

Space Segment - Part of a space system, placed in space, to fulfil the space mission objectives. Examples, Annex B.1: spacecraft, payload, platform (ECSS, 2023). Note: A space segment is manufactured by satellite manufacturers, while being purchased and operated by satellite operators. A single organisation can act as a satellite manufacturer and operator at the same time.

Space System - System that contains at least a space, a ground or a launch segment. Generally a space system is composed of all three segments and is supported by a support segment (ECSS, 2023).

Space Traffic Management - STM encompasses the means and the rules to access, conduct activities in, and return from outer space safely, sustainably, and securely (defence-industry-space.ec.europa.eu, 2025).

Spacecraft - Manned or unmanned vehicle designed to travel in space, excluding launchers. Launchers are excluded and treated separately in this PEFCR. Note: a spacecraft is a space segment element.

Specific data – directly measured or collected data representative of activities at a specific facility or set of facilities.

A synonym of ‘primary data’.

Sub-category - a product category may be split into multiple sub-categories, each carrying vertical modelling rules specific for its (final) products in scope. For final products only, a comparison of products belonging to the same sub-category shall always be allowed. The TS may decide and shall explicitly state in the PEFCR if a cross-comparison of products belonging to two or more different sub-categories is allowed.

Subdivision – subdividing involves disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The process is investigated to see whether it may be subdivided. Where subdivision is possible, inventory data should be collected only for those unit processes directly attributable to the products/services of concern.

Sub-population – any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes a homogenous sub-set of the whole population.

A synonym of ‘stratum’.

Sub-processes – processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form (see Figure 1).

Sub-sample - a sample of a sub-population.

Sub-system (of a spacecraft or launcher) – Subsystem refers to a distinct, self-contained set of equipment and components that performs a specific function necessary for the spacecrafts or launchers operation. Subsystems are typically functional independent, but they are interconnected and interrelated to work together to ensure correct operation of the system. Examples of subsystems of a launcher include propulsion subsystem, structural subsystem. Examples of subsystems of a spacecraft are power subsystem, communication subsystem.

Supply chain – all of the upstream and downstream activities associated with the operations of the user of the PEF method, including the use of sold products by consumers and the end of life treatment of sold products after consumer use.

Supply chain-specific – refers to a specific aspect of a company’s specific supply chain. For example, the recycled content of aluminium produced by a specific company.

Supporting ground infrastructure – part of the ground infrastructure that supports the data collection and data treatment of the space mission. It covers the satellite Earth station and ground communication network (Technical Secretariat of the Space PEFCR, 2025).

System (of a spacecraft or launcher) – System refers to the complete, integrated configuration of subsystems that work together to ensure the spacecraft/launcher achieves its overall mission / goal and operates effectively in space.

System boundary – definition of aspects included or excluded from the study. For example, for a ‘cradle-to-grave‘ EF analysis, the system boundary includes all activities ranging from the extraction of raw materials, through processing, distribution, storage and use, to the disposal or recycling stages.

System boundary diagram – graphic representation of the system boundary defined for the PEF study.

Temporary carbon storage – this happens when a product reduces the greenhouse gases in the atmosphere or creates negative emissions, by removing and storing carbon for a limited amount of time.

Type III environmental declaration – an environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.

Uncertainty analysis – procedure for assessing uncertainty in the results of a PEF study due to data variability and choice-related uncertainty.

Unit process – smallest element considered in the LCI for which input and output data are quantified.

Upper stage(s) – Optional additional stage(s) attached on top of the core stage

User segment - Segment which is composed of all subsystems that are necessary for the processing and use of the data and/or signal by the end user. The User Segment is not standardised but is usually considered to be composed of all subsystems that are necessary for the processing and use of the data/signal by the end user. That can be the end-user antenna and data/signal processing chain in case of Telecommunications missions (i.e. the RF – Radio Frequency – equipment and the modem as well as the interfaces to the user networks and the user himself), the GNSS chipset/receiver used for Navigation, the distress radio beacon used for Search and Rescue, or the payload data (science data) processing from raw satellite data and the storage of the processed data (Technical Secretariat of the Space PEFCR, 2025).

Vertical Rules – Modelling rules only applicable to a certain sub-category. Horizontal rules prevail over the vertical ones; however, specific derogations from this principle may be allowed if properly justified in the PEFCR (Extracted from the main text of the EC recommendation 2021/2279, Section A.3.1).

Weighting – a step that supports the interpretation and communication of the analysis results. PEF results are multiplied by a set of weighting factors (in %), which reflect the perceived relative importance of the impact categories considered. Weighted EF results may be directly compared across impact categories, and also summed across impact categories to obtain a single overall score.

1. Introduction

The Product Environmental Footprint (PEF) method provides detailed and comprehensive technical rules on how to conduct PEF studies that are more reproducible, consistent, robust, verifiable, and comparable. Results of PEF studies are the basis for the provision of EF-information. They may be used in a diverse number of potential fields of applications, including in-house management and participation in voluntary or mandatory programmes.

For all requirements not specified in this Product Environmental Footprint Category Rule (PEFCR) the user of the PEFCR shall refer to the documents this PEFCR is in conformance with (see 2.7).

The compliance with the present PEFCR is optional for PEF in-house applications, whilst it is mandatory whenever the results of a PEF study or any of its content is intended to be communicated.

Terminology: shall, should and may

This PEFCR uses precise terminology to indicate the requirements, the recommendations and options that can be chosen when a PEF study is conducted.

The term “shall” is used to indicate what is required in order for a PEF study to be in conformance with this PEFCR.

The term “should” is used to indicate a recommendation rather than a requirement. Any deviation from a “should” requirement has to be justified when developing the PEF study and made transparent.

The term “may” is used to indicate an option that is permissible. Whenever options are available, the PEF study shall include adequate argumentation to justify the chosen option.

GUIDELINES FOR THE READER DURING THIS FIRST OPEN CONSULTATION

This first open consultation primarily addresses the modelling rules for the space sector. We kindly ask readers to focus on the clarity and comprehensiveness of the guidelines provided. Selected results from the initial draft representative products are presented in sections 4 and 7. It should be noted, however, that the PEF-RP modelling is limited to the data available to date (see Annex 4.2 for further details). All feedbacks (including those on the excel annexes) are to be provided through the excel file „Feedback Template for First Open Consultation”.
Note 1: For Earth Observation, no PEF-RP study has been conducted; instead, two case studies are presented.

Note 2: For PNT, no PEF-RP results are provided due to the availability of data. Data limitations will be addressed in the second draft of this PEFCR4space.

If your time is limited or you like to focus on the most crucial points, please provide input on specific questions posted in grey text. We ask for explicit feedback on the following main aspects:

- Do you agree with the system boundaries as presented, do you see missing elements (Section 3.4)?
- Do you agree with the first indications of mandatory-company specific data (Section 3.4)?
- Is the suggested additional environmental and technical information complete or difficult to comply with (section 3.6 and 3.7)?
- Are the defined Functional Units and reference flows correct, understandable and reproducible (section 3.3)?
- The allocation approaches were widely discussed. Further feedback on the questions in section 6 are welcome.

Within the sub-categories we ask your attention to the following crucial questions:

- Earth observation: *No fundamental questions.*

- Positioning, Navigation and Timing services: For PNT services, the representative product consists of GNSS, LEO PNT and SBAS technologies. We are asking input on the relevance of modelling EGNOS as part of the representative product. The representative product is described in section 3.2.2.

- Satellite video services: As the impact is highly driven by the use stage, we ask for special attention on the assumptions taken for the use stage scenario. Inputs on how to select the user termina, the chosen amount of standby and download hours (see section *6.6.3.4).*

- Satellite connectivity services: For connectivity services, inputs are highly welcome on the default demand scenario that should enable comparability in terms of user demand and service in Europe. This default demand scenario acts as a scaling of one's own system (the user of the PEFCR) towards the reference, which is included as a scaling factor in the reference flow. Currently, the Reference Flow has a double counting which can only be solved once the default demand scenario is clarified. Therefore, we suggest adaptations to the Functional Unit. Please read Chapter 3.3.4 entirely and provide inputs on how we can enable fair comparability.

- In-space transport services: *No fundamental questions.*

- Uncrewed launch services from Earth to space: The burn-up rate shall be calculated before the demise emissions can be derived. Inputs on a suitable free accessible tool or pre-defined tool requirements to calculate the burn-up rate are highly welcome (See details in section 5.15.2). Furthermore, inputs on several data gaps in the use and end of life stage (such as launch ground activities, launch site, launch pad, flight safety centre, infrastructure and operations, antennas and RF infrastructure) are highly welcome.

2. General information about the PEFCR

2.1 Technical Secretariat

[The list of the organisations in the Technical Secretariat at the time of approval of the final PEFCR shall be provided. For each one, the type of organisation shall be reported (industry, academia, NGO, consultant, etc.), as well as the starting date of participation. The Technical Secretariat may decide to include also the names of the members of the persons involved for each organisation.]

This PEFCR for space-based services delivered to EU stakeholders was developed by a Technical Secretariat[4] led by DG DEFIS, with support of consortium partners, other EC services, 10 private companies, 1 international and 3 national organisations, 1 non-governmental organisation, and 3 universities.

Table 1: Technical Secretariat (TS) of the PEFCR for space-based services and their membership type

	Name of organization	**Type of organisation**	**Name of the representative of the member**	**Member type**
1	DG DEFIS	EC Directorate General	Vera Pinto	Chair
2	VITO	Consultancy	An Vercalsteren	Co-chair
3	PRé Sustainability	Consultancy	An De Schryver	Co-chair
4	Novaspace	Consultancy	Jean-Loup Rondeau	Co-chair
5	EC services	EC Directorate General	Marina Tasiopoulos	EC services
6	ESA	International organization	Sara Morales Replaced temporarely in S2 2025 by:	TS member

[4] The final list of the organisations in the Technical Secretariat will be updated at the time of approval of the final PEFCR

			Andrea Calio.	
7	CNES	National space agency	Alain Rosak (replacing Bruno Millet as of Sept'25)	TS member
8	Royal Netherlands Aerospace Centre	Research Technology Organisation for Aerospace	Daniël Kan	TS member
9	Cosmos For Humanity	NGO	David Many	TS member
10	Airbus Defense and Space	Private company	Matthieu Derrey	TS member
11	Alpha Impulsion	Private company	Martin Gros	TS member
12	ArianeGroup	Private company	Céline Brun-Buisson	TS member
13	Dawn Aerospace	Private company	Neta Palkovitz	TS member
14	Eutelsat	Private company	James Matthews	TS member
15	MaiaSpace	Private company	Antoinette Ott	TS member
16	OHB System AG	Private company	Raphael Lescouzeres (replacing Andrea Calio as of Feb '25)	TS member
17	SES	Private company	Charles-Aimé Nzeussi Mbouendeu	TS member
18	Thales Alenia Space	Private company	Jean-Philippe Chessel Replaced by: Nicolas Petitpas	TS member
19	The Exploration Company	Private company	Nathalie Bergmann	TS member
20	EPFL Space Center	University	Mathieu Udriot	TS member
21	University of Stuttgart, Institute of Space Systems	University	Jan-Steffen Fischer	TS member

22	VITO	Consultancy	Carolin Spirinckx	TS member
23	Novaspace	Consultancy	Kat Hickey	TS member
24	PRé Sustainability	Consultancy	Marina Dumont	TS member
25	PRé Sustainability	Consultancy	Georgios Pallas	TS member

2.2 Consultations and stakeholders

[For each open consultation the following information shall be provided:
- Opening and closing date of the open consultation
- Number of comments received
- Names of organisations that have provided comments
- Link to the online platform]

Two open consultations took place.

The **first stakeholder consultation** was related to the 1^{st} draft of the PEFCR for space-based services delivered to EU stakeholders and the 1^{st} version of the PEF-RP studies. See further details of this consultation below:

- Opening & closing date of the 1^{st} open consultation: from 15 October 2025 till 1st of December 2025
- Number of comments received: X
- Names of organisations that have provided comments: X
- Link to the online platform: X

The **second stakeholder consultation** was related to the 2^{nd} draft PEFCR for space-based services delivered to EU stakeholders and the 2^{nd} version of the PEF-RP studies. See further details of this consultation below:

- Opening & closing date of the 2^{nd} open consultation: from X
- Number of comments received: X
- Names of organisations that have provided comments: X
- Link to the online platform: X

2.3 Review panel and review requirements of the PEFCR

[This section shall include the names and affiliations of the members of the review panel. The member that is chairing the review panel shall be identified.]

The PEFCR development and any related Deliverables are reviewed by a dedicated review expert panel, as displayed in Table 2. It covers both LCA/PEF expertise and knowledge of the space sector.

Table 2: Composition of the PEFCR`s review panel

Name of the member	**Affiliation**	**Role**
Ugo Pretato	Studio Fieschi & soci S.r.l. Head of RD and Operations	Review chair, LCA/PEF expert
Chris Foster	EuGeos srl Director	Review member, LCA expert
Natacha Wonneberger	Deloitte Conseil Senior Consultant	Review member, LCA and space expert

- The reviewers have verified that the following requirements are fulfilled[5]:
- The PEFCR has been developed in accordance with the requirements provided in Annex I and Annex II;
- The PEFCR supports the creation of credible, relevant and consistent PEF profiles;
- The PEFCR scope and the representative products are adequately defined;
- The functional unit, allocation and calculation rules are adequate for the product category under consideration;
- Datasets used in the PEF-RPs and the supporting studies are relevant, representative, reliable, and in compliance with data quality requirements;
- The selected additional environmental and technical information are appropriate for the product category under consideration and the selection is done in accordance with the requirements stated in Annex I,
- The model of the RP and corresponding benchmark (if applicable) represent correctly the product category or sub-category;
- The RP models, disaggregated in line with the PEFCR and aggregated in ILCD format, are EF compliant following the rules available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml;
- The RP model in its corresponding excel version is compliant with the rules outlined in section A.2.3 of Annex II;
- The Data Needs Matrix is correctly implemented;
- The classes of performance, if identified, are appropriate for the product category.

[5] The TS might add additional requirements before the review process takes place.

The public review reports are provided in **Annex 3** of this PEFCR.

[The Technical Secretariat may add additional review criteria as appropriate]

[The review panel shall produce:

- a public review report for each PEF-RP,
- a public review report for the final PEFCR].

2.4 Review statement

This PEFCR was developed in compliance with the PEF method adopted by the Commission on *[indicate the date of approval of the latest version available].*

The representative product(s) correctly describe the average product(s) sold in Europe (EU+EFTA) for the product category/sub-category in scope of this PEFCR.

PEF studies carried out in compliance with this PEFCR would reasonably lead to reproducible results and the information included therein may be used to make comparisons and comparative assertions under the prescribed conditions (see section on limitations). *[the last part of this statement shall be deleted in case the PEFCR is for intermediate product(s)].*

[The review statement shall be completed by the reviewer.]

2.5 Geographic validity

This PEFCR is valid for all space-based services delivered to EU+EFTA stakeholders.

Each PEF study shall identify its geographical validity listing all the countries where the service is delivered with the relative market share. In case the information on the market for the specific service of the study is not available, EU+EFTA shall be considered as the default market, with an equal market share for each country.

2.6 Language

The PEFCR is written in English. In case of conflict, the original version (English) supersedes translated versions.

2.7 Conformance to other documents

This PEFCR has been prepared in conformance with:

- Annexes I and II of the of the Commission recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisation (European Commission 2021).
- To be completed

3. PEFCR Scope

This PEFCR is applicable for the assessment of the environmental footprint of all **space-based services delivered to stakeholders in the EU**. It covers all launching and operator services, which include activities between space and Earth as well as in-space operations and services (ISOS). The scope covers the entire life cycle, as defined within the system boundary (Section 3.4 of this PEFCR).

This PEFCR provides (i) horizontal rules which are overarching for all space-based services in scope, and (ii) vertical rules with specific requirements for a number of more detailed defined services, described in the sub-categories. As launch services can be quite different from spacecraft services, it was in certain cases needed to split the horizontal rules in two sub-sections. Per chapter we clarify if certain horizontal rules are valid for spacecraft, valid for launch services, or valid for both. If not specified differently, by default the respective sections are valid for both.

Six sub-categories are identified, each with their own defined vertical rules. In case of conflict, the horizontal rules prevail over the vertical ones.

Table 3 provides an overview of the six sub-categories covered in this PEFCR, together with a detailed description and some typical example activities included and excluded.

Table 3: The product sub-categories covered in this PEFCR, their description and typical activities in- and excluded.

Sub-category	Description	Typical activities included	Typical activities excluded
Earth observation services	Public/private activities designed to collect data about Earth's systems for the purposes of monitoring, analysis, and decision-making.	Space missions using remote sensing to monitor land, atmosphere or climate. Earth-related science missions.	n/a
Position, Navigation and Timing services (PNT)	Public/private satellite services delivering PNT signals to human activities on the Earth’s surface and in its atmosphere.	Position, navigation and timing services provided as an Open Service (OS) by Global Navigation Satellite Systems (GNSS), LEO PNT and Space-Based Augmentation Systems (SBAS).	High Accuracy Service (HAS) with improved position for authorized users; Public Regulated Service (PRS) which is an encrypted service for government use; Search and Rescue (SAR) to help locate distress signals worldwide.
Satellite video services	The transmission of video content via satellite, enabling long-distance video delivery for broadcasting, live events, and security applications.	TV broadcast services.	n/a
Satellite connectivity services	The use of satellite systems to provide data exchange (internet and connectivity services), for fixed and mobile applications.	Broadband consumer / enterprise connectivity, Internet of Things, Direct-to-Device connectivity, voice, secure government communications.	n/a

In-space transport services	Activities that cover transport of cooperative objects in Earth orbits with a servicer spacecraft with a high degree of autonomy*. **High degree of autonomy refers to their ability to independently perform services and functions with minimal or no ground control intervention. This encompasses advanced system capabilities, including autonomous decision-making, on-board software-driven operations, and robotic functionalities, enabling greater self-sufficiency in mission execution.*	Large and small space tugs and other servicer spacecrafts used to transport satellites or cargo between two orbits.	Any transport from Earth to space and from space to Earth, including re-entry capabilities of space capsules and deorbiting to Earth of cooperative objects; any transport beyond Earth orbits; removal or deorbiting of space debris; the (first use of the) kick stage, as this is part of the launch service; in-orbit servicing other than in-space transport, such as inspection, repair, refuel and reconfiguration.
Uncrewed launch services from Earth to space	Activities that involve the planning, commercialisation, preparation, and execution of sending a spacecraft into orbit by use of a launch vehicle. Launch vehicles are used to send uncrewed spacecraft, satellites or cargo to LEO/ SSO/ MEO/ GTO orbits. Types of launch vehicles include: expendable or (partially) reusable micro (<350kg payload), small (0.35-2t), medium (2-20t), heavy (<20-50t), and super heavy (>50t) launchers.	Uncrewed launch services to transport a payload, such as satellites, in orbit.	Crewed launch services; beyond GTO transport.

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Space-based service not covered by the six-sub-categories are indicated below (non-exhaustive list). For these, as explained previously, the horizontal rules of this PEFCR shall be used to the extend possible. In case a horizontal rule is not applicable, provisions in the general PEF method (EC, 2021/2279) shall be used.

- Space tourism & human space transport;
- Space stations;
- Defence;
- Planetary defence;
- Science activities (except those related to Earth observation);
- Space mining;
- Radio broadcasting;
- Space transport beyond GEO (for example Cislunar space transport);
- Stand alone inter-satellite communication services delivered to another operator[6];
- In-orbit servicing other than in-space transport, such as inspection, repair, refuel and reconfiguration;
- Removal of space debris and deorbiting of cooperative objects.

3.1 Product classification

[Based on the product category/sub-category, provide the corresponding Classification of Products by Activity (CPA) (based on the latest CPA list version available). Where multiple production routes for similar products are defined using alternative CPAs, the PEFCR shall accommodate all such CPAs. Identify the sub-categories not covered by the CPA, if any.]

At the date of publication, the available NACE and CPA codes that describe the activities included in this overall PEFCR are (non-exhaustive list):

NACE: 26.51 - Manufacture of instruments and appliances for measuring, testing and navigation	CPA: 26.51.11 - Direction-finding compasses; other navigational instruments and appliances CPA: 26.51.20 - Radar apparatus and radio navigational aid apparatus CPA: 26.51.81 - Parts of radar apparatus and radio navigational aid apparatus
NACE: 30.30 - Manufacture of air and spacecraft and related machinery	CPA: 30.30.40 Spacecraft (incl. satellites) and spacecraft launch vehicles

[6] Intersatellite communication services here only refers to the stand-alone intersatellite communication service delivered to another operator, i.e. as a separate satellite.

NACE: 30.31 – Manufacture or civilian air and spacecraft related machinery	
NACE: 30.32 – Manufacture of military air and spacecraft related machinery	
NACE: 33.16 – Repair and maintenance of civilian aircraft and spacecraft	CPA: 33.16.10 - Repair and maintenance services of civilian aircraft and spacecraft
NACE: 33.18 - Repair and maintenance of military fighting vehicles, ships, boats, air and spacecraft	
NACE: 51.22 – Space transport	CPA: 51.22.11 - Space transport services for passengers CPA: 51.22.12 - Space transport services for freight
NACE: 52.23 - Service activities incidental to air transportation	CPA: 52.23.20 - Services incidental to space transportation
60.2 - Television programming and broadcasting activities	60.20.1 – Television programming and broadcasting services
NACE: 61.10 - Wired, wireless, and satellite telecommunication activities	CPA : 61.10 - Wired, wireless, and satellite telecommunication activities
NACE: 84.22 - Defence activities	CPA : 84.22.11 – Military defence services CPA : 84.22.12 – Civil defence services

The NACE and CPA codes linked to the respective sub-categories are provided in Table 4.

Table 4. NACE codes covered by the different sub-categories.

Sub-category	NACE Rev.2 4 digits	CPA 6 digits
Earth Observation	30.30 - Manufacture of air and spacecraft and related machinery	CPA: 30.30.40 Spacecraft (incl. satellites) and spacecraft launch vehicles
	33.16 – Repair and maintenance of civilian aircraft and spacecraft	CPA: 33.16.10 - Repair and maintenance services of civilian aircraft and spacecraft
	51.22 – Space transport	CPA: 51.22.11 - Space transport services for passengers CPA: 51.22.12 - Space transport services for freight

Position Navigation and Timing (SatNav)	26.51 - Manufacture of instruments and appliances for measuring, testing and navigation	26.51.11 - Direction-finding compasses; other navigational instruments and appliances
		26.51.20 - Radar apparatus and radio navigational aid apparatus
		26.51.81 - Parts of radar apparatus and radio navigational aid apparatus
	30.30 - Manufacture of air and spacecraft and related machinery	30.30.40 - Spacecraft (including satellites) and spacecraft launch vehicles
Satellite video services	60.2 - Television programming and broadcasting activities	60.20.1 – Television programming and broadcasting services
	61.10 - Wired, wireless, and satellite telecommunication activities	61.10 - Wired, wireless, and satellite telecommunication activities
Satellite connectivity services	61.10 - Wired, wireless, and satellite telecommunication activities	61.10 - Wired, wireless, and satellite telecommunication activities
In-space transport services	52.23 - Service activities incidental to air transportation	52.23.20 - Service incidental to space transportation
Launch services	30.30 - Manufacture of air and spacecraft and related machinery	30.30.40 - Spacecraft (including satellites) and spacecraft launch vehicles
	51.22 – Space transport	51.22.12 - Space transport services for freight

3.2 Representative products

[The PEFCR shall include a description of the representative product(s) and how it has been derived. The Technical Secretariat shall provide in an Annex to the PEFCR

information about all the steps taken to define the 'model' of the RP(s) and report the information gathered].

For the sub-categories Positioning, Navigation and Timing services, satellite video services, satellite connectivity services, in-space transport services and uncrewed launch services from Earth to space, a representative product (RP) has been developed. For Earth Observation Services, no Representative Product (RP) has been defined.

The RPs in this PEFCR reflect the average service delivered to European stakeholders in the year 2028. While the development of this PEFCR started in 2024, the year 2028 has been chosen as market average for the PEF-RP for a number of reasons. Firstly, the Space sector is characterised by its very long production period before a product is brought to market. Secondly, the technologies used are evolving very fast. Considering these two characteristics, it is decided that modelling for the year 2028 will reflect better reality by the time the PEFCR will be published and applied.

The future changes have been assessed on two levels: considering the difference (i) in technology and (ii) in market share. The choice for developing the RPs for the year 2028 (instead of 2025) has an impact on the sub-categories (i) PNT and (ii) in-space transport (see Table 5).

Table 5. Effect on RP when modelling the year 2028 instead of 2025.

Sub-category	**New technology?**	**Different market shares?**
Earth observation	n/a	
Position Navigation and Timing	No (Emerging technologies already operational)	Yes (Market share of LEO-PNT expected to increase)
Satellite video services	No	No
Satellite connectivity services	No	No (not operational in 2028)
In-space transport services	Yes (for the multi-use servicers)	Yes (Market share for multi-use IST expected to increase)
Launch services	No	No

The sections below give a description of each PEF-RP developed.

Within this first draft PEFCR the scope of the first PEF-RPs is limited to the industry data received. Annex 4.2 describes the adapted scope of the PEF-RPs developed for this first draft PEFCR.

3.2.1 Earth Observation Services

For Earth Observation Services, no Representative Product (RP) has been defined, as the delivered services are highly diverse and no single product can adequately represent this variety; therefore, this PEFCR does not provide a benchmark.

For the hotspot analysis, two case studies are conducted: the CO2M mission and the Altius mission.

CO2M

The CO2M (Copernicus Carbon Dioxide Monitoring) mission, under the European Union's Copernicus Sentinel Expansion Programme and the European Space Agency, is designed to monitor key greenhouse gases, specifically atmospheric carbon dioxide (CO_2) and methane (CH_4), with a focus on emissions resulting from human activity. In addition, CO2M observations will provide data on aerosol optical depth and nitrogen dioxide levels (NO_2) in the lower atmosphere. CO2M will measure images of atmospheric columns of CO_2 with the resolution, accuracy, time sampling and spatial coverage required to provide the key space component inputs of the Operational Anthropogenic CO_2 Emissions Monitoring & Verification Support (MVS) Capacity, therefore enabling scientists and policymakers to track emissions down to individual sources such as countries, megacities and industrial facilities. CO2M will operate with a medium revisit rate and high accuracy as defined in section 3.8.1.1. The current CO2M baseline is a constellation of two satellites with an option to include a third one. The three spacecrafts are identical. The target launch date for both PFM and FM2 spacecraft is the second half of 2025. The satellite will be launched with the VEGA-C launcher. The operational mission will last for 7 years, with an extension of up to 5 years, depending on the status of the satellites and consumables.
This mission will significantly enhance the EU's ability to assess progress toward climate targets and support international climate agreements, such as the Paris Accord, by providing independent, science-based data.

OHB is the main contractor and is responsible for the full satellite platforms and overall system delivery. Each CO2M payload includes three instruments, provided by Thales Alenia Space:

- An integrated CO_2/NO_2 (carbon dioxide/nitrogen dioxide) spectrometer (CO2I) based on a near-infrared and shortwave-infrared
- A Multi-Angle Polarimeter (MAP) based on four identical cameras, contained in a dedicated optical unit, to estimate the effective light path effects of the aerosols
- A CLoud IMager (CLIM), derived from the flight-proven Proba-V instrument, to detect low and high clouds in the spatial sample of CO2I for removal of this data from the retrieval process

Altius

The Altius (Atmospheric Limb Tracker for Investigation of the Upcoming Stratosphere) mission from Redwire Space is an innovative Earth Observation satellite under ESA's

Earth Watch programme. Built on a PROBAP200 three-axis stabilised platform, Altius carries a high-resolution 2D spectral imager that operates in the ultraviolet, visible, and nearinfrared. Flying in a Sunsynchronous orbit at ~668 km with a three-day global revisit, it utilizes limbsounding techniques to generate detailed vertical profiles (1–3 km resolution) of stratospheric ozone—critical for tracking the recovery of the ozone layer—as well as measuring trace gases like aerosols and greenhouse constituents. The mission's data will support weather forecasting, climate modelling, and environmental policy, while reinforcing Europe's operational EO capabilities. Altius will operate with a medium revisit rate and high accuracy as defined in section 3.8.1.1. The mission will consist of a single spacecraft with a planned operational lifespan of at least three years.

3.2.2 Positioning, Navigation and Timing Services

The section below outlines how the final RP will be modelled. Due to data collection issues, the scope of the first PEF-RPs has been limited. Annex 4.2 details the limited scope of the first PEF-RP for PNT. In this first iteration, no RP results are presented due to absence of data for Global Navigation Satellite Systems. Due to their large market share, they are a key component of the RP.

Currently there are several major systems delivering PNT services to users within the Earth's atmosphere. PNT services are typically not differentiated in systems located in LEO, MEO and GEO, they are rather categorized in globally and regionally operating systems. The following systems are available on the EU market and represent the different technological solutions currently available or expected to be available by 2028:

1. **Global Navigation Satellite systems (GNSS)**
   GNSS systems are globally operating constellation systems. There are four different systems delivering services to the EU market:
   a. Galileo is the European Union's independent GNSS, managed by the European Commission. It is operated by the European Union Agency for the Space Programme (EUSPA); and the European Space Agency (ESA) supports its development. It consists of 30 satellites operating in MEO, of which 24 are operational and 6 are spare ones. The system provides different services, such as 1) an Open Service (OS) for civilian users (free positioning service); 2) a High Accuracy Service (HAS) with improved position for authorized users; 3) a Public Regulated Service (PRS) which is an encrypted service for government use; and 4) Search and Rescue (SAR) to help locate distress signals worldwide. Only the Open Service is covered by the vertical PEFCR on PNT systems, the other services are covered by the horizontal PEFCR.
   b. GPS (Global Positioning System) is a GNSS owned and operated by the United States. It consists of 31 operational satellites in MEO. It provides a free Standard Positioning Service (SPS) to civilian users and a Precise Positioning Service (PPS) encrypted for U.S. military and authorized

government users. Only the Open Service is covered by the vertical PEFCR on PNT systems, the other services are covered by the horizontal PEFCR.

c. GLONASS is owned and operated by the Russian space agency. It consists of 22 operational satellites in MEO orbit and provides services similar to Galileo, GPS and BeiDou.
d. BeiDou Navigation Satellite System (BDS) is owned and operated by the China National Space Administration (CNSA). It provides services similar to GPS, GLONASS and Galileo. It consists of 44 satellites out of which most operate in the MEO orbit, however, there are also satellites operating in GEO and IGSO orbit.

2. **LEO PNT systems**

LEO PNT systems are globally operating systems. They are recently developed and aim to address some of the key challenges faced by traditional GNSS, including vulnerability to signal disruptions or signal blockage. LEO satellites are closer to Earth, allowing for stronger signal strength and faster transmission times, which improve resilience, reliability, and precision – also in challenging environments, such as urban or even indoor. They use a different technology compared to GNSS systems, with new compact architectures incorporating a wider range of signals and standards. They either work stand-alone or can complement the GNSS. Combined with conventional GNSS, LEO PNT allows for faster convergence times of high-accuracy solutions. The systems which are currently (by 2027) providing services to the EU market are listed below:

a. Xona (USA) plans to operate a LEO constellation of approximately 260 small PNT satellites, of which the first has been launched in 2022, with a confirmed open service alongside premium high-precision options.
b. LEO PNT IoD (in-orbit demonstration) financed and operated by ESA. This 10-satellite demonstration constellation will be operational by 2027.

3. **Regionally operating satellite systems (GNSS + SBAS)**

Regionally operating satellite systems or augmentation systems enhance GNSS signals, by increasing accuracy reliability and availability over a specific geographical area. There are several types of augmentation systems, such as space-based AS (SBAS), ground-based AS (GBAS) and aircraft-based AS (ABAS). GBAS and ABAS are out of scope. EGNOS (European Geostationary Navigation Overlay Service) is a satellite-based augmentation system (SBAS) operated by the European Union Agency for the Space Programme (EUSPA). The system uses geostationary satellites and ground stations to enhance navigation signals. It is not a standalone constellation, instead, it is an augmentation system that currently enhances existing GNSS signals from GPS. It can also be used to improve signals from Galileo, although this is not yet the case. The services provided by EGNOS are 1) an Open Service (OS) to improve the accuracy of GPS signals; 2) Safety of life (SoL) Service designed for aviation and critical applications; and 3) EGNOS Data Access Service (EDAS) provides real-time EGNOS data via the internet, useful for professional applications like agriculture and surveying. Only the Open Service is covered by the vertical PEFCR on PNT systems, the other services are covered by the horizontal PEFCR.

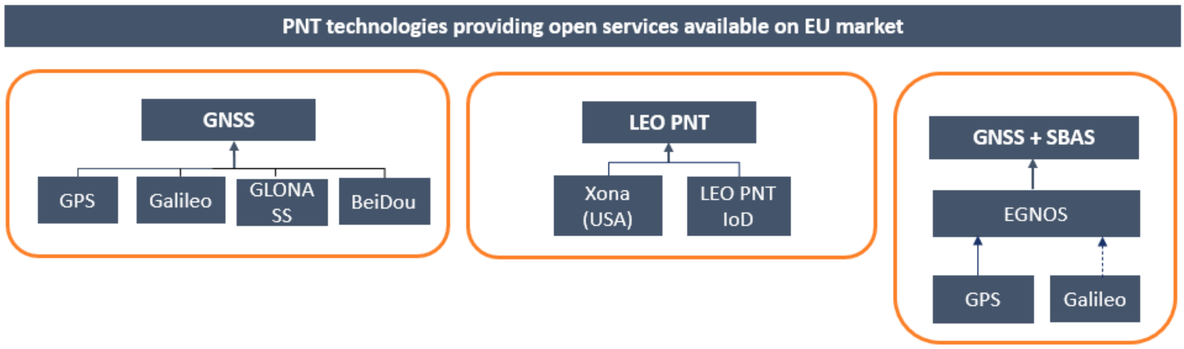

Figure 2: Overview of PNT technologies providing Open Services to the EU market.

The RP for PNT services is a virtual product, with sub-categories represented by the most appropriate (in terms of representativity for EU or data availability) constellation of their subgroup. The subgroups are 1) GNSS systems; 2) LEO PNT; [3) GNSS + SBAS]. For the GNSS systems, Galileo is considered the most appropriate constellation to model the sub-group. For emerging LEO PNT, the most appropriate constellation is LEO PNT IoD, due to the expected data availability for this system. EGNOS is the only regionally operating system. It is not a stand-alone system but currently works to enhance GPS signal. In the future it will also be possible to use EGNOS together with Galileo. Due to data constraints for GPS, the RP model is a combination of EGNOS together with Galileo.. The RP is visualised in Figure 3.

The RP virtual product will be modelled based on the average use of different PNT technologies within the European Union. The proposed weighting set (market share) reflects the estimated usage of PNT signals in Europe by 2028, covering the three main technologies: GNSS, GNSS enhanced with SBAS, and emerging LEO PNT. This weighting is established based on company insights into current activities and expected future bids, and further justified by the open-service nature of these technologies. Although SBAS systems often generate revenue through value-added services, their adoption is limited compared to GNSS, which underpins the vast majority of services and usage scenarios. Observations indicate that approximately 96% of users rely on GNSS, while 2% use SBAS-enhanced signals, and an additional 2% is projected for LEO PNT to ensure its inclusion in the representative product and reflect its anticipated emergence by 2028. These market share estimates will be reviewed and refined in future updates of the PEFCR to reflect technological and market developments.

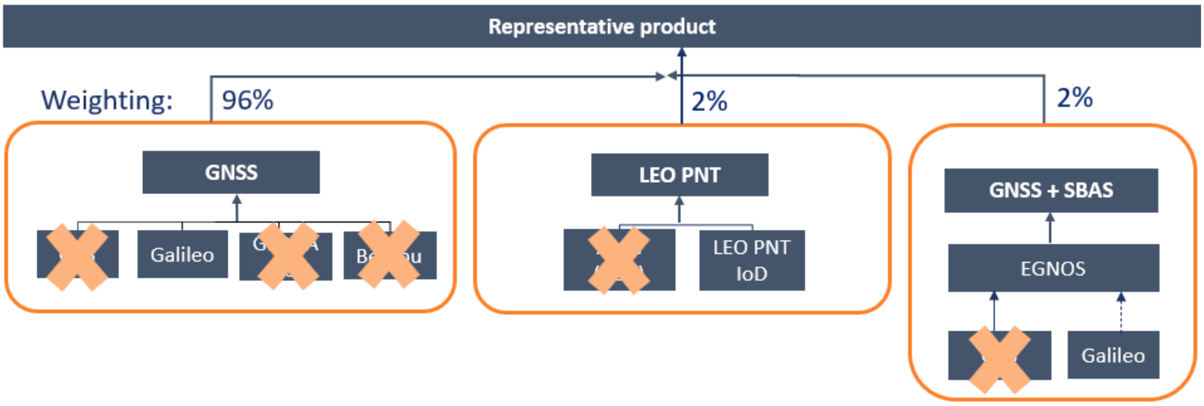

Figure 3: Representation of the RP model for PNT technologies providing services to the EU market, as projected for the year 2028.

3.2.3 Satellite Video Services

The section below outlines how the final RP for video will be modelled. Due to data collection constrains, the scope of this first PEF-RPs is limited. Annex 4.2 details the limited scope of the first PEF-RP for Video services.

The broadcast video services currently delivered in Europe are solely derived from GEO satellites. These satellites are positioned approximately 36,000 kilometres above the Earth's equator, maintaining a fixed position relative to the Earth's surface, which is ideal for consistent and reliable video broadcasting. While each operator has large similarities (such as the platform or launcher design and the ground infrastructure used), the following main differences have been identified when looking at the existing solutions today:

- Frequency bands used: Primarily Ku-band (12–18 GHz) and C-band (4–8 GHz)
- Transponders applied: Typically equipped with multiple transponders, each with a bandwidth between 26 and 50 MHz, facilitating the relay of television signals.
- Satellite power: Broadcasting satellites generally have power capacities ranging from 5 to 25 kilowatts (kW), depending on design and mission requirements.
- User terminals: direct-to-home (DTH) satellite dish with Low Noise Block downconverter (LNB) account for the majority of most common user terminals.

The RP for satellite video services is modelled as the most representative configuration of a satellite delivering video services up in GEO orbit today. The RP is a virtual product, based on most common configuration defined by the TS. Table 6 presents the most common configuration for a broadcasting satellite, used as basis for the RP.

Table 6. Key Technical Parameters for Video Services RP.

Orbit	GEO-Stationary Orbit
Number of Satellites	One

Dry Mass of Satellite[7]	Approx. 3400 kg
Satellite Power	15 kW
Frequency Band	Ku-Band
Transponders	55
User terminal	60 cm user terminal (Ku-band satellite dish) with LNB
Ground infrastructure	5.6 m gateway
Life time	15 years
Redundancies	Extra communication equipment (TWTA)

3.2.4 Satellite Connectivity Services

The section below outlines how the final RP for connectivity will be modelled. Due to data collection constrains, only a part of the market could be modelled. Annex 4.2 details the limited scope of the first PEF-RP for connectivity.

The most common configurations for delivering satellite connectivity services in Europe are based on satellites orbiting in GEO, MEO, and LEO orbits. Therefore, the variability of product configurations delivering satellite connectivity services is broader than for video services. LEO satellites are highly scalable and provide lower-latency global broadband connectivity. LEO satellites are usually also smaller in size, and due to their closer proximity of Earth have a smaller coverage, which requires more satellites for achieving global coverage (taking into account that those satellites are continuously rotating around Earth). Those are called constellations (or even mega-constellations for the bigger ones), at the moment 600 to 7000 per existing ones, and projected to rise to potentially 45000 satellites per constellation in the future. GEO satellites provide broadband connectivity using high-throughput (HTS) or very-high-throughput (VHTS) payloads designed for multi-spot beam coverage. GEO satellites are typically single, large satellites positioned in a fixed geostationary position (since GEO orbit implies that satellite is rotating at the same speed than Earth). MEO satellites provide lower latency than GEO and are used for high-capacity enterprise networks, cellular backhaul, and mobility services. MEO satellites are usually smaller than GEO, but larger than LEO satellites. Small constellations can be positioned in MEO (usually consisting of a few dozen satellites per constellation).

In 2024, 78.6% of connectivity-related delivered capacity (in Gbps) came from LEO satellite systems. The current solutions delivering satellite connectivity services over Europe today are listed in Table 7. Figure 4 presents a visual overview.

[7] A rough approximation is that for chemical propulsion satellites, the wet mass Is usually 2 times the dry mass, whereas for electrical propulsion satellites the wet mass is approximately 1.2 times the dry mass.

Table 7. Delivered capacity of connectivity services in 2024, split by orbit, provider, and satellites[8]. Ordered on level of delivered capacity.

Orbit and Satellite provider	Offered capacity in 2024 (based on delivered Gbps)
LEO (Low Earth Orbit)	78.6%
SpaceX: Starlink	*Of which, 99%*
Eutelsat: OneWeb Gen 1	*Of which, 1%*
GEO (Geostationary Orbit)	21%
Eutelsat: Konnect VHTS	*Of which, 66%*
Viasat: Ka-SAT	*Of which, 9%*
Viasat: Inmarsat-5 F5	*Of which, 7%*
Eutelsat: Konnect	*Of which, 6%*
Eutelsat: Eutelsat 10B	*Of which, 3%*
MEO (Medium Earth Orbit)	0.3%
SES: mPower	*Of which, 100%*

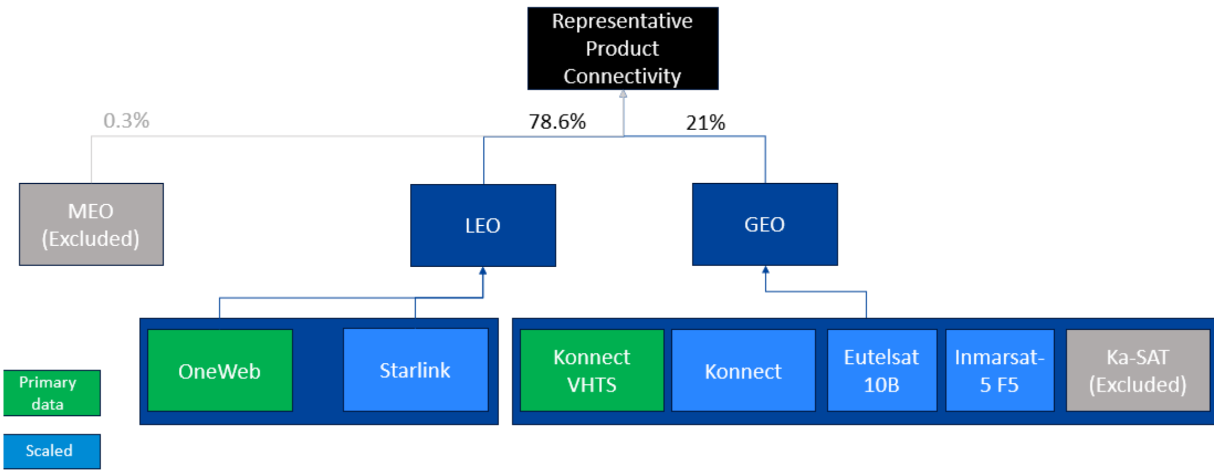

Figure 4. Overview of Connectivity technologies providing services to the EU market.

The RP for satellite connectivity services is modelled as a market-average of satellites in those various orbits, based on delivered capacity in 2024. The RP is therefore a virtual product based on a model for LEO representation (78.6%), and a GEO representation (21%). Due to the low delivered capacity from MEO (0.3%), MEO is excluded from the RP. The shares of LEO and GEO are therefore scaled to 100%. Additionally, the Viasat KA-Sat satellite in GEO is also excluded, as it was launched in 2010 and will reach its end of life by the end of 2025.

For the LEO orbit, which has the largest share of delivered capacity, 99% of the delivered capacity is delivered by the mega-constellation of Starlink (today approximately 7,000 Starlink satellites are deployed). Due to data constraints, the

[8] High Throughput Satellite, 7th edition, Novaspace, April 2024.

Starlink model is built on Eutelsat's OneWeb (Gen1), via scaling parameters based on expert judgement.

[Further work is ongoing, inputs during the consultation on the scaling of Starlink based on OneWeb are welcome.]

In the GEO orbit, the largest share of capacity is delivered by Eutelsat's Konnect VHTS. It therefore serves as the main model to represent GEO solutions. The model is further scaled for a number of technical parameters (as listed in Table 8) to represent the other relevant satellites (contributing to >90% of delivered capacity in 2024) in GEO orbit (excl. Viasat KA-Sat), and thereafter market-weighted based on delivered capacity to obtain the model for GEO satellites.

Table 8 presents the technical information of the satellites currently in GEO delivering up to 90% of capacity over Europe in 2024. The scaling from Konnect VHTS to the other satellites to obtain the GEO representation is performed based on power and market-weighted by delivered capacity.

Table 8. Technical information of most relevant GEO satellites delivering connectivity services (>90% delivered capacity in 2024, excl. Viasat's KA-Satellite).

	Eutelsat			**Viasat**
	Konnect VHTS	**Konnect**	**Eutelsat 10B**	**Inmarsat 5**
Date Launch	2022	2020	2022	2019
Lifetime (Years)	15	15	15	15
Mass (tons)	6.5	3.6	4.5	6.1
Power (kW)	23	15	14	15
Propulsion	Electric	Electric	Electric	Electric
Delivered capacity in 2024 (Gbps)	500	75	35	89
Frequency band	Ka	Ka	Ku	Ka
Gateways (Nr)	12	7	4	n/a

The satellites in MEO orbit currently only deliver 0.3% of the connectivity services capacity delivered in the EU. Due to the low relevance of delivered capacity and thereby the low market share it would receive in the modelling, the solutions in the MEO orbit are excluded from the RP for connectivity services.

In the future, it is expected that connectivity services delivered from the LEO orbit increase. However, by 2028, it is not expected that those solutions will yet be operational in orbit. Hence, the RP for connectivity services does not include future projections.

User terminals for connectivity services can have a large variances. Varying applications (e.g., land-based, maritime, aero) and varying technology types (e.g., 1. OTM/OTP (on the move, on the pause), 2. Deployable, handheld and secure IOT, 3. Fixed and backauling[9]) make it difficult to generalize a representative single user terminal, specifically since one satellite or the constellation can serve all those terminals. Table 9 present the user terminal distribution worldwide for connectivity services, clustered by typology. The user terminal for the RP for connectivity services is therefore based on the most relevant typology, namely the consumer broadband terminal, which is projected to increase in share towards 2028.

Table 9. Global user terminal distribution for connectivity sat.com services[10].

Main typologies of connectivity user terminal applications	In 2024	Projected in 2028
Consumer Broadband	71.0 %	81.4 %
Enterprise networks	26.4 %	16.7 %
Cellular backhaul	1.8 %	1.3 %
Maritime connectivity terminals	0.6 %	0.5 %
Aero connectivity terminals	0.2 %	0.2 %

3.2.5 In-Space Transport Services

The in-space transport sub-category covers the transport of an object within space, either within the same orbit or between orbits. In-space transport is done by a dedicated servicer spacecraft (e.g. an orbital transfer vehicle or a space tug) or in some cases a kick stage with a specific functionality for that purpose. The sub-category includes all in-space transport service providers that serve the European market.

There are two common situations where in-space transport is required:

1) Last mile delivery: transport of objects from a launch vehicle separation to a final orbit. It is common that several satellites share a launcher, typically to an orbit dictated by the mission requirements of the principal payload of the launcher. The ridesharing smaller satellites may require further transport to their destination location. Note that the last mile delivery can include kick stages which can be reused and therefore become servicer spacecraft. The initial kick stage operation shall be allocated to the launch stage, see section 5.10 on the modelling of the kickstage. Only new operation happening after the initial operation of the kick stage is considered part of the scope of in-space transport services.

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[9] https://www.euspa.europa.eu/sites/default/files/documents/GNSS_Secure_SATCOM_User_Tech_Report.pdf

[10] Novaspace, Ground Segment Market Prospects, 2024.
Available at: https://nova.space/hub/product/ground-segment-market-prospects/

2) Transport from one location in space to another (relocation). Note that the transport can be within the same orbit or to another orbit, including the graveyard orbit.

Note that the following aspects are not within the scope of the sub-category in-space transport:

- Any transport from Earth to space and from space to Earth, including re-entry capabilities of space capsules and deorbiting to Earth of cooperative objects;
- Any transport beyond Earth orbits;
- Removal or deorbiting of space debris;
- The (first use of the) kick stage, as this is part of the launch service;
- In-orbit servicing other than in-space transport, such as inspection, repair, refuel and reconfiguration.

Examples of servicer spacecraft within the in-space transport sub-category include operational systems like D-Orbit's ION, as well as future providers such as Exotrail's SpaceVan, Redshift (RFA), and MaiaSpace's reusable kickstage. In contrast, non-reusable orbital transfer vehicles (OTVs) from launch providers (i.e. initial kickstage, e.g., ArianeGroup, Blue Origin, Firefly) and reentry-capable vehicles like The Exploration Company's Nyx or legacy cargo spacecraft such as the ATV are excluded from the scope of this sub-category and are covered by the horizontal rules.

Service spacecrafts used globally have variable designs and several different configurations. The main aspects that differentiate current service spacecrafts, as well as prospective designs by 2028, are the following:

- Single-use or multi-use
- Designed to be refuelled
- Re-entry capabilities of space capsules
- Propulsion type
- Capture or docking technology such as magnetic, robotic arms, standard interface, etc.
- Capability to provide other services or a combination of services, including life extension services such as refuelling, repair, functional upgrades, etc. (note that these services are not part of the scope of this sub-category).

The section below outlines how the RP for in-space transport services will ideally be modelled in the final PEFCR. Due to data collection constraints, the scope of the first PEF-RPs is limited. Annex 4.2 details the limited scope of the first PEF-RPs in more detail.

The RP for in-space transport is a virtual product, in order to accommodate different technologies, as no single mature service currently dominates the market. The subgroups are defined based on single-use and multi-use, as well as on different technologies, being chemical propulsion and electrical propulsion. Single use is defined as a transport system that delivers one or multiple satellites into the same orbit at approximately the same time, meaning it completes its mission in a single deployment, while a multi-use servicer would allow for deploying satellites in multiple orbits, at different times, or serving multiple missions with the same vehicle.

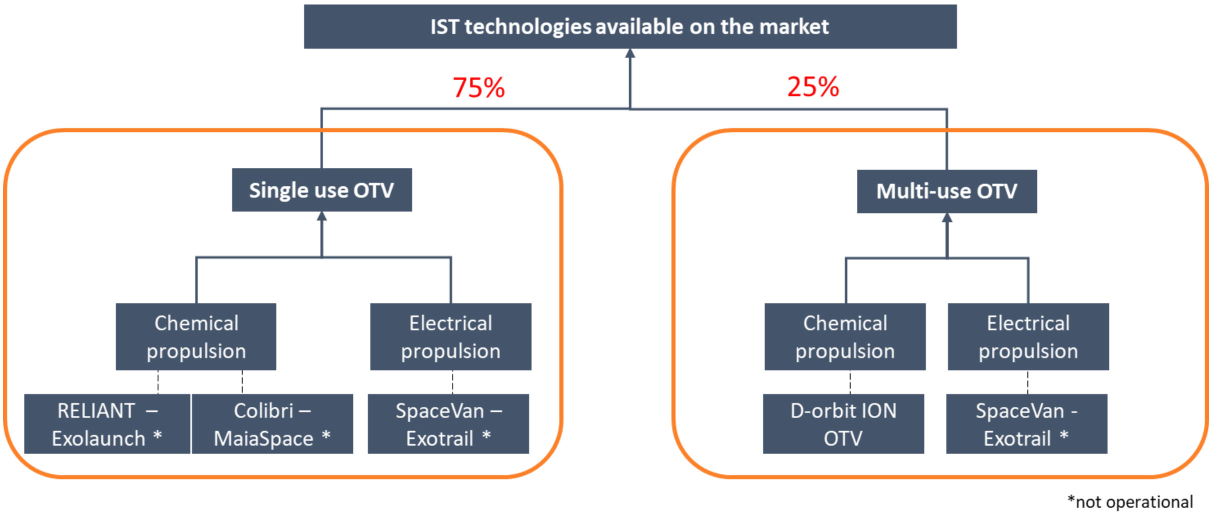

Figure 5: Overview of IST technologies providing services to the EU market.

The following assumptions have been made to define the RP and estimate the associated market shares. By 2028, single-use OTVs are expected to capture about 75% of the market, as they remain the most practical option for the dominant demand in constellation deployments thanks to their maturity, lower upfront costs, and simpler integration with launch services. Multi-use OTVs, while offering promising capabilities for servicing, repositioning, and logistics, are projected to reach only about 25%, as they still face higher costs, operational complexity, and rely on the gradual emergence of in-orbit infrastructure such as refueling hubs. In 2025, their market share is expected to remain very limited, reflecting early-stage adoption and the fact that only a few operators (e.g., D-Orbit, Exotrail) are beginning to scale reusable solutions. These figures are indicative estimates used to establish the RP and can be refined as the market evolves and as reusable technologies mature and become more widely accepted.

3.2.6 Uncrewed launch services from Earth to space

The section below outlines how the final RP for uncrewed launch services from Earth to space will be modelled. Due to data collection constrains, the scope of the first PEF-RPs is limited. Annex 4.2 details the limited scope of the first PEF-RP uncrewed launch services from Earth to space.

The uncrewed launch services from Earth to space sub-category covers the transport and release of a payload from Earth to space. The sub-category includes all global launch service providers that serve the European market in 2028.

Launchers

Launchers used globally have variable designs and configurations. A launcher consists of several stages:

- Core stage (main stage, sometimes also called ‘booster’)
- Upper stage(s) (a kick stage is also considered an upper stage)
- Strap-on booster stage (additional to the core stage)
- Payload section stage

The main factors that differentiate launchers are:

1. Number of core and upper stages (single/two/three/four or more)
2. With/without kick stage (is considered an upper stage)
3. With/without strap-on boosters
4. Engine cycle per stage (incl. nozzle)
5. Propellant type per stage and booster (incl. fuel tank, fuelling, and launch emissions)

The most representative launchers that serve the European market – based on their market share – are Ariane 6, Vega C, Falcon 9, Falcon Heavy, and several small and micro-launcher designs. Their market share is calculated by the total payload mass transported in orbit. Specifically, about 95% of the planned satellite launches by 2028 are covered by Ariane 6, Vega C, Falcon 9, and Falcon Heavy launchers. The remaining 5% of the launch services are performed by other launchers, about 2% by PSLV (medium size, India based), 2% by Spectrum (small size, Germany based), 1% by RFA One (small and micro size, Germany based), and other launchers (see Figure 6). These data reflect only the European companies/ organisations/ countries that have defined and communicated their launch provider (Novaspace, 2024).

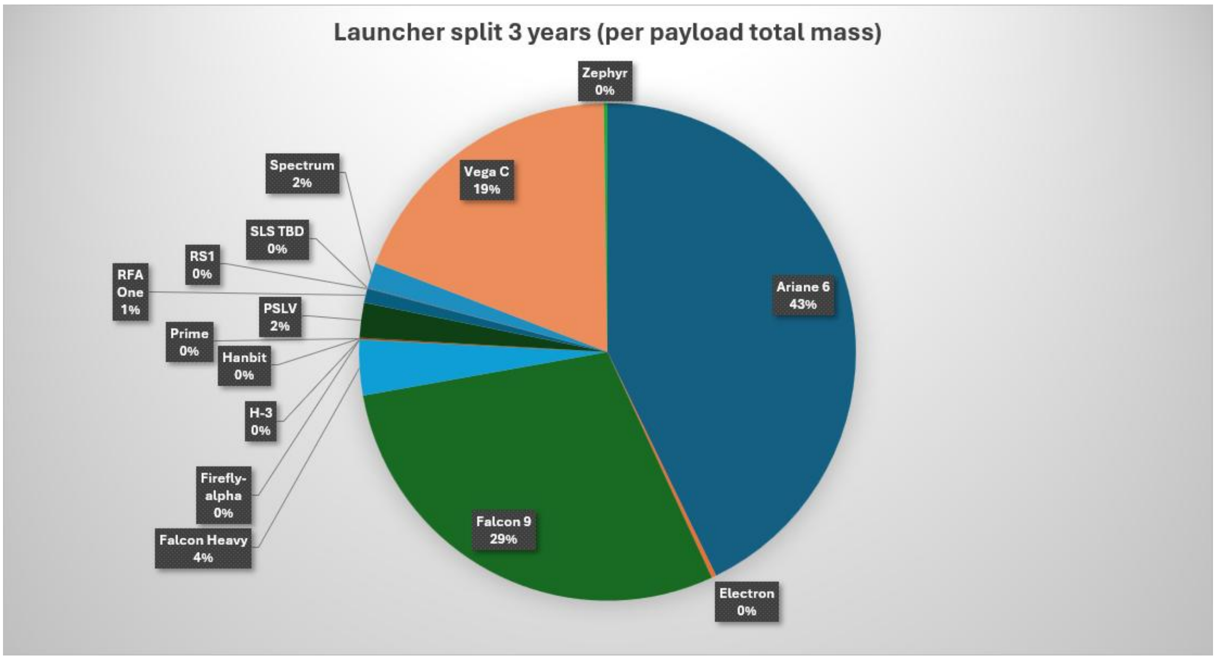

Figure 6: Market share of different launcher providers, per payload total mass, by 2028, for the operators that have publicly reported their launch service provider (Novaspace, 2024).

The main factors of the different types of launchers and their expected market share in 2028 are summarized in Table 10.

Table 10: Main factors of the different launchers and their expected market share (based in total payload mass transported in orbit) by 2028. When multiple options are available, market shares of the different options are provided within brackets.

	Ariane 6	Vega C	Falcon 9	Falcon Heavy	Small/ Micro launchers [3]
Market shares in 2028	43%	19%	29%	4%	5%
Number of stages (core and upper)	Two	Four (including kick stage)	Two	Two	Two (three if includes a kick stage)
With or without kick stage	Without	With	Without	Without	With or Without
With or without strap-on boosters	2 boosters or 4 boosters	Without	Without	2 boosters	Without
Engine cycle per stage (S) [1]	S1: Vulcain engine; Gas generator /open cycle S2: Vinci engine;	S1: Solid S2: Solid S3: Solid	S1: Gas generator S2: Gas generator	S1: Gas generator S2: Gas generator	S1: Gas generator S2: Gas generator

	expander /closed cycle	S4: Pressure fed/ closed cycle			
Propellant per stage (S) or booster (B) [2]	S1: LOX/LH2 (6.03) S2: LOX/LH2 (6.1) B: 19% aluminium powder, 69% ammonium perchlorate, 12% hydroxyl terminated polybutadiene binder	S1-S3: 19% aluminium powder, 69% ammonium perchlorate, 12% hydroxyl terminated polybutadiene binder S4: N2O4/UDMH 2:1	S1: LOX/RP-1 (2.36) S2: LOX/RP-1 (2.375)	S1: LOX/RP-1 (2.36) S2: LOX/RP-1 (2.375) B: LOX/RP-1 (2.36)	S1: LOx/LCH4 S2: LOx/LCH4 S3: Ethanol/ H202

[1] The engine cycle is only relevant to liquid or hybrid propulsion and is differentiated as: electric-fed, open cycle (gas generator, expander, tap-off), closed cycle (expander, stage combustion partly flow, stage combustion full flow, pressure-fed).
[2] The amount of propellant per kg of payload differs per destination orbit – see later in this section. Numbers in brackets next to the propellant type indicate the mixing ratio.
[3] Represented by Maiaspace

The representative product is a virtual average product that is calculated based on the market share of the different launchers as defined in Table 10. The RP is illustrated in Figure 7.

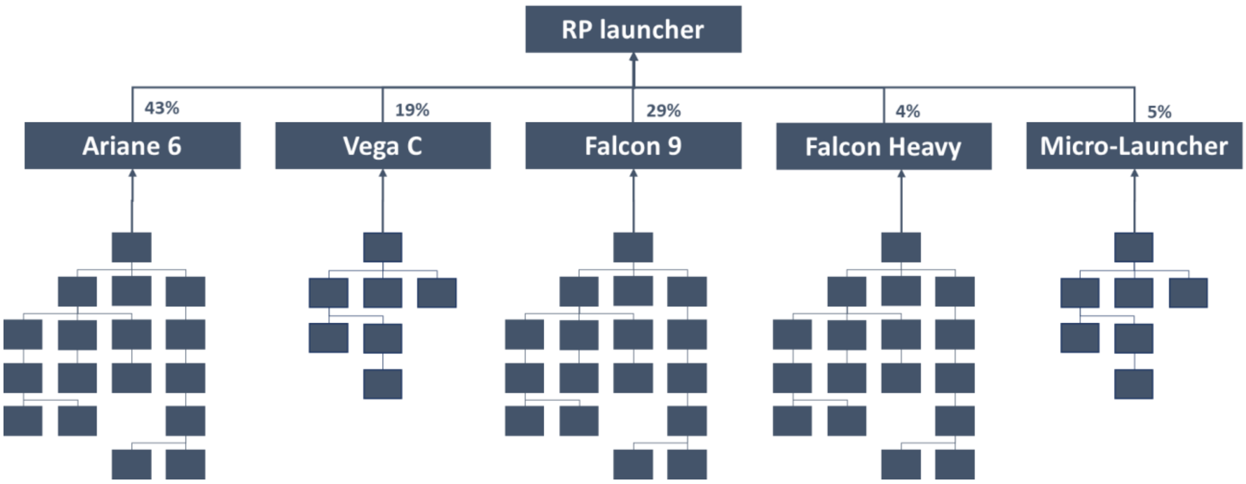

Figure 7: Representation of the representative product for uncrewed launch services from Earth to space

Reusability

Some equipment or subsystems of the launcher are reusable (e.g., a core stage of a launcher that is landed/recovered in order to be reused). The high level information of the parts of the launcher that are reusable is provided per launcher and main component in Table 11. If a component is reusable, the number of reuses is provided within brackets.

Reusability[11] is defined per stage as:

- **Expendable stage**: non-reusable stage
- **Partially reusable stage**: includes change of subsystems; i.e., ***some*** subsystems are reused with the replacement of some equipment, while some subsystems are non-reusable and are fully replaced.
- **Fully reusable stage**: includes only inspections and change of ***some*** equipment (e.g., new lighters for the engines); i.e., ***all*** subsystems are reused, and some equipment is reused, while some equipment is non-reusable and is replaced.

Table 11: Reusability of launcher components.

Components – high level	Ariane 6	Vega C	Falcon 9	Falcon Heavy	Small/ Micro launchers [1]
Stages (S)	Expendable	Expendable	S1: reusable S2: expendable	S1: expendable S2: expendable	S1: reusable S2: expendable
Kick stage	Expendable	Expendable	N/A	xxx	Reusable
(Strap-on) boosters	Expendable	N/A	N/A	Reusable	N/A
Fairing	Expendable	Expendable	Expendable	Expendable	Expendable

[1] Represented by Maiaspace

For reusable launchers, additional data on the number of reuses of various subsystems and equipment will be collected via a data collection template. The reusability information is used when calculating the reference flow.

Propellant

Each launcher stage or booster uses a specific propellant as defined earlier. For each stage and booster there is a fuel tank related to the propellant type used. Each propellant, including its fuel tank, fuelling emissions, and launch emissions, is thus launcher-specific. There are three different propellant types: solid, liquid and hybrid. Where RP1 stands for Rocket propellant, being refined kerosine:

[11] In general, for launch systems, "partially reusable" means that only certain stages can be reused, while "fully reusable" implies that all stages are reusable. In the PEFCR, we take this a step further by defining reusability at the individual stage level.

- Solid: APN/Al/HTPB
- Liquid: LH2/LOx, CH4/LOx, Propane/LOx, RP1/LOx, RP1/HTP, UDMH/NTO (N2O4), MMH/NTO (N2O4)
- Hybrid: Paraffin/LOx, HTPB/LOx, Polymer/LOx, Paraffin/N2O, HTPB/N2O, Polymer/N2O

The amount of propellant is launcher-specific. The launcher fuelling emissions and the launch emissions scale linearly to the amount of propellant. The launch emissions from propellant usage are calculated per launcher for each reference ΔV, then averaged according to the market share of different launchers. The ΔV (delta V) represents the velocity a payload requires to reach a designated orbit. Four different reference ΔVs are defined in km/sec – the detailed definition is provided in section 3.3.6 on the functional unit. In the case a launcher does not reach a specific ΔV, then zero-percent market share will be assumed for that ΔV, for that specific launcher. The amount of propellant is always the same, independently of the ΔV, since it is launcher-specific. What changes per ΔV is the total payload mass that can be sent to orbit. The propellant amount as well as the payload mass per reference ΔV per launcher is collected via the data collection template.

The PEF profile will be calculated for the RP per ΔV. Four benchmark results will be provided, one for each ΔV. The user of the PEFCR shall compare their results with the respective results of the reference ΔV that is applied to their launcher.

3.3 Functional unit and reference flow

[The PEFCR shall describe (i) how each aspect of the functional unit affects the environmental footprint of the product, (ii) how to include this effect in the EF calculations and (iii) how an appropriate reference flow shall be calculated. Furthermore, the PEFCR shall explain and document any omission of the functions of the product in the definition of the functional unit and justify why. In case calculation parameters are needed, the PEFCR shall provide default values or shall request these parameters in the list of mandatory company-specific information. A calculation example shall be provided].

The functional unit (FU) for space activities delivered to EU stakeholders is to provide one space-based service, with a prescribed duration, goal and well-defined quality. The four key elements covered by the functional unit are specified further in Table 12. The quality of the service may be defined by considering the requirements of the space-based service or mission requirements.

Table 12: Key Aspects to define the Functional Unit (FU)

What?	A space-based service with a prescribed goal
How much?	1 service
How well?	With a defined quality
How long?	Over the duration of the service provided

The reference flow is the amount of product (being space craft or launcher) required to fulfil the defined function and shall be measured in kg of spacecraft/ launcher. All quantitative input and output data collected in the study (e.g., manufacturing activities, infrastructure, use or end of life activities) shall be calculated in relation to this reference flow. In practice, the easiest is to model the life cycle of the entire spacecraft or launcher (according to the system boundaries of section 3.4) over its entire lifetime, covering its entire service provided. While the reference flow calculates the amount of spacecraft or launcher required, the same denominator is used to scale all life cycle stages (including use and end of life) towards the FU (this is also explained in the respective life cycle sections). For spacecraft and launchers, the "total dry mass" shall be used. This is defined as the mass of spacecraft or launcher excluding propellant or other consumables (such as pressurants).

To calculate the amount of spacecraft or launcher needed for the functional unit, being one service delivered, the following formula shall be used:

$$Dry\ mass\ of spacecraft/launcher\ required\ (in\ kg/FU) = \frac{Total\ dry\ mass}{\#\ Services\ provided_{LT}}$$

Where:

- "Total dry mass" refers to the mass of spacecraft or launcher excluding propellant or other consumables (such as pressurants).
- "# Service provided$_{LT}$" relates to the amount (or number) of service(s) provided by the spacecraft or launcher during its lifetime. For spacecrafts, the lifetime is defined as the design service lifetime from the moment reaching its destination orbit (excluding the time needed to reach the orbit) and is defined by the manufacturer of the spacecraft. For launchers this is defined as the time that the launcher is providing its actual service (including reusability). For the defined sub-categories more details are provided below.

[Shall the life time of the mission only be based on the service lifetime, or also consider the reliability of the mission and probability that the satellite is still functional at end of life? This could be added as a multiplication factor to the service lifetime. However, if considered, how shall this reliability factor be calculated? Input on (i) is this important to consider and (ii) how shall it be measured, is welcome during the open consultation.]

In case the spacecraft or launcher provides multiple service types, an allocation to the specific service in scope is required. Section 5.7 provides more details on the different allocation rules to be followed.

For the sub-categories, Table 13 and Table 14 provide the relevant functional units and reference flows.

Table 13: Functional units per sub-category

Sub-category	**Functional unit per sub-category**
Earth observation	To generate 1 GB of raw Earth Observation data, as prepared for transmission to Earth, as measured before any on-board processing excluding compression, measured at spacecraft sensor level, relevant to the scope of the mission, with a defined accuracy, resolution and revisit rate.
Position Navigation and Timing	To send/receive PNT as open service, with a minimum availability* of 90% under clear sky condition, over one year with a minimum horizontal location accuracy of 15 m, vertical location accuracy of 7.5m and with a time accuracy of minimum 31 Nsec.
Satellite video	To receive 1Mbps of broadcast services over 100km^2, at a min. availability** of 99.7% under clear sky conditions, over one year.
Satellite connectivity	To exchange 1 Mbps of data at min. availability** of 99.5% under clear sky conditions, over one user terminal over one year. [Proposed FU is: To uplink/downlink data within a (pre-defined) default demand scenario, per user terminal with a default user profile, at a minimum 99.5% availability under clear sky condition, over one year. Please See Chapter 3.6.4 for more information.]
In-space transport services	To transport 1 kg of cooperative object in space by providing a certain ΔV, with a defined precision.
Uncrewed launch services from Earth to space	To transport and release 1 kg of payload in orbit at certain ΔV, for 1 launch, at a defined minimum safety and precision.

*Availability of X% for PNT signal: The UTC Time Dissemination Service Availability is defined as the percentage of time during which a user can access a healthy signal that enables accurate estimation of Coordinated Universal Time (UTC) under normal operating conditions (definition taken from Galileo Open Service - Service Definition Document, Issue 1.3 (OS SDD), European Commission, 2023)

**Availability of X% for Sat.com (video and connectivity) signal: The availability % represents the design yearly availability of the end-to-end service calculated from link margin in clear sky conditions.

The reference flows presented above shall be used to scale the entire life cycle of the spacecraft to the common Functional Unit. This also includes all ground infrastructure needed to serve the spacecraft over its entire lifetime. The modelling of each life cycle stage shall be performed, as described in Section 0. The modelled impact for the entire life time of the spacecraft will then be divided back to the functional unite via the reference flow. This way, not only the spacecraft itself, but all other activities during the distribution and use (such as the supporting ground infrastructure) is scaled to the desired functional unit.

[Are the defined Functional Units and reference flows correct, understandable and reproducable?]

Table 14. Reference flows per sub-category.

Sub-category	**Dry mass of spacecraft or launcher required (in kg/FU)**	**Parameters used**
Earth observation	$\frac{Total\ spacecraft\ dry\ mass\ (in\ kg)}{(Total\ raw\ data\ generated\ over\ design\ service\ lifetime\ )}$	Total raw data generated (in GB) Design service lifetime (in years)
Position Navigation and Timing	$\frac{Total\ spacecraft\ dry\ mass\ (in\ kg)}{(Design\ service\ life\ time\ )}$	Design service lifetime (in years)
Satellite video	$\frac{100\ km^2 \times Total\ spacecraft\ dry\ mass\ \ (in\ kg)}{(Design\ service\ lifetime\ \times\ Sum\ of\ beam\ coverage \times Total\ capacity)}$	Design service lifetime (in years) Sum of beam coverage (in km²) Total capacity (in Mbps)
Satellite connectivity	$\left(\frac{Total\ spacecraft\ dry\ mass\ (in\ kg)}{(Design\ service\ lifetime \times maximum\ useful\ capacity \times user\ terminals)}\right)$ * scaling factor [Proposed Ref Flow is: (Dry mass / (lifetime * user terminals (default demand))) * Scaling factor Please See Chapter 3.6.4 for more information.]	Design service lifetime (in years) Maximum useful capacity (in Mbps) User terminals (in #pieces)
In-space transport services	$\frac{Total\ servicer\ spacecraft\ dry\ mass\ (in\ kg)}{Total\ effective\ capacity\ (in\ kg)}$	Total effective capacity (in kg)
Uncrewed launch services from Earth to space	$\frac{Launcher\ reusable\ stages\ (in\ kg) + Launcher\ expendable\ stages\ (in\ kg)}{Payload\ (kg)}$	Launcher reusable stages (in kg) Launcher expendable stages (in kg) Payload (in kg) See section 3.3.6 for detailed calculation.

3.3.1 Earth Observation Services

The functional unit (FU) for the Earth Observation Services is to generate 1 GB of raw Earth Observation data, as prepared for transmission to Earth, as measured before any on-board processing excluding compression, measured at spacecraft sensor level, relevant to the scope of the mission, with a defined accuracy, resolution and revisit rate.

Note: The scope is to generate raw Earth Observation data, level 0 (L0) data processing, hence excluding products derived from Earth observation data and associated value-added services. The system boundaries are reached once the data is generated, before it is transmitted to Earth. The downlink to Earth, storage and additional processing of the data on Earth are not included in the functional unit but will be accounted for in the impact of the Earth Stations. At the Earth Station, the data considered is the total GB of raw Earth Observation data, as prepared for transmission to Earth after any on-board processing (including compression).

Table 15. Key Aspects to define the Functional Unit (FU) of Earth Observation Services

What?	To generate raw data
How much?	1 GB of raw Earth Observation data, as prepared for transmission to Earth, as measured before any on-board processing excluding compression, measured at spacecraft sensor level, relevant to the scope of the mission, with a defined accuracy, resolution and revisit rate
How well?	With a defined accuracy
How long?	The required duration of the service

Relevant to the mission's scope is defined as the raw Earth Observation data collected by the spacecraft sensor that directly supports the mission's intended objectives. This includes capturing the right type of information (such as land, ocean, or atmospheric data), using the appropriate sensor if specified, and covering the correct areas at the required times. The data must meet the mission's specifications for resolution, accuracy, and revisit rate, ensuring it is suitable for the mission's planned applications, even if further processing happens later on the ground. Data related to the TM/TC transmissions, manoeuvrers instructions or any other spacecraft operations related activities is excluded.

The **resolution** is defined as the spatial resolution when applicable, expressed as the Ground Sample Distance (GSD) — the smallest unit that maps to a single pixel within an image. This applies to both horizontal and vertical resolutions (e.g., for an altimeter). Resolution should be expressed in meters unless the sensor is a sounder, in which case it should be given as a concentration level (e.g., in parts per million (ppm)).

The **accuracy** refers to the absolute accuracy relative to a fixed reference point, such as a Ground Control Point (GCP). It is measured in terms of deviation, such as Circular Error 90% (CE90). If the measurement is taken on the ground, it is defined as geolocation accuracy. Accuracy should be expressed in the same unit as the resolution.

The **revisit rate** is the frequency at which a system passes over and observes the same location. The average time interval between consecutive observations of the same point within the defined area of interest under nominal operating conditions at a zero off-nadir angle, is typically measured in days or hours, depending on the system's orbit and constellation size.

A scaling factor is required to calculate the amount of spacecraft delivering EO services to the level of the functional unit, being a EO service fulfilling the minimum requirements of the FU, being 1 GB of raw Earth Observation data, as prepared for transmission to Earth, as measured before any on-board processing excluding compression, measured at spacecraft sensor level, relevant to the scope of the mission, with a defined accuracy, resolution and revisit rate. The following formula shall be used:

$$Dry\ mass\ of\ spacecraft\ required\ (in\ kg)\ to\ generate\ 1\ GB\ of\ raw\ data = \frac{Total\ spacecraft\ dry\ mass\ (in\ kg)}{(Total\ GB\ generated\ over\ service\ lifetime\ )}$$

Where:

The "Total GB over service lifetime" is defined as the total amount of raw data that is produced by the spacecraft, over its total service lifetime. The effects of compression or any other data processing performed either onboard the satellite or on the ground, are considered at the ground infrastructure level, not at the satellite level.

The Functional Unit is defined as the volume of raw Earth Observation data (Level 0) in gigabytes (GB), measured prior to any onboard processing, including compression.

At the ground level, however, the total data volume refers to the data as prepared for downlink—i.e., after onboard processing and compression—and includes all storage and processing operations up to, but excluding, Level 3 (L3) products. All associated ground-based resources required to achieve this level of processing must be accounted for. Further details will be provided in the dedicated section on the Payload data ground segment Section 6.6.1.4.

Table 16: Definition of the different processing levels – NASA EOSDIS

Level	Description
L0	Raw satellite data with communication noise removed. Still unprocessed.
L1A	Reformatted raw data with time stamps and extra info like calibration and location references.
L1B	Calibrated data — sensor readings are converted into physical units (like brightness).
L1C	L1B data with added variables to explain how the data was modified or copied. More traceable.
L2	Data converted into actual physical values (e.g., temperature, gas levels).
L2A	Extra info from raw sensor data — like ground elevation or surface metrics from waveforms.
L2B	Processed version of L2A — not always available for every instrument.
L3	L2 data organized onto consistent grids (by time and space) for easier use.
L4	Modeled or interpreted data using lower-level data (e.g., forecasts or trends).

3.3.2 Positioning, Navigation and Timing Services

The functional unit (FU) for PNT services is to send / receive PNT as open service, with a minimum availability of 90% under clear sky condition, over one year with a minimum horizontal location accuracy of 15 m, vertical location accuracy of 7.5 m and with a time accuracy of minimum 31 Nsec. The four key elements covered by the functional unit are specified further in Table 17.

The minimum values are taken from table 21 of the Galileo Open Service - Service Definition Document, Issue 1.3 (OS SDD) (European Union, 2023).

Table 17. Key Aspects to define the Functional Unit (FU) of PNT Services.

What?	To send/receive PNT signal as open service
How much?	At min. 90% availability under clear sky conditions
How well?	At min.15 m horizontal location accuracy, 7.5 m vertical location accuracy and min. 31 Nsec time accuracy
How long?	Over one year

The functional unit is restricted to 'Open Services' meaning that services other than the open positioning, navigation and timing services are excluded (see RP description).

For PNT services, data quantity is not a key parameters, where availability is. Availability is therefor used to define ‘How much?’ in the functional unit.

The user of the PEFCR needs to ensure that the PNT services delivered are designed for a minimum availability of 90% under clear sky conditions, a horizontal location accuracy of 15 m, vertical location accuracy of 7.5 m and a minimum time accuracy of 31 Nsec. If the product in scope delivers a PNT service below these design values, a PEF-study cannot be performed.
Service availability, location accuracy (horizontal and vertical) and time accuracy shall be defined according to the Galileo OS SDD definition (as described in European Union, 2023). The user of the PEFCR shall declare the design values as additional technical information (see section 3.6.2).

A scaling factor is required to calculate the amount of spacecraft delivering PNT services to the level of the functional unit, being a PNT service fulfilling the minimum requirements of the FU delivered over one year. By including these minimum requirements in the functional unit, systems fulfilling the requirements can be compared. Indeed, for open services, there is no need to increase availability, time accuracy and location (horizontal and vertical) accuracy above the defined minimum levels. To calculate the reference flow, the following formula shall be used:

$$Dry\ mass\ of\ spacecraft\ required\ (in\ kg/FU) = \frac{Total\ spacecraft\ dry\ mass\ (in\ kg)}{design\ service\ life\ time\ (in\ years)}$$

Where:

- For “design service lifetime” (in years) see the horizontal rules above.

3.3.3 Satellite Video Services

The functional unit (FU) for satellite video services is to receive 1 Mbps broadcast services over 100 km^2, over one year, at a minimum 99.7% availability under clear sky condition. The four key elements covered by the functional unit are specified further in Table 18.

Table 18. Key Aspects to define the Functional Unit (FU) of Satellite Video Services.

What?	To receive broadcast services
How much?	1 Mbps over 100 km^2
How well?	At minimum 99.7% availability, under clear sky conditions
How long?	Over one year

[We propose the following change and welcome any feedback: for the “how much”: 1 Mbps over 100 km^2 (with 210 user terminals)]

In this Functional Unit, a 100 km^2 average European area is included to ensure comparability of the user density. The 100 km^2 reference area is assumed to cover a European average density of 210 users and thus user terminals. For the assumptions and calculations, please see Chapter 6.6.3.4.

Definition of Video service availability of 99.7%: The availability figure represents the yearly design availability of the end-to-end Satellite communication service calculated from link margin in clear sky conditions. The availability shall include the earth stations and the satellite.

The user of the PEFCR needs to ensure that the video service delivered is designed at a minimum availability of 99.7% under clear sky conditions. If the product in scope delivers a video service below this design availability, the PEF-study performed is not in compliance with this PEFCR.

To calculate the amount of satellite needed to deliver the functional unit, being one Mbps over 100km^2, the following reference flow shall be used:

Drymass of Spacecraft required (in kg/FU):

$$\frac{100\ km2\ x\ total\ dry\ mass\ spacecraft}{(Design\ service\ lifetime\ X\ sum\ of\ beam\ coverage\ x\ total\ capacity)}$$

Where:

- For „design service lifetime” (in years) see the horizontal rules above.
- The “sum of beam coverage” (in km^2) is defined as the total area covered by all satellite beams to the total ground area on Earth that a satellite’s beam can cover. See instructions for calculation below.
- The “total capacity“ (in Mbps) is defined as the maximum data throughput (in Mbps) the satellite can deliver across all beams. See instructions for calculation below.
- The total spacecraft (in kg), calculated in dry mass.

Calculate sum of beam coverage:

The total sum of beam coverage in km^2 is the sum of the surface expressed in km^2 at the level of Earth for each beam of the satellite providing video services.

Calculate total capacity:

The total capacity shall be calculated as the sum of all beams capacity considering the bandwidth per beam (in Mhz) multiplied by average spectral efficiency on a per beam basis (in Mbps/Mhz). The result shall be in Mbps.

[The instructions to calculate the "sum of beam coverage" (in km2) and "total capacity" (in Mbps) seem difficult and insufficient. Please provide further inputs on how the user shall calculate it, so that comparability across the systems can be ensured.]

3.3.4 Satellite Connectivity Services

[The section of Functional unit, reference flow, and the required default demand scenario are still under discussion. Suggestions, corrections and proposed default values are highly welcomed during the open consultation.]

The functional unit (FU) for satellite connectivity services is to exchange 1 Mbps of data over one user terminal, at a minimum 99.5% availability under clear sky condition, over one year. The four key elements covered by the functional unit are specified further in Table 19.

Table 19. Key Aspects to define the Functional Unit (FU) of Satellite Connectivity Services.

What?	To exchange data
How much?	1 Mbps over one user terminal
How well?	At min. 99.5% availability under clear sky conditions
How long?	Over one year

[We propose the following changes: The "What" to be: To uplink/downlink data within a (pre-defined) default demand scenario. The "how much" to be: 1 user terminal with a default user profile. Please read the entire section before providing inputs.]

Definition of connectivity service availability 99.5%: The availability figure represents the yearly design availability of the end-to-end Satellite connectivity service calculated from link margin in clear sky conditions. The availability calculation shall include the earth stations, the satellite and the user satellite terminal.

The user of the PEFCR needs to ensure that the connectivity services delivered are designed at a minimum availability of 99.5% under clear sky conditions. If the product in scope delivers a connectivity service below that design availability, the PEF-study performed is not in compliance with this PEFCR.

As the FU for connectivity is per user terminal, comparability must be ensured between assessments. To achieve that, a default demand scenario is to be applied to make sure that the system under study fulfils the required capacity to reach the pre-defined user terminals over Europe, with a pre-defined user pattern (on level of Mbps and timing online/offline). This alignment is being achieved via a scaling factor, which is included in the reference flow. It serves the purpose of scaling the system under study to match a default demand. The default demand scenario is explained below. For more information on the user terminal modelling, please see Chapter 6.6.4.4.

To calculate the amount of satellites needed to deliver the functional unit, being 1 Mbps of data exchanged per user terminal, the following reference flow shall be used:

Dry mass of Spacecraft required (in kg/FU):

$$\left(\frac{Total\ dry\ mass\ spacecraft}{(Design\ service\ lifetime\ x\ maximum\ useful\ capacity\ x\ user\ terminals)}\right) * \text{scaling factor}$$

[The formula above is still under discussion. (i) First the scaling factor shall be applied to scale the satellite system to an equivalent default demand scenario (which reflects the distribution of the users and user profile to be reached). (ii) Once the satellite system is scaled it shall be referenced to a FU. We propose to remove the “maximum useful capacity” from the denominator of the reference flow formula as it seem to lead to double counting. The satellite system should have be based on its own maximum useful capacity and user terminals in step (i). The number of user terminals used in the denominator shall be then derived from the default demand scenario.

[We propose the following changes: Dry mass of Spacecraft required (in kg/FU):

$$\left(\frac{Total\ dry\ mass\ spacecraft}{(Design\ service\ lifetime\ x\ user\ terminals\ (from\ default\ scenario))}\right) *\ scaling\ factor\ ]$$

Where:

1. For “design service lifetime” (in years) see the horizontal rules above.

The “maximum useful capacity“ (in Mbps) is defined as the maximum amount of Mbps that are effectively delivered to the end users. Relevant core concepts are [Might be revised]:

2.
    - Total Raw Capacity (TRC): The maximum data throughput a connectivity satellite can technically deliver across all beams and frequencies under ideal operating conditions (measured in Mbps or Gbps).
    - Maximum useful capacity (MUC): The proportion of TRC that is effectively delivered to actual end-user, accounting for real-world constraints like demand distribution, interference, and protocol overhead.
    - Filling ratio (FR): Also known as the utilization ratio, it quantifies how much of the total raw capacity is “filled” with useful traffic. A low filling ratio, even with a high TRC, signals that the satellite’s potential isn't optimized — often due to inefficient dynamic beam management, demand mismatch, or operational constraints. FR = MUC / TRC
3. The “user terminals” (in pieces) refer to the amount of user terminals reached by the maximum useful capacity delivered. [Might be revised]
4. The total spacecraft (in kg), calculated as dry mass.
5. The scaling factor is used to scale the system of the user to comply with a default demand scenario (in terms of capacity and users reached), as explained below.

[The instructions to calculate the "maximum useful capacity" (in Mbps) seems difficult and insufficient. Please provide further inputs on how the user shall calculate it, so that comparability across the systems can be ensured. Even in the case of revision of the text above, the maximum useful capacity is needed to calculate the scaling factor.]

Default demand scenario for connectivity

To create a common baseline and enable comparability across connectivity systems, a default demand scenario is provided, in terms of demand volume, distribution, and amount of user terminals, over Europe (See Figure 8). This scenario shall be used to calculate a scaling factor to scale one's own system to complying with the default demand scenario. This step is important to enable comparability between different satellite systems with varying degrees of flexibility[12] in the calculations. Flexibility can be managed differently by the systems and for example implies active antennas with on-board processing, instead of passive antennas. They can however respond flexibly and therefore cover demand where needed. Time dynamism[13] capability of a satellite system is excluded from this computation.

[12] Flexibility refers to a satellite's ability to reconfigure its capacity allocation, frequency, and coverage zones during its lifetime, by e.g., shifting bandwidth between beams, changing coverage areas, adjusting frequency plans etc. This is usually pre-programmed or reconfigured on command, not in real-time.
[13] Dynamism in turn refers to a satellite's ability of real-time or near-real-time reallocation of resources based on actual traffic demand and network conditions, e.g., adapting coverage and capacity instantly, responding autonomously to demand spikes, optimizing resource use continuously.

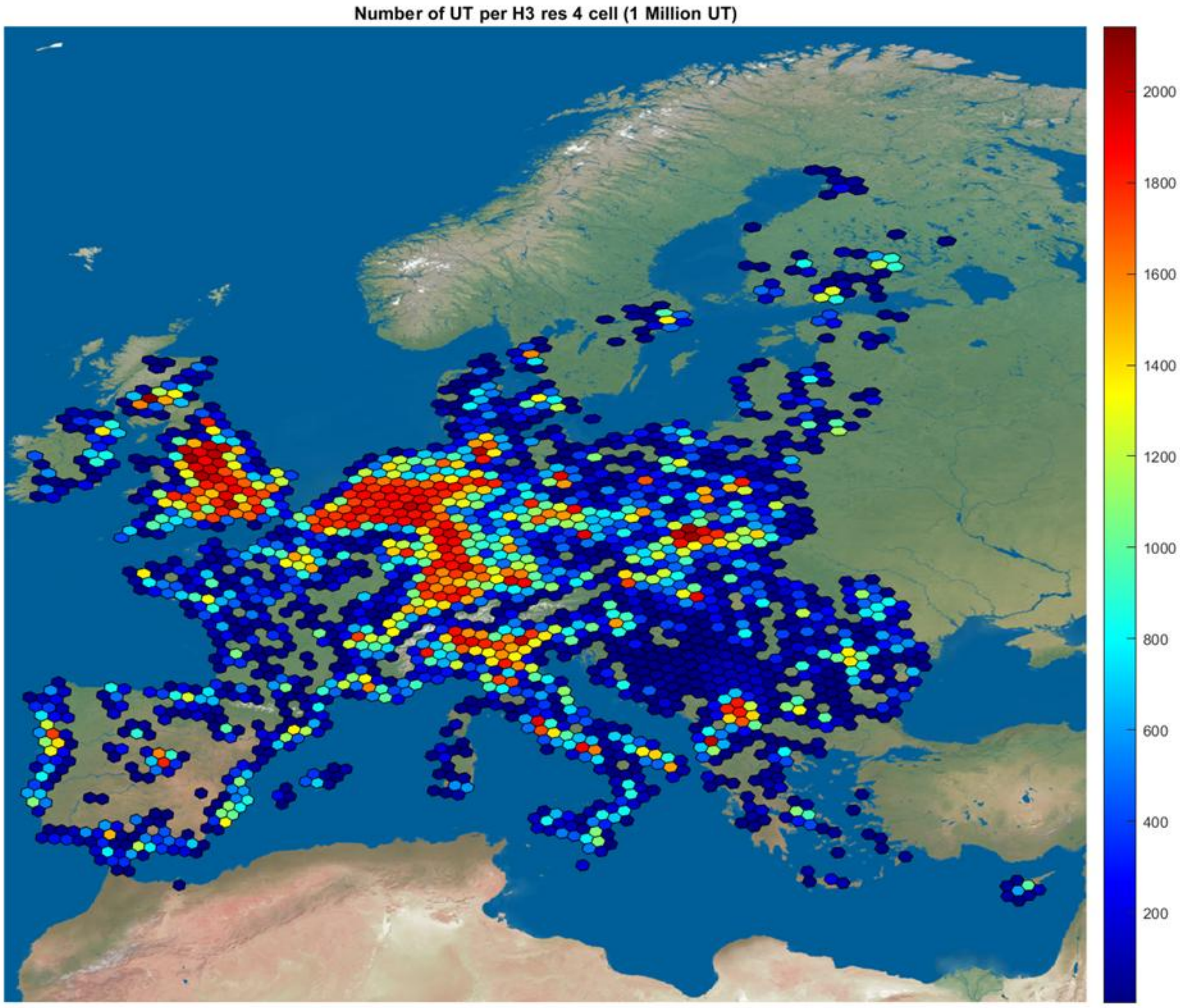

Figure 8. Default Distribution of User Terminals (UT) for satellite connectivity services in Europe, NOVASPACE 2025.

The default demand scenario map (Figure 8) is based on the following elements:

- The population density over Europe in 2025.
- For the highest population density areas, high urban density areas, a cap at 3000 inhabitants/km² has been set.
- Scaling this, we obtained a density map, in which 1 million user terminals are distributed over Europe. This forms the amount of default terminals to be served and used in the reference flow.
- The assumed default capacity per user terminal in 100 Mbps downlink and 20 Mbps uplink.
- The assumed default user profile is 0.25 hrs/day upload, 2 hrs/day download, and 21.75 hrs/day standby.

- This representation is based on the use of the H3[14] cell model.

Calculating the scaling factor to serve the default demand scenario

Formula: Scaling factor = Company user demand provision / reference default demand scenario

The total raw capacity (in Mbps) of the user's own system shall be computed for each beam, by multiplying the bandwidth (in MHz) per beam by the spectral efficiency (in bps/Hz). The calculated raw capacity per beam shall be summed up to obtain total maximum theoretical raw capacity provided by the satellite system (in Mbps).

To determine the maximum useful capacity of the satellite system under study that can serve the default demand scenario, the user of the PEFCR shall first map the satellite's actual geographical coverage and beam layout against the default European demand map provided above. The default amount of user terminals is 1,000,000 and the default assumed data rate per user terminal is 100 Mbps downlink and 20 Mbps uplink.

Then, for each satellite or constellation of satellites, calculate the portion of its raw capacity that overlaps with regions of actual demand. If the satellite can flexibly steer beams, adjust the beam placement within its technical constraints to match the default demand. The Maximum Useful Capacity is the sum of all capacity segments that can be realistically redirected or allocated to European demand regions, factoring in beam footprints, spectrum reuse, steering limits, regulatory constraints, etc. The maximum useful capacity that can be (re)directed to serve the default demand scenario above shall be used in the reference flow to scale to the functional unit of 1 Mbps. The amount of user terminals that can be reached by the user's own system shall be used in the reference flow.

The user shall, based on its own maximum useful capacity and reached user terminals, ensure that the user demand scenario can be met. If it cannot be met, e.g. either capacity and/or reached user terminals are below the demand scenario, a scaling factor shall be applied in the reference flow to scale one's own system to be compliant with the default demand scenario. For this, the maximum scaling factor shall be applied.

Example: the user's own system can serve 90% of the required capacity from the default demand scenario, and 95% of the required user terminals in the right regions, the user shall apply the larger scaling factor, e.g. here divide the reference flow by 0.9 (as serving 90% of the demand is lower than 95%, thus the system needs to be scaled more to comply).

[14] H3 is a discrete global grid system for indexing geographies into a hexagonal grid, developed at Uber. Coordinates can be indexed to cell IDs that each represent a unique cell. Indexed data can be quickly joined across disparate datasets and aggregated at different levels of precision.

[(1) Default demand scenario: The intention of the default demand scenario is to enable comparability on the level of per user terminal with a default demand. The user shall assess its own's system capabilities in terms of 1. Useful capacity, 2. User distribution, and 3. Datarate online/offline to the default scenario. This scaling factor serves the purpose to make sure that the system under study fulfils the required capacity to reach the pre-defined user terminals over Europe with the pre-defined user pattern (on level of Mbps and timing online/offline). The default demand scenario has not been finalized, due to the absence of data. A default user density map is required. If this is not available, we propose to contintue with an average European user density of 0.2 users / km2 as a pan-European average density. This assumption is based on 4.47 million km2 European land, and 1000000 user terminals.
Please provide inputs on the default demand scenario, its assumptions (such as average user density), and the default density map.

(2) Reference flow implication: Today there is a double counting in the reference flow formula, in regards to the max. useful capacity, user terminals, and the scaling factor (in the light of FU to be achieved). Once the scaling factor allows to scale the entire service to a default demand scenario, then we can express the scaled service per user terminal, thus converting it to the FU. Today, the division by max. useful capacity and user terminals next to the scaling factor leads to double counting. If the demand scenario manages to achieve its purpose for comparison, we propose to remove the maximum useful capacity from the formula. Please provide inputs.

(3) Functional unit implication: the „What": should be from the user perspective, and thereby needs to reflect a default user profile in Europe (See reference default demand scenario above). For the „What", we therefore propose: „To Uplink/downlink data withing a (pre-defined) user density scenario". The „how Much" – in this light would not be 1 Mbps, but „1 user terminal with an average profile". Please provide inputs.]

3.3.5 In-Space Transport Services

The functional unit (FU) for in-space transport is to transport 1 kg of cooperative object in space by providing a certain ΔV, with a defined precision.
Note: The scope is the transportation of cooperative objects within space. It starts after spacecraft deployment once the launcher has detached, and the spacecraft will be transported by an in-space servicer spacecraft. The use phase of the servicer spacecraft starts after its deployment from the launcher. Rendezvous and docking are included, if necessary to provide the transportation services, for example during relocation of an object. The scope is limited to the transport of cooperative objects only. Space debris removal activities and de-orbiting of cooperative spacecrafts are explicitly excluded from this sub-category and are covered by the horizontal rules in this PEFCR. Other in-space services such as refuelling and repair, are not included in the scope of this sub-category.

Table 20. Key Aspects to define the Functional Unit (FU) of in-space transport

What?	To transport a cooperative object in space by providing a certain ΔV
How much?	1 kg
How well?	With a defined precision
How long?	The required duration of the transport

Precision is determined by the percentage deviation from the target orbit. It combines both altitude and inclination deviations to provide a single metric representing orbital accuracy. It is defined as:

$$Deviation\ from\ main\ target\ orbit(\%) = \frac{\sqrt{0.1 * \left(\frac{\Delta a}{atarget}\right)^2 + 0.9 * \left(\frac{\Delta i}{itarget}\right)^2}}{2} \times 100$$

where:

- Δa= absolute semi-major axis deviation (in km).
- $atarget$= nominal target semi-major axis.
- Δi= absolute inclination deviation (in degrees).
- $itarget$= nominal target inclination.

To be completed with ranges of minimum and maximum deviation that ensure comparability between different IST missions. This requires data of the deviation parameter values that would result in comparable missions. If you have any data for this, please share.

To better represent the real operational cost of correcting orbital deviations, the deviation formula incorporates weighting factors based on ΔV sensitivity. The ΔV sensitivity was evaluated across three representative orbital regimes: LEO, MEO, and GEO. Inclination changes scale linearly with orbital velocity, while semi-major axis corrections follow an inverse-square relationship with orbital radius and orbital velocity. Averaging the sensitivity values from these regimes shows that, for equivalent normalized deviations, correcting inclination costs about 20× more ΔV than adjusting the semi-major axis. Accordingly, we assign a weighting factor of 90% to inclination and 10% to semi-major axis, to better reflect the average ΔV burden across orbit types.

A scaling factor is required to calculate the amount of the servicer spacecraft to the level of the functional unit, being the transport of 1 kg of cooperative object in space by providing a certain ΔV. The following formula shall be used:

$$Dry\ mass\ of\ servicer\ spacecraft\ required\ (in\ kg/FU) = \frac{Total\ servicer\ spacecraft\ dry\ mass\ (in\ kg)}{Total\ effective\ capacity\ (in\ kg)}$$

Where the “total effective capacity” (in kg) is defined as the maximum mass that the servicer spacecraft is expected to transport effectively over its entire operational lifetime, based on its design and mission profile. This value is defined by the spacecraft's operator or manufacturer, and assumes a specific ΔV requirement. Note that in the case a reusable servicer spacecraft provides multiple transport services over its full lifetime, the total effective capacity can be calculated as the maximum expected effective capacity per transport multiplied by the maximum expected number of transport services according to the design of the servicer spacecraft.

3.3.6 Uncrewed launch services from Earth to space

Launchers are optimized for a respective destination orbit and mass (payload). The most relevant parameters to describe the difference is the relationship between launched mass and ΔV (being the velocity at which a payload is released in orbit). The relationship is however not linear, while LCA and thus the scaling within a sub-category normally is. The problem of comparability would remain even with the sub-category split per orbit LEO/MEO/GEO, due to the large orbit ranges and the non-linearity within an orbit range. Therefore, the impact result and also the benchmark depend on the ΔV considered for 1 kg of launched payload.

The functional unit for uncrewed launch services from Earth to space is to transport and release 1 kg of payload in orbit, at certain ΔV, for 1 launch, at a defined minimum safety and precision. The four key elements covered by the functional unit are specified in Table 21.

Table 21: Key aspects to define the functional unit of uncrewed launch services from Earth to space

What?	To transport and release a payload in orbit
How much?	1 kg at certain ΔV
How well?	With a defined minimum safety and precision
How long?	For 1 launch

Safety refers explicitly to launching activities and is defined by international standards, as well as by local regulations and standards in the countries where launching occurs. At minimum, launching activities should be compliant with relevant standards of the launching countries.

Precision is determined by the deviation in **altitude** and **inclination** of the released payload. The maximum altitude deviation is ±20 km, aligned with the Ariane 6 user manual for a semi-major axis of 40 km. The maximum deviation from the inclination ranges from 0.02 to 0.04 degrees.

For a payload to reach a destination orbit it requires to obtain a specific **ΔV**. The ΔV ranges that correspond to the different destination orbits and their respective reference ΔV to be used are defined in Table 22. The user of this PEFCR shall identify the range applicable to its launcher and use the respective reference ΔV in its PEF calculations to ensure fair comparability. The destination orbit does not affect the FU, it is merely provided as additional information to indicate which orbit specific ΔV ranges can reach.

Table 22: ΔV ranges and reference ΔV to be used in PEF studies. Destination orbit is merely provided as additional information as it does not affect the FU.

Destination orbit	ΔV ranges (km/sec)	Reference ΔV (km/sec)
LEO	8.6 to 10.6	ΔV 9
SSO	9.0 to 11.0	ΔV10
MEO	9.6 to 11.6	ΔV10.6
GTO	11.0 to 13.0	ΔV12

A **scaling factor** is required to calculate the amount of the launcher to the level of the functional unit, being the transport and release of 1 kg of payload in orbit, at certain ΔV. The following reference flow shall be used:

$$Launcher\ (kg) = \frac{Launcher\ expendable\ stages\ (kg)}{Payload\ (kg)} + \frac{Launcher\ reusable\ stages\ (kg)}{Payload\ (kg)}$$

A launcher is made of different stages. Each stage is made of several subsystems, and each subsystem is made of various equipment. The formula has two parts, (i) first related to the stages used only once (Launcher expendable stages) and (ii) second related to those stages which are used partly or fully multiple times (launcher reusable stages). The part of the equation on "*Launcher reusable stages*" can be further broken down at the subsystem and equipment level. The amount of material required for the launcher reusable stages depends on the individual reuse time of the integrated equipment. Section 5.11 gives more details on how the reusable stages shall be modelled, after which this shall be divided by the payload to scale back to the FU. The amount of propellant needed to reach a specific ΔV is launcher-specific and is also scaled to the FU.

3.4 System boundary

[This section shall include a system diagram clearly indicating the processes and life cycle stages that are included in the product category/sub-category. A short description of the processes and life cycle stages shall be provided. The diagram shall include an indication of the processes for which company-specific data are required and the processes excluded from the system boundary.]

The life cycle stages as defined in PEF and in a typical LCA study for the space sector are quite different. Typically, space system LCA studies make distinction between space-, launch- and ground-segment activities on the one hand, and all phases of a space mission following the European Cooperation for Space Standardization (ECSS, 2023) on the other hand. Within this PEFCR the different ground-based infrastructures of the ground segment are not separated and assessed with the activities of the respective life cycle stage.

To make a clear distinction between the PEF life cycle stages „raw material acquisition & pre-processing" and „Manufacturing" the terms equipment, subsystems and systems need to be clearly defined. The following terminology is used in the description of the life cycle stages for space-based services:

- Equipment refers to the physical devices, tools, instruments installed on the spacecraft/launcher that enable it to perform its specific function or mission. They are categorized into different subsystems. Equipment can include both hardware and software components.
- Subsystem refers to a distinct, self-contained set of equipment and components that performs a specific function necessary for the spacecrafts or launchers operation. Subsystems are typically functional independent, but they are interconnected and interrelated to work together to ensure correct operation of the system. Examples of subsystems of a launcher include propulsion subsystem, structural subsystem. Examples of subsystems of a spacecraft are power subsystem, communication subsystem.
- System refers to the complete, integrated configuration of subsystems that work together to ensure the spacecraft/launcher achieves its overall mission / goal and operates effectively in space.

As the system boundary for spacecrafts is quite different from launchers, they are presented below in the sub-sections 3.4.1 and 3.4.2 respectively.

Each PEF study done in accordance with this PEFCR shall provide in the PEF study a diagram indicating the activities falling in situation 1, 2 or 3 of the data needs matrix.

3.4.1 System boundary for spacecrafts

Table 23 gives an overview of the PEFCR life cycle stages and processes that shall be included in the system boundary of spacecraft related studies. All sub-categories related to spacecraft follow this overview.

Table 23: Life cycle stages for spacecrafts

Life cycle stage	Short description of the processes included
Raw material acquisition and pre-processing	Production of raw materials, components, equipment and subsystems needed to develop and manufacture flight and test models of the spacecraft systems (incl. office work, manufacturing, assembling, integration and testing)
Manufacturing	Development and manufacturing of flight and test models of the final spacecraft systems (incl. office work, manufacturing, assembling, integration and testing)
Distribution	All transport from spacecraft manufacturing site up to destination orbit (including all launch activities and fuel needed)
Use	All activities once operational in orbit (including supporting ground infrastructure and spares)
End of life	All activities needed at end of life (including re-entry, or recycling on Earth)

If intersatellite communication services are used to enhance the service delivery of one of the sub-categories (e.g. satcom) and integrated on the satellite themselves, e.g., in Software-defined-satellites, the additional payload shall be included in the system boundaries and its entire lifecyle shall be modelled. If intersatellite communication is delivered as a separate service to another operator, e.g., with a dedicated satellite solely delviering intersatellite communication to someone else, it is not covered by the sub-categories and shall be modelled following the horzional rules (see Chapter 3 PEFCR Scope).

The system diagram for spacecrafts is presented in Figure 9. For Earth Observation Services, please refer to section 6.6.1.4 for the system boundary diagram of life cycle stage 4-Use.

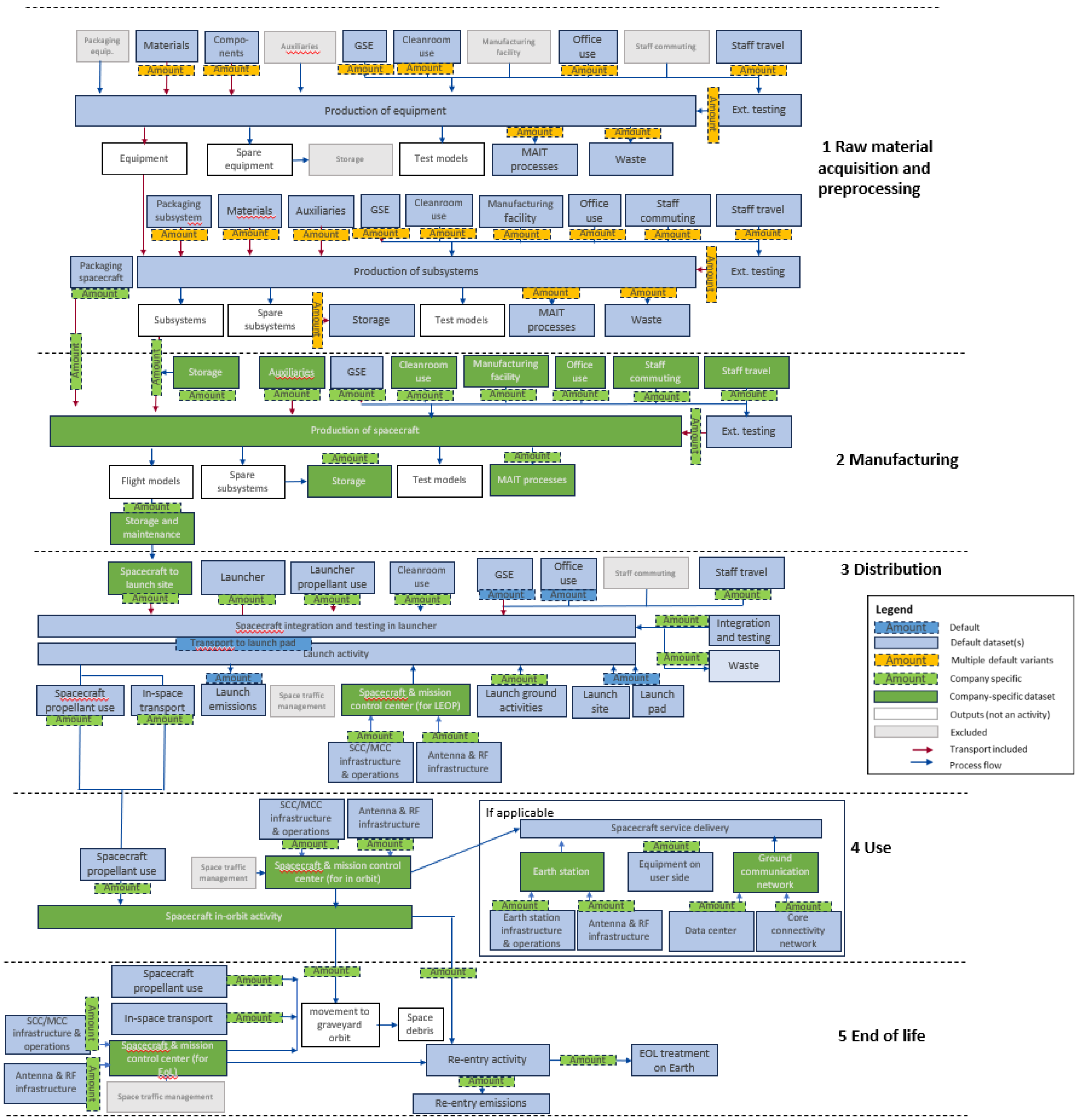

Figure 9: System diagram for spacecraft related services. "Launcher" at distribution stage includes all manufacturing steps and end of life of the launcher used. GSE: ground support

equipment, EOL: End of Life, MAIT: Manufacturing, assembling, integration and testing, Ext. testing: external testing.

[Do you agree with the system boundaries as presented, do you see missing elements? The proposed company-specific amounts and datasets are further evaluated after the first open consultation. However, feedbacks are more than welcome already.]

To be completed after the first open consultation: According to this PEFCR, the following processes may be excluded based on the cut-off rule:

- *[include the list of processes that shall be excluded based on the cut off rule]*
- XXX

No additional cut-off is allowed. OR According to this PEFCR, no cut-off is applicable.

3.4.2 System boundary for launchers

For launchers, and thus the sub-category „launch based services", Table 24 shall be followed. Table 24 gives an overview of the PEFCR life cycle stages and processes that shall be included in the system boundary for launcher related studies. The different infrastructures or ground segments required are assessed with the activities in the respective life cycle stage.

Table 24: Life cycle stages for launchers

Life cycle stage	Short description of the processes included
Raw material acquisition and pre-processing	Production of raw materials, components, equipment and subsystems needed to develop and manufacture launcher and test models (incl. office work, manufacturing, assembling, integration and testing).
Manufacturing	Development and manufacturing of launchers (stages and boosters) and test models (incl. office work, manufacturing, assembling, integration and testing). For (partially) reusable launchers, the refurbishment activities are included.
Distribution	All storage and transport of the launcher from the manufacturing site to launching site.
Use – Launch campaign	All activities to prepare for launching. It includes the integration of launcher (stages) with the spacecraft, and

	the launcher fuelling (including fuel production and transport).
Use – Launch event	All activities related to launching, incl. emissions from fuel usage. For (partially) reusable launchers, the re-entry activities are included.
End of life	All activities needed at end of life (including re-entry and recovery, debris, and treatment method).

The system diagram for launchers is presented in Figure 10.

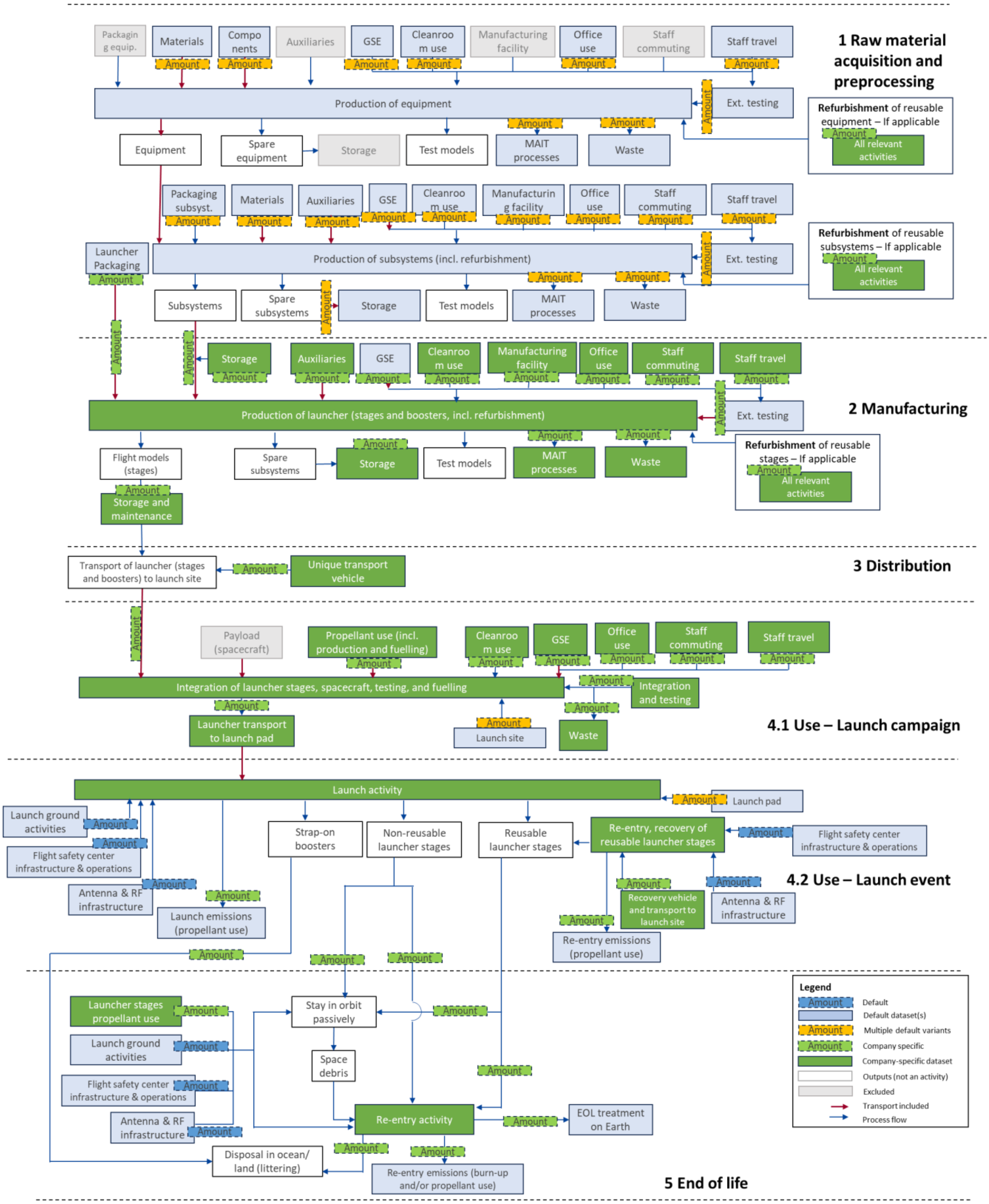

Figure 10: System diagram for the launcher related services. GSE: ground support equipment, EOL: End of Life, MAIT: Manufacturing, assembling, integration and testing, Ext. testing: external testing

[Do you agree with the system boundaries as presented, do you see missing elements? The proposed company-specific amounts and datasets are further evaluated after the first open consultation. However, feedbacks are more than welcome already.]

To be completed after the first open consultation: According to this PEFCR, the following processes may be excluded based on the cut-off rule:

- *[include the list of processes that shall be excluded based on the cut off rule]*
- XXX

No additional cut-off is allowed. OR According to this PEFCR, no cut-off is applicable.

3.5 List of EF impact categories

Each PEF study carried out in compliance with this PEFCR shall calculate the PEF-profile including all EF impact categories listed in Table *25*.

[The Technical Secretariat shall indicate in the table if the sub-categories for climate change shall be calculated separately. In case one or both sub-categories are not reported on, the Technical Secretariat shall include a footnote explaining the reasons, e.g.: 'The sub-indicators 'Climate change – biogenic' and 'Climate change - land use and land transformation' shall not be reported separately because their contribution to the total climate change impact, based on the benchmark results, is less than 5% each.']

Table 25: List of the impact categories to be used to calculate the PEF profile

EF impact category	**Impact category indicator**	**Unit**	**Characterisation model**
Climate change[15]	Global Warming Potential (GWP100)	kg CO_2 eq	Baseline model of 100 years of the IPCC (based on IPCC 2021)
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time

[15] The indicator "Climate Change, total" is constituted by three sub-indicators: Climate Change, fossil; Climate Change, biogenic; Climate Change, land use and land use change. The sub-indicators are further described in Section 5.9 of this PEFCR. The sub-categories 'Climate change –fossil', 'Climate change – biogenic' and 'Climate change - land use and land use change', shall be reported separately if they show a contribution of more than 5% each to the total score of climate change.

			horizon (WMO 2014 + integrations)
Human toxicity, cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	Based on USEtox 2.1 model (Fantke et al. 2017), adapted as in (Saouter et al. 2018)
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	Based on USEtox 2.1 model (Fantke et al. 2017), adapted as in (Saouter et al. 2018)
Particulate matter	Impact on human health	disease incidence	PM model (Fantke et al. 2016) in (UNEP/SETAC Life Cycle Initiative 2016)
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq ^{235}U eq	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al. 2000)
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (van Zelm et al. 2008) as applied in ReCiPe 2008
Acidification	Accumulated Exceedance (AE)	mol H^+ eq	Accumulated Exceedance (Seppälä et al. 2006; Posch et al. 2008)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006; Posch et al. 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al. 2009) as applied in ReCiPe
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al. 2009) as applied in ReCiPe
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTU_e)	CTU_e	Based on USEtox 2.1 model (Fantke et al. 2017), adapted as in (Saouter et al. 2018)

Land use[16]	Soil quality index[17]	Dimensionless (pt)	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on LANCA CF version 2.5 (Horn and Maier 2018)
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 water eq of deprived water	Available WAter REmaining (AWARE) model (Boulay et al. 2018; UNEP/SETAC Life Cycle Initiative 2016)
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	van Oers et al. 2002 as in CML 2002 method v4.8
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)[18]	MJ	van Oers et al. 2002 as in CML 2002 method v4.8

The full list of normalisation factors and weighting factors are available in **Annex 1** of this PEFCR. Note that EPFL has been working on a space specific weighting set, which can be interesting for future updates. *[Reference to be provided. Input is welcome.]*

The full list of characterisation factors is available at this link http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml . *[The Technical Secretariat shall specify the EF reference package to be used.]*

As launch emissions and high altitude emissions are not covered in the current EF reference package, part of the climate change impacts are calculated separately. See Section 0 for more details on the calculations and reporting.

3.6 Additional technical information

Additional technical information is non-environmental information that is calculated and communicated by the user of the PEFCR alongside the PEF profile. The following additional technical information shall be reported separately in all PEF studies compliant with this PEFCR:

---

[16] Refers to occupation and transformation.

[17] This index is the result of the aggregation, performed by JRC, of 4 indicators (biotic production, erosion resistance, mechanical filtration, and groundwater replenishment) provided by the LANCA model for assessing impacts due to land use as reported in De Laurentiis et al, 2019.

[18] In the EF flow list, and for the current recommendation, Uranium is included in the list of energy carriers, and it is measured in MJ.

1. Number of times of reuse
2. Amount of recycled content, as % per material type (total sum in the spacecraft/launcher shall be based on company-specific data). In case no company-specific information is available a default value of zero shall be reported.
3. Noise measured in dB, at a distance of 5km from the launch pad/landing site, during (i) lift-off, (ii) maximum dynamic pressure (Q_{max}) and (iii) landing.
4. Orbit of operation
5. A description of the post mission disposal scenario
6. For a PEF study performed within a sub-category: the quality of the service delivered. Please consult the sections below for more details (3.6.1 - 3.6.6)

For spacecrafts only:

6. Service lifetime
7. Whether the spacecraft is designed to be refuelled. Note that the refuelling activity is not within the scope of this PEFCR.

For the sub-categories in scope, other technical information in addition to those listed above above might be required. This is described per sub-category in the sections below.

[Is the suggested additional environmental and technical information complete or difficult to comply with?]

3.6.1 Earth Observation Services

No additional technical information to be reported, besides those provided in section 3.6 above.

3.6.2 Positioning, Navigation and Timing Services

The quality of the service delivered shall be reported by the design values for

- Service availability: The UTC Time Dissemination Service Availability is defined as the percentage of time during which a user can access a healthy signal that enables accurate estimation of Coordinated Universal Time (UTC) under normal operating conditions (Galileo OS SDD, Issue 1.3 (European Commission, 2023);
- Horizontal and vertical location accuracy as calculated according to the guidelines given in the Galileo OS SDD, Issue 1.3 (European Commission, 2023);
- Time accuracy as calculated according to the guidelines given in the Galileo OS SDD, Issue 1.3 (European Commission, 2023).

3.6.3 Satellite Video Services

The quality of the service delivered shall be reported by the design values for spatial resolution (pixel resolution) of the video service provided. For example Standard Definition (SD - 480p (720×480 pixels)), high definition (HD - 720p (1280×720 pixels) or 1080p (1920×1080 pixels)), Full HD (1080p (1920×1080 pixels)), 4k Ultra HD (2160p (3840×2160 pixels)) and 8k (4320p (7680×4320 pixels)).

3.6.4 Satellite Connectivity Services

The quality of the service delivered shall be reported by the design values for latency.

Latency of the connectivity service shall be reported as the average round-trip time experienced between the user terminal and a public internet exchange point under normal operating conditions, measured in milliseconds (ms). Services shall be classified into one of the following latency brackets:

- Bracket A: Ultra-Low (<70 ms)
- Bracket B: Low (70–150 ms)
- Bracket C: Moderate (150–600 ms)
- Bracket D: High (>600 ms)

The bracket shall be selected based on measured or modelled average latency values. Where available, 95th percentile latency may also be reported.

3.6.5 In-Space Transport Services

For the sub-category in-space transport, the user of the PEFCR shall additionally report on:

- Whether the servicer spacecraft main propulsion system is designed based on chemical or electrical propulsion;
- Whether the servicer spacecraft is designed to provide other in-space services beyond in-space transport, including life extension services such as refuelling, repair, functional upgrades, etc.
- Whether the servicer spacecraft is designed for re-entry.

3.6.6 Uncrewed Launch Services from Earth to space

For reusable launchers: the user of the PEFCR shall additionally report on the environmental impact of the:

- **Expendable** version of the launcher (reuse number is set to 1)
- **Default** number of reuses

The business case of the reusable launcher shall reported as the main PEF profile. More information on reusable launchers is provided in section 5.11.2.

3.7 Additional environmental information

[Specify which additional environmental information shall/should be reported (provide units). Avoid if possible the use of should. Reference all methods used to report additional information.]

The additional environmental information is used to capture to the extent possible the space-related data gaps in the PEF impact assessment methodology (more details provided in Section 3.8). The following additional env. information shall be reported upon separately, next to the PEF profile:

1. IN-ORBIT related impacts (orbital occupation and potential impact on debris): the amount of space debris left in space at year 5 and year 100 after the life cycle is completed (after EOL). This shall be reported upon (at 5 yr and 100 yr) as (i) number of objects, (ii) mass left in space per object, (iii) cross-section area of the objects, and (iv) the estimated altitude. [It is suggested to excluded this information request as the space debris mitigation guidelines prescribe the avoidance of space debris. Shall other parameters be requested instead? Inputs are welcome during the open consultation].

2. Remaining mass after (active or passive) re-entry during EOL stage, if re-entry occurs within 5 or 100 years. This shall be reported upon as mass of littering on Earth (oceans or terrestrial). The remaining mass shall be based on the composition of the spacecraft and its burn-up rate.

3. The main launch emissions from the launcher (including nozzle and afterburning from propellant use) currently not covered by the PEF profile (Inspired by (The Shift Project, March 2024) shall be reported. This shall be reported upon as the mass of substance being emitted at 6 different altitudes ranges (0km-5km, 5-15km, 15km-35km, 35km-50km, 50km-75km, 75km-100km). **More details on the required company-specific information, how to calculate the emission profile and climate change impact is provided in Section 5.15.1.** The follow substances shall be reported, as well as their total climate change impact:
    a. Carbon dioxide (CO_2, in mg)
    b. Carbon oxide (CO, in mg)
    c. Chloride (Cly, in mg)
    d. Hydrochloric acid (HCl, in mg)
    e. Water vapor (H_2O, in mg)
    f. Aluminium oxide (Al_2O_3, in mg)
    g. Nitrogen oxides (NOx, in mg)
    h. PM10 (Black carbon, in mg)

4. The main substances being emitted during re-entry at year 5 and year 100 after the life cycle is completed (after EOL) currently not covered by the PEF profile

(The Shift Project, March 2024) shall be reported. This shall be reported upon as the mass of substance due to burning from friction/heath and propellant use emitted at 6 different altitudes ranges (0km-5km, 5-15km, 15km-35km, 35km-50km, 50km-75km, 75km-100km) for year 5 and 100. **More details on the required company-specific information, how to calculate the emission profile and climate change impact is provided in Section 5.15.2.** The follow substances shall be reported, as well as their total climate change impact:

a. Carbon dioxide (CO_2, in mg)
b. Dichloride (Cl2, in mg)
c. Water vapor (H_2O, in mg)
d. Aluminium oxide (Al_2O_3, in mg)
e. Titanium dioxide (TiO_2, in mg)
f. Iron oxide (Fe_2O_3, in mg)
g. Magnesium oxide (MgO, in mg)
h. PM10 (black carbon, in mg)

5. The use of strategic and critical raw materials as defined in Articles 3 and 4 of the Regulation (EU) 2023/0079 entering in the production stage, should be reported - if available - in compliance with the latest list published[19].

[Is the suggested additional environmental and technical information complete or difficult to comply with? It is questionable if critical raw materials shall be part of the additional reporting requirements. And if so, which ones should be reported upon. We welcome any feedback on this during the open consultation.]

3.8 Limitations

[This section shall include the list of limitations a PEF study will have, even if carried out in accordance with this PEFCR. Filled in later.]

3.8.1 Comparisons and comparative assertions

Provided that PEF studies are compliant with the rules outlined in this PEFCR:

- Only PEF studies in scope of the same sub-category can be compared or used for comparative assertion towards each other or the respective benchmark, except for Earth observation. For the sub-category "Earth observation services" specific restrictions are specified in Section 3.8.1.1 below.
- PEF studies performed outside the scope a sub-category, using the overarching horizontal rules only, are allowed to be compared only when having the exact

[19] EC: https://single-market-ecoomy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

same mission requirements. In all other cases, it is not allowed to make comparison among studies or towards any benchmark provided in this PEFCR.

3.8.1.1 Earth observation services

For Earth observation services, no representative product is defined and therefore no comparison to the benchmark is possible. Comparison between different Earth observation services is only allowed if the services cover the same mission‘s scope. As stated in section 3.3.1, the mission’s scope is defined as the raw Earth Observation data collected by the spacecraft sensor that directly supports the mission’s intended objectives. This includes capturing the right type of information (such as land, ocean, or atmospheric data), using the appropriate sensor if specified, and covering the correct areas at the required times. The data must meet the mission’s specifications for resolution, accuracy, and revisit rate, ensuring it is suitable for the mission’s planned applications, even if further processing happens later on the ground. Data related to the TM/TC transmissions, manoeuvrers instructions or any other spacecraft operations related activities is excluded. Table 26 defines the ranges of the mission’s specifications for which Earth observation services are comparable. Comparison is therefore allowed between two services covering the same ranges for both accuracy and revisit rate.

Table 26 - Predefined ranges for accuracy and revisit rate related to the comparability of Earth observation services

	Metric	LOW	MEDIUM	HIGH
Accuracy	% of the defined resolution (same unit as the resolution)	>1000%	1000-150%	<150%
Revisit rate	Average revisit time (days)	> 10 days	10 days – 1 day	Sub daily revisit

Common type of instruments (non-exhaustive list) for Earth Observation Services:

- Optical;
- Hyperspectral;
- Thermal sensors;
- Radar (active sensors);
- Laser altimeter (active);
- Sounders (active);
- Spectrometer;
- Radiometer.

3.8.1.2 Uncrewed launch services from Earth to space

Within this sub-category, PEFCR study results may be compared among each other or with the provided benchmark only when the calculations are performed for the same ∆V range while using the respective reference ∆V. See section 3.3.6 for more information on the ∆V reference values to be used.

3.8.2 Missing environmental impacts

It is important to acknowledge that not all relevant impacts are covered by the environmental impact categories of PEF.
- Note that space radiation (and related human health impacts) is not created by space activities as such but comes directly from the space environment. Although recognised as being important, it is not an effect caused by human related space activities and therefore not relevant (out of scope) for this impact assessment.
- Note that potential impacts occuring in orbit are not covered and considered out of scope. The PEF methodology measures the impact on the earth environment. Impacts in space, such as the use of spectrum as a resource, radio frequency interferences, and light pollution or optical impacts, as well as the creation of space debris, are therefore out of scope.

Impacts from higher atmosphere are not covered by standard impact assessment models. These missing impacts shall be solved (i) at the level of inventory data and (ii) at the level of impact assessment methodology.

On the level of emission inventory, clear gaps are present today for launch and re-entry emissions. Measuring exactly what is burned at what altitude during launch or re-entry is still very difficult. Today the industry is not ready for detailed company-specific reporting, which leads to a first data gap in the inventory modelling of the life cycle of spacecrafts and launchers. Annex XX presents the list of launch and re-entry emissions currently missing in this PEFCR (excluding those covered by the additional environmental information). For this list, the future scientic developments are needed: (i) the development of engine, trajectory, and altitude specific emission calculations, (ii) the development of altitude specific impact assessment factors, and (iii) the integration of these substances and characterisation factors into the future Environmental Footprint reference package. However, some (limited) theoretical models do exist who can provide first insights in the potential emissions. It is acknowledged and motivated to scientists in this field to keep working on this.
Within this PEFCR theoretical launch and re-entry emission profiles for the most relevant substances are to be reported upon as additional environmental information (see Section 3.7 and Section 5.15). However, these still have some limitations such as (i) no engine specificity, (ii) no trajectory specifity and (iii) a full stochiometric combustion approach for re-entry emissions without intermediate species. Some of these lower altitude emissions are captured by the current EF impact method, however, most climate change impacts as well as higher altitude impacts are still missing (see Section 0 on which launch impacts are covered in this PEFCR).

The full integration of launch and re-entry emissions within the impact assessment categories of the environmental profile will be rediscussed in the next update of this PEFCR.

On the level of impact assessment methodology development, three types of gaps are identified today within the scientific community developments:

1. Impacts that can be calculated with the PEF impact assessment models but are currently missing (as elementary flows or characterisation factor). Examples are Hydrochloric Acid emissions in the impact category acidification, aluminium oxide emissions affecting human and ecotoxicity, soot particles and water vapour affecting climate change, and missing metals from resource depletion.
2. Impacts that could be covered with the PEF impact assessment models but for which part of the cause-effect pathway is currently missing. Typical example is nozzle/afterburning emissions at high altitude (such as black carbon, alumina and thermal NOx emissions) and their impact to climate change and ozone depletion.
3. Impacts that are not covered by the current impact assessment models of PEF. A typical example is the physical impacts from re-entry debris. The use and loss of critical raw materials is covered by the impact category resource depletion but not to the extent of raw materials being lost in space.

To integrate these missing environmental impacts into the PEF methodology, new elementary flows, new characterisation factors, and new impact categories are required. It has been recommended to introduce new emission compartments (e.g, upper and lower stratosphere) to capture the altitude effect from the emissions on certain impact categories (such as ozone depletion and climate change) and to look for synergies with the aviation industry.

However, this is not possible within the context of the current PEFCR but we stress the importance of further developing these different impact pathways over the coming years and the need for integration in the next update of the PEFCR.

Part of these gaps are covered by the required additional environmental information.

3.8.3 Data gaps and proxies

[This section will be completed after the open consultation.]

[This section shall include:

The list of data gaps on the company-specific data to be collected that most frequently are encountered by companies in the specific sectors and how these data gaps may be solved in the context of the PEF study;

The list of processes excluded from the PEFCR due to missing datasets that shall not be filled in by the user of the PEFCR;

The list of processes for which the user of the PEFCR shall apply ILCD-EL compliant datasets.

The Technical Secretariat may decide to indicate in the LCI excel file (see section B.5 of this Annex) for which processes no datasets are available and therefore are considered data gaps and for which processes proxies shall be used.]

3.8.3.1 Data gaps frequently encountered for company-specific data

[This section will be completed after the open consultation.]

3.8.3.2 Processes excluded from the PEFCR due to missing datasets

[This section will be completed after the open consultation.]

3.8.3.3 Data gaps for secondary datasets and guidance to select proxies

[This section will be completed after the open consultation.]

3.8.3.4 List of processes requiring ILCD-EL compliant proxies

[This section will be completed after the open consultation.]

4. Most relevant impact categories, life cycle stages, processes and elementary flows

This section presents the results of the first representative products as modelled according to Annex 4.2: Limited scope of the first PEF-RPs. The scope of the different sub-categories is not complete at this stage. Relevant data inventory such as launch site, end of life activities and demise emissions are missing. Therefore, these first results shall be assessed with care and in context with the limited scope described in Annex 4.2.

For all sub-categories the most relevant impact categories, life cycle stages, processes and elementary flows are assessed with and without climate change impacts from launch and re-entry emissions from propellant use (see also Section 0). In the sections below, the results are presented separately for both scenarios ONLY when there is a difference in results of more than 2%.

4.1 Most relevant EF impact categories

The most relevant impact categories for the sub-category **Earth Observation Services** are the following for the **CO2M** mission[20]:

- Resource use, minerals and metals – 29.6 %
- Climate change – 19.9%
- Resource use, fossils – 15.4%
- Eutrophication, freshwater – 9.69%
- Acidification – 5.07%
- Particulate matter – 4.84%

The most relevant impact categories for the sub-category **Earth Observation Services** are the following for the **Altius** mission[20]:

- Resource use, minerals and metals – 26.8 %
- Climate change – 21.1%
- Resource use, fossils – 16.7%
- Eutrophication, freshwater – 5.99%
- Particulate matter – 5.74%
- Acidification – 5.07%

[20] The results including or excluding GWP of launch and re-entry emissions differ less than 2%, therefore only the results including max. launch emissions are reported.

The most relevant impact categories for the sub-category **Positioning Navigation and Timing Services** are the following:

- No results available today.

The most relevant impact categories for the sub-category **Satellite Video Services** are the following:

- Resource use, minerals and metals – 65%
- Climate change – 9%
- Resource use, fossils – 7%[21]

The most relevant impact categories for the sub-category **Satellite Connectivity Services** are the following:

- Resource use, minerals and metals – 75%
- Climate change – 6%
- *Eutrophication, freshwater – 5%*[21]

The most relevant impact categories for the sub-category **In-Space Transport Services** are the following[22]:

- Climate change – 23%
- Resource use, minerals and metals – 22%
- Resource use, fossils – 16%
- Eutrophication, freshwater – 12%
- Particulate matter – 5%
- Acidification – 5%

The most relevant impact categories for the sub-category **Uncrewed Launch Services from Earth to Space** per reference ΔV are listed below. For this sub-category, the results with and without climate change impacts from launch and re-entry emissions from propellant use differ for some impact categories. When they are different, these are presented separately.

For reference ΔV 9:

- Climate change – 26% (including climate change impact from launch and re-entry) and 24% (excluding climate change impact from launch and re-entry)
- Resource use, fossils – 19%
- Resource use, minerals and metals – 14%
- Water use – 8%

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[21] According to the PEFCR rules, minimum 3 most relevant impact categories shall be selected. Therefore, a third impact category has been added.

[22] The RP consists of two main technologies – single use and multi use OTVs. Large differences were observed in the environmental impacts of these different technologies, which are likely mainly related to data gaps and inconsistencies in which processes where included for the different technologies. The results will likely change a lot in future iterations where the data gaps are tackled and should therefore be interpreted carefully.

- Particulate matter – 7%
- Eutrophication, freshwater– 6%
- Acidification – 6%

For reference ΔV 10:

- Climate change – 25% (including climate change impact from launch and re-entry) and 24% (excluding climate change impact from launch and re-entry)
- Resource use, fossils– 19%
- Resource use, minerals and metals– 14% (including climate change impact from launch and re-entry) and 15% (excluding climate change impact from launch and re-entry)
- Water use – 8%
- Particulate matter– 7%
- Eutrophication, freshwater – 6%
- Acidification – 6%

For reference ΔV 10.6:

- Climate change – 26% (including climate change impact from launch and re-entry) and 24% (excluding climate change impact from launch and re-entry)
- Resource use, fossils– 19%
- Resource use, minerals and metals – 14% (including climate change impact from launch and re-entry) and 15% (excluding climate change impact from launch and re-entry)
- Water use– 8%
- Particulate matter – 7%
- Eutrophication, freshwater – 6%
- Acidification – 6%

For reference ΔV 12:

- Climate change – 25% (including climate change impact from launch and re-entry) and 23% (excluding climate change impact from launch and re-entry)
- Resource use, fossils – 19%
- Resource use, minerals and metals – 15%
- Water use – 9% (including climate change impact from launch and re-entry) and 10% (excluding climate change impact from launch and re-entry)
- Particulate matter– 7%
- Acidification – 6%

4.2 Most relevant life cycle stages

The most relevant life cycle stages (together with their contribution %) per sub-category are listed in Table 27. For PNT, there are currently no results available.

For the following sub-categories the use stage contributes with more than 50%:

- Satellite Video Services
- Satellite Connectivity Services
- Uncrewed launch services from Earth to space (for all ΔV)

*Table 27. Per sub-category, the most relevant life cycle stages per most relevant impact category. The % indicates the life cycle stage contribution to the total impact of the impact category. 1. Raw materials extraction and pre-processing, 2. Manufacturing, 3. Distribution, 4. Use, 5. End of life. NR: Not Relevant. *Sub-categories with use stage larger than 50%.*

Impact category	Earth Observation Services		Satellite Video services*	Satellite Connectivity Services*	In-space transport services[22]
	CO2M	Altius			
Acidification	LCS3 – 54.9% LCS2 – 24.1% LCS1 – 19.1%	LCS3 – 73.2% LCS4 – 12.7%	NR	NR	LCS1 – 66.2% LCS3 – 33.6%
Climate Change	LCS2 – 35% LCS1 – 31.5% LCS3 – 30.8%	LCS3 – 77.7% LCS2 – 13.2%	LCS4 – 82% LCS3 – *(62% excl. use)* LCS1 – *(33% excl. use)*	LCS4 – 94.5 % LCS3 – *(56% excl. use)* LCS1 – *(36% excl. use)*	LCS1 – 68.6% LCS3 – 31.1%
Eutrophication, freshwater	LCS2 – 47.4% LCS1 – 34.9%	LCS3 – 71.4% LCS4 – 11.4%	NR	LCS4 – 97.6% LCS1 – *(55% excl. use)* LCS3 – *(41% excl. use)*	LCS1 – 85.5%
Resource use, fossils	LCS2 – 35.1% LCS1 – 32.8% LCS3 – 28.5%	LCS3 – 66.1% LCS2 – 23.7%	LCS4 – 76% LCS3 – 11% *(45% excl. use)* LCS1 – *(41% excl. use)*	NR	LCS1 – 68.1% LCS3 – 31.7%
Resource use, minerals and metals	LCS1 – 53.6% LCS2 – 24.2% LCS4 – 11.4%	LSC3 – 32.1% LCS4 – 31.8% LCS1 – 26.3%	LCS4 – 98% LCS1 – *(62% excl. use)* LCS3 – *(36% excl. use)*	LCS4 – 99.6% LCS3 – *(46% excl. use)* LCS1 – *(36% excl. use)*	LCS1 – 82.3%
Particulate matter	LCS1 – 35% LCS3 – 32.8% LCS2 – 27.7%	LCS3 – 74.4% LCS2 – 13.2%	NR	NR	LCS1 – 60.5% LCS3 – 39.2%
Note on scope:	LCS5 and LCS4 are only partly assessed	LCS4 is partly assessed LCS5 is not assessed			LCS4 is partly assessed LCS5 is not assessed

Table 28. For Uncrewed launch services from Earth to Space sub-category, the most-relevant life cycle stages per most-relevant impact category identified per reference ΔV. The % indicates the life cycle stage contribution to the total impact of the impact category. LCS1. Raw materials extraction and pre-processing, LCS2. Manufacturing, LCS3. Distribution, LCS4. Use, LCS5. End of life. NR: Not Relevant. With and without use stage is presented.

Impact category		*Uncrewed launch services from Earth to space*			
		ΔV 9	*ΔV 10*	*ΔV 10.6*	*ΔV 12*
Climate change	**including** launch and re-entry emissions from propellant use	LCS4 – 70% LCS1 – 26% (87% excluding Use stage)	LCS4 – 68% LCS1 – 28% (87% excluding Use stage)	LCS4 – 69% LCS1 – 27% (88% excluding Use stage)	LCS4 - 66% LCS1 - 29% (87% excluding Use stage)
Climate change	**excluding** launch and re-entry emissions from propellant use	LCS4 – 67% LCS1 – 28% (87% excluding Use stage)	LCS4 – 66% LCS1 – 30% (87% excluding Use stage)	LCS4 – 67% LCS1 – 29% (88% excluding Use stage)	LCS4 - 63% LCS1 - 32% (87% excluding Use stage)
Resource use, fossils		LCS4 - 53% LCS1 – 38% (81% excluding Use stage)	LCS4 – 51% LCS1 – 39% (80% excluding Use stage)	LCS4 – 53% LCS1 – 39% (82% excluding Use stage)	LCS4 – 50% LCS1 – 40%
Resource use, minerals and metals		LCS1 - 78% LCS4 – 20%	LCS1 – 79% LCS4 – 18%	LCS1 – 78% LCS4 – 20%	LCS1 – 82%
Water use		LCS4 - 82% LCS1 – 18% (97% excluding Use stage)	LCS4 – 81% LCS1 – 18% (97% excluding Use stage)	LCS4 – 82% LCS1 – 18% (97% excluding Use stage)	LCS4 – 84% LCS1 – 15% (97% excluding Use stage)
Particulate matter		LCS4 - 59% LCS1 – 35% (84% excluding Use stage)	LCS4 – 57% LCS1 – 36% (84% excluding Use stage)	LCS4 – 59% LCS1 – 35% (84% excluding Use stage)	LCS4 – 55% LCS1 – 38% (85% excluding Use stage)
Eutrophication, freshwater		LCS4 - 56% LCS1 – 43% (96% excluding Use stage)	LCS4 – 53% LCS1 – 45% (96% excluding Use stage)	LCS4 – 56% LCS1 – 43% (96% excluding Use stage)	NR
Acidification		LCS4 - 59% LCS1 – 35% (85% excluding Use stage)	LCS4 – 57% LCS1 – 36% (85% excluding Use stage)	LCS4 – 59% LCS1 – 35% (85% excluding Use stage)	LCS4 – 53% LCS1 – 40% (85% excluding Use stage)
Note on scope:		LCS5 was not assessed	LCS5 was not assessed	LCS5 was not assessed	LCS5 was not assessed

4.3 Most relevant processes

The most relevant processes per sub-category in scope of this PEFCR are presented in this chapter. For PNT, there are currently no results available.

[this table shall be filled in based on the final results of the PEF studies of the representative product(s). Provide one table per sub-category, if appropriate.]

The most relevant processes per most relevant impact category for **Earth Observation Services** are presented in Table 29 for the CO2M mission and Table 30 for the Altius mission.

Table 29: List of most relevant processes per most relevant impact category for Earth Observation Services case study CO2 mission (indicated with „X").

Processes per life cycle stage	**Resource use, minerals and metals**	**Climate change**	**Resource use, minerals and metals**	**Eutrophication, freshwater**	**Particulate matter**	**Acidification**
LCS1: Raw material acquisition and pre-processing						
Building, multi-storey {RER}	x	x	x	x	x	x
Printed wiring board, Pb containing {GLO}	x					
Silver {GLO}	x					
Electricity, low voltage {DE}	x	x	x	x	x	x
Cobalt {GLO}	x				x	
Printed Board Assembly EEE {DE}						
Aluminium, primary, liquid {GLO}		x	x	x	x	x
Electricity, low voltage {RER}		x	x	x		x
Nitrogen, liquid {RER}		x	x		x	x
District or industrial heat, natural gas {Europe without Switzerland}		x	x			
Electricity, low voltage {FR}			x			
Electricity, low voltage {BE}			x			
Magnesium {GLO}					x	
LCS2: Manufacturing						
Building, multi-storey {RER}	x	x	x	x	x	x
Electricity, low voltage {DE}	x	x	x	x	x	x
Cobalt {GLO}	x				x	
Aluminium, primary, liquid {GLO}		x	x	x	x	x
Electricity, low voltage {RER}		x	x	x	x	x
Nitrogen, liquid {RER}		x	x			x
District or industrial heat, natural gas {Europe without Switzerland}		x	x			
Natural gas, high pressure {Switzerland}			x			
Magnesium {GLO}					x	
LCS3: Distribution						
Building, multi-storey {RER}	x	x	x	x	x	x
Launcher RP DeltaV 9 (LEO)	x	x		x	x	x
Electricity, low voltage {DE}	x	x	x	x	x	x

Cobalt {GLO}	x				x	
RP Propellant use DeltaV 9 (LEO)		x	x	x	x	x
Aluminium, primary, liquid {GLO}		x	x	x	x	x
Electricity, low voltage {RER}		x	x	x	x	x
Nitrogen, liquid {RER}		x	x			
District or industrial heat, natural gas {Europe without Switzerland}		x	x			x
RP Launch emissions DeltaV 9 (LEO)		x				
Magnesium {GLO}					x	
LCS4: Use stage						
Building, multi-storey {RER}	x				x	x
Electricity, low voltage {RER}		x	x	x	x	
Nitrogen, liquid {RER}		x	x			x
District or industrial heat, natural gas {Europe without Switzerland}		x				
LCS5: End of Life stage						
Electricity, low voltage {RER}		x	x	x	x	
Nitrogen, liquid {RER}		x	x			x
District or industrial heat, natural gas {Europe without Switzerland}		x				

Table 30: List of most relevant processes per most relevant impact category for Earth Observation Services case study Altius mission (indicated with „X").

Processes per life cycle stage	**Resource use, minerals and metals**	**Climate change**	**Resource use, minerals and metals**	**Eutrophication, freshwater**	**Particulate matter**	**Acidification**
LCS1: Raw material acquisition and pre-processing						
Printed board assembly EEE {DE}	x			x		
Gold {GLO}	x					
Aluminium, primary, liquid {GLO}						x
LCS2: Manufacturing						
Electricity, low voltage {BE}	x	x	x	x	x	x
Building construction hall {CH}					x	
LCS3: Distribution						
Launcher RP Delta V9 (LEO)	x	x	x	x	x	x
Steel, chromium 18/8 {RER}	x	x	x	x	x	x
RP propellant use – DeltaV 9 (LEO)	x	x	x	x	x	x
Transport, freight, aircraft, long haul {GLO}		x	x			x
RP Launch emissions – DeltaV 9 (LEO)		x				
Hydrazine {RpW}				x		
Aluminium, primary, liquid {GLO}						x
LCS4: Use stage						
Building, multi-storey {GLO}	x			x	x	x
Steel, chromium 18/8 {RER}	x	x	x	x	x	x
Integrated circuit, logic type {GLO}	x					
Printed wiring board, Pb free {GLO}	x					

Transport, freight, aircraft, long haul {GLO}		x	x			x
Hydrazine {RpW}				x		
LCS5: End of Life stage						
Hydrazine {RpW}				x		

The most relevant processes per most relevant impact category for **Satellite Video Services**, including and excluding use stage, are presented in Table 31, and for **Satellite Connectivity Services** in Table 32.

Table 31: List of the most-relevant processes per most relevant impact category for Satellite Video Services (incl. and excl. use stage) (indicated with „X").

Processes per life cycle stage	**Resource use, minerals and metals**	**Climate change**	**Resource use, fossils**
LCS1: Raw material acquisition and pre-processing			
Copper, cathode {GLO}	(X excl. Use)		
Silver {GLO}	(X excl. Use)		
Gold {GLO}	(X excl. Use)		
Printed board assembly EEE {DE}	(X excl. Use)		
Printed wiring board {GLO}	(X excl. Use)		
Cobalt {GLO}	(X excl. Use)		
Nitrogen, liquid {RoW}		(X excl. Use)	(X excl. Use)
Electricity, low voltage {DE}		(X excl. Use)	(X excl. Use)
Aluminium, primary, liquid {GLO}		(X excl. Use)	
Electricity, medium voltage {FR}		(X excl. Use)	(X excl. Use)
LCS2: Manufacturing			
Electricity, medium voltage {FR}			(X excl. Use)
LCS3: Distribution			
Launcher RP Production - DeltaV 12 (GTO)	(X excl. Use)	(X excl. Use)	(X excl. Use)
RP Propellant use - DeltaV 12 (GTO)	(X excl. Use)	(X excl. Use)	(X excl. Use)
RP Launch emissions - DeltaV 12 (GTO)		(X excl. Use)	
LCS4: Use stage			
Printed wiring board {GLO}	X	X	X
Integrated circuit, logic type {GLO}	X	X	X
Electric connector {GLO}	X		
Electricity, low voltage {EU}		X	X
Chromium {GLO}		X	X
Aluminium, primary, liquid {IAI Area, EU27 & EFTA		X	
Integrated circuit, memory type {GLO}		X	
Display, liquid crystal, 17 inches {GLO}		X	
Electricity, medium voltage {EU}			X
LCS5: End of Life stage			
NR			

Table 32. List of the most-relevant processes per most relevant impact category for Satellite Connectivity Services (incl. and excl. use stage) (indicated with „X").

Processes per life cycle stage	**Resource use, minerals and metals**	**Climate change**	***Eutrophication, freshwater***
LCS1: Raw material acquisition and pre-processing			
Copper, cathode {GLO}	(X excl. Use)		
Silver {GLO}	(X excl. Use)		
Printed board assembly_EEE	(X excl. Use)		
Electricity, low voltage {DE}	(X excl. Use)	(X excl. Use)	(X excl. Use)
Gold {GLO}	(X excl. Use)		
Printed wiring board {GLO}	(X excl. Use)		
Nitrogen, liquid {RoW}		(X excl. Use)	(X excl. Use)
Transport, passenger, car, petrol, medium size, EURO 5 {RER}		(X excl. Use)	
LCS2: Manufacturing			
Transport, passenger, car, petrol, medium size, EURO 5 {RER}		(X excl. Use)	
LCS3: Distribution			
Launcher RP Production - DeltaV 12 (GTO)	(X excl. Use)	(X excl. Use)	(X excl. Use)
RP Propellant use - DeltaV 12 (GTO)	(X excl. Use)	(X excl. Use)	(X excl. Use)
RP Launch emissions - DeltaV 12 (GTO)		(X excl. Use)	
Xenon, gaseous {RER}			(X excl. Use)
LCS4: Use stage			
Printed wiring board {GLO}	X	X	X
Integrated circuit, logical type {GLO}	X	X	X
Chromium {GLO}		X	
Aluminium, primary, liquid {IAI Area, EU27 & EFTA}		X	
Integrated circuit, memory type {GLO}		X	
Display, liquid crystal, 17 inches {GLO}		X	
Electricity, medium voltage {RER}		X	
Nickel, class 1 {GLO}		X	
Electricity, medium voltage {DE}		X	X
Electric connector {GLO}			X
Copper, anode {RU}			X
LCS5: End of Life stage			
Xenon, gaseous {RER}			(X excl. Use)

The most relevant processes per most relevant impact category for **in-space transport services** are presented in Table 33.

Table 33: List of most relevant processes per most relevant impact category for in-space transport services (indicated with „X")[22].

Processes per life cycle stage	**Climate change**	**Resource use, minerals and metals**	**Resource use, fossil**	**Eutrophication, freshwater**	**Particulate matter**	**Acidification**
LCS1: Raw material acquisition and pre-processing						

Building, multi-storey {RER}| building construction, multi-storey | Cut-off, S	X	X		X	X	X
Electricity, low voltage {DE}| market for electricity, low voltage | Cut-off, S	X	X	X	X	X	X
Nitrogen, liquid {RoW}| market for nitrogen, liquid | Cut-off, S	X		X	X	X	X
Electricity, low voltage {FR}| market for electricity, low voltage | Cut-off, S			X			
LCS2: Manufacturing						
/						
LCS3: Distribution						
Launcher Representative Product (RP) [per kg payload] - DeltaV 9 (LEO) - excl. LCS4 propel. & emissions - System [library]	X	X	X		X	X
RP Propellant use - DeltaV 9 (LEO) [per kg payload] - System [library]	X		X	X	X	X
LCS4: Use stage						
/						
LCS5: End of Life stage						
LCS5 is not assessed						

The most relevant processes per most relevant impact category for **Uncrewed launch services from Earth to Space** per reference ΔV , including and excluding use stage, are presented in Table 34 for ΔV9, Table 35 for ΔV10, Table 36 for ΔV10.6 and Table 37 for ΔV12.

Table 34. List of most relevant processes per most relevant impact category for Uncrewed launch services from Earth to Space sub-category, per reference ΔV9 (indicated with „X").

Processes per life cycle stage	**Climate change[23]**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**	**Particulate matter**	**Eutrophication, freshwater**	**Acidification**
LCS1: Raw material acquisition and pre-processing							
Aluminium, primary, liquid {GLO}	X	X		(X excl. Use)	X	X	X
Electricity, medium voltage {DE}	X	X			X	X	X
Electricity, medium voltage {FR}	X	X		(X excl. Use)	X	(X excl. Use)	X
Cobalt {GLO}	X	X	X	X	X	X	X
Acrylonitrile {GLO}	X	X		(X excl. Use)	X		X
Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}	X[24] (X excl. Use)[25]	X			X		X
Aluminium, cast alloy {RER}	(X excl. Use)		X	(X excl. Use)	X	(X excl. Use)	X
Oxygen, liquid {RER}, market for	(X excl. Use)	X		(X excl. Use)		X	X
Steel, chromium steel 18/8 {RER}	(X excl. Use)		X		X	X	X
Laser machining, metal, with YAG-laser, 500W power {RER}	(X excl. Use)		X	(X excl. Use)		(X excl. Use)	X
Electricity, medium voltage {NL}	(X excl. Use)						
Electricity, medium voltage {RER}	(X excl. Use)					(X excl. Use)	
Energy and auxilliary inputs, metal working factory {RER}	(X excl. Use)						
Nitrogen, liquid {RER}	(X excl. Use)			(X excl. Use)		(X excl. Use)	

[23] The most relevant processes when including and excluding climate change impact from launch and re-entry emissions are the same, unless otherwise indicated.
[24] Applies only when climate change impact from launch and re-entry emissions is **excluded.**
[25] Applies only when climate change impact from launch and re-entry emissions is **included**.

Processes per life cycle stage	Climate change[23]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Aluminium, wrought alloy {GLO}	(X excl. Use)						
Electricity, low voltage {FR}		X					
Silver {GLO}			X			X	
Zinc {GLO}			X				
Molybdenum {RER}			X				
Copper, cathode {GLO}			X				
Electronics, for control units {RER}			X				
Water, deionised {Europe without Switzerland}, market for water				(X excl. Use)			
Water, deionised {Europe without Switzerland}, water production				(X excl. Use)			
Oxygen, liquid {RER}, industrial gases production, cryogenic air separation				(X excl. Use)			
Magnesium {GLO}					X		
Tungsten, metallic {GLO}					X		X
Magnesium-alloy, AZ91 {RER}					X		
Building, hall, steel construction {CH}					X		
Electricity, low voltage {RER}						(X excl. Use)	
Iron-nickel-chromium alloy {RER}							X
Nickel, 99.5% {GLO}							X
LCS2: Manufacturing							
Electricity, high voltage {BR-North-eastern grid}	(X excl. Use)	X			X		X
Building, hall, steel construction {CH}	(X excl. Use)				(X excl. Use)		(X excl. Use)
Electricity, medium voltage {FR}	(X excl. Use)	X					
MAIT processes					(X excl. Use)		(X excl. Use)
LCS3: Distribution							
Diesel, low-sulfur {RER}|	(X excl. Use)	(X excl. Use)			(X excl. Use)		(X excl. Use)
LCS4: Use stage							

Processes per life cycle stage	Climate change[23]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Sodium perchlorate {GLO}, sodium perchlorate production	X	X	X	X	X	X	X
Hazardous waste, for incineration {Europe without Switzerland}	X	X			X	X	X
Sodium perchlorate {GLO}, market for sodium perchlorate	X	X	X	X	X	X	X
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	X	X			X	X	X
Hydrogen, gaseous, methanol reforming, propellant {French Guiana}	X				X		
Electricity, high voltage {BR-North-eastern grid}	X	X			X		X
Nitrogen, liquid {RER}	X	X		X	X	X	X
Heat, district or industrial, natural gas {RER}	X	X					
Heat, central or small-scale, other than natural gas {RoW}	X	X			X		X
Liquid storage tank, chemicals, organics {RoW}	X	X			X	X	X
Methanol {GLO}	X	X					X
Heat, district or industrial, natural gas {FR}	X	X					
Ammonia, anhydrous, liquid {RER}	X						
Butadiene {RER}		X					
Diesel, low-sulfur {RER}		X					
Distribution network, electricity, low voltage {GLO}			X				
Chemical factory, organics {GLO}			X				
Oxygen, liquid {FG}				X			
Sulfuric acid {RER}					X		X

Processes per life cycle stage	Climate change[23]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Launch emissions - DeltaV9 (LEO)	X[26]						X
LCS5: End of Life stage							
LCS5 was not assessed							

Table 35. List of most relevant processes per most relevant impact category for Uncrewed launch services from Earth to Space sub-category, per reference ΔV10 (indicated with „X").

Processes per life cycle stage	Climate change[27]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
LCS1: Raw material acquisition and pre-processing							
Aluminium, primary, liquid {GLO}	X	X		(X excl. Use)	X	X	X
Electricity, medium voltage {DE}	X	X			X	X	X
Electricity, medium voltage {FR}	X	X		(X excl. Use)	X	X	X
Cobalt {GLO}	X	X	X	X	X	X	X
Acrylonitrile {GLO}	X	X		(X excl. Use)	X		X
Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}	X	X			X		X
Aluminium, cast alloy {RER}	X[28] (X excl. Use)[29]		X	(X excl. Use)	X	(X excl. Use)	X
Oxygen, liquid {RER}, market for	(X excl. Use)	X		(X excl. Use)		X	X
Steel, chromium steel 18/8 {RER}	(X excl. Use)		X		X	X	X

[26] Applies only when climate change impact from launch and re-entry emissions is **included**.
[27] The most relevant processes when including and excluding launch emissions and re-entry emissions from propellant use of re-usable launchers are the same, unless otherwise indicated.
[28] Applies only when climate change impact from launch and re-entry emissions is **excluded.**
[29] Applies only when climate change impact from launch and re-entry emissions is **included**.

Processes per life cycle stage	**Climate change[27]**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**	**Particulate matter**	**Eutrophication, freshwater**	**Acidification**
Laser machining, metal, with YAG-laser, 500W power {RER}	(X excl. Use)		X	(X excl. Use)		(X excl. Use)	X
Electricity, medium voltage {NL}	(X excl. Use)						
Electricity, medium voltage {RER}	(X excl. Use)					(X excl. Use)	
Aluminium, wrought alloy {GLO}	(X excl. Use)				X		
Energy and auxilliary inputs, metal working factory {RER}	(X excl. Use)						
Nitrogen, liquid {RER}	(X excl. Use)			(X excl. Use)		(X excl. Use)	
Electricity, low voltage {FR}		X					
Silver {GLO}			X			X	
Zinc {GLO}			X				
Molybdenum {RER}			X				
Copper, cathode {GLO}			X				
Electronics, for control units {RER}			X				
Water, deionised {Europe without Switzerland}, market for water				(X excl. Use)			
Water, deionised {Europe without Switzerland}, water production				(X excl. Use)			
Oxygen, liquid {RER}, industrial gases production, cryogenic air separation				(X excl. Use)			
Magnesium {GLO}					X		
Tungsten, metallic {GLO}					X		X
Magnesium-alloy, AZ91 {RER}					X		
Electricity, low voltage {RER}						(X excl. Use)	
Iron-nickel-chromium alloy {RER}							X
Nickel, 99.5% {GLO}							X
LCS2: Manufacturing							
Electricity, high voltage {BR-North-eastern grid}	(X excl. Use)	X			X		X
Building, hall, steel construction {CH}	(X excl. Use)				(X excl. Use)		(X excl. Use)

Processes per life cycle stage	Climate change[27]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Electricity, medium voltage {FR}	(X excl. Use)	X					
MAIT processes					(X excl. Use)		(X excl. Use)
LCS3: Distribution							
Diesel, low-sulfur {RER}	(X excl. Use)	X			(X excl. Use)		(X excl. Use)
LCS4: Use stage							
Sodium perchlorate {GLO}, sodium perchlorate production	X	X	X	X	X	X	X
Hazardous waste, for incineration {Europe without Switzerland}	X	X			X	X	X
Sodium perchlorate {GLO}, market for sodium perchlorate production	X	X	X		X	X	X
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	X	X			X	X	X
Hydrogen, gaseous, methanol reforming, propellant {French Guiana}	X				X		
Electricity, high voltage {BR-North-eastern grid}	X	X			X		
Nitrogen, liquid {RER}	X	X		X	X	X	X
Heat, central or small-scale, other than natural gas {RoW}	X	X			X		X
Heat, district or industrial, natural gas {RER}	X	X					
Liquid storage tank, chemicals, organics {RoW}	X	X			X	X	X
Methanol {GLO}	X	X					X
Heat, district or industrial, natural gas {FR}	X	X					
Ammonia, anhydrous, liquid {RER}	X	X					
Butadiene {RER}		X					
Distribution network, electricity, low voltage {GLO}			X				
Chemical factory, organics {GLO}			X				
Oxygen, liquid {FG}				X			

Processes per life cycle stage	Climate change[27]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Sulfuric acid {RER}					X		X
Launch emissions DeltaV10 (SSO)	X[30]						X
LCS5: End of Life stage							
LCS5 was not assessed							

Table 36. List of most relevant processes per most relevant impact category for Uncrewed launch services from Earth to Space sub-category, per reference ΔV10.6 (indicated with „X").

Processes per life cycle stage	Climate change[31]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
LCS1: Raw material acquisition and pre-processing							
Aluminium, primary, liquid {GLO}	X	X		(X excl. Use)	X	X	X
Electricity, medium voltage {DE}	X	X			X	X	X
Electricity, medium voltage {FR}	X	X		(X excl. Use)	X	X	X
Cobalt {GLO}	X	X	X	X	X	X	X
Acrylonitrile {GLO}	X	X		(X excl. Use)	X		X
Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}	X[32] (X excl. Use)[33]	X			X		X
Aluminium, cast alloy {RER}	(X excl. Use)		X	(X excl. Use)	X	(X excl. Use)	X
Oxygen, liquid {RER}, market for	(X excl. Use)	X		(X excl. Use)		X	X
Steel, chromium steel 18/8 {RER}	(X excl. Use)		X		X	X	X

[30] Applies only when climate change impact from launch and re-entry emissions is **included**.
[31] The most relevant processes when including and excluding climate change impact from launch and re-entry emissions from propellant use are the same, unless otherwise indicated.
[32] Applies only when climate change impact from launch and re-entry emissions is **excluded.**
[33] Applies only when climate change impact from launch and re-entry emissions is **included**.

Processes per life cycle stage	**Climate change[31]**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**	**Particulate matter**	**Eutrophication, freshwater**	**Acidification**
Laser machining, metal, with YAG-laser, 500W power {RER}	(X excl. Use)		X	(X excl. Use)		(X excl. Use)	X
Electricity, medium voltage {NL}	(X excl. Use)						
Electricity, medium voltage {RER}	(X excl. Use)					(X excl. Use)	
Nitrogen, liquid {RER}	(X excl. Use)			(X excl. Use)		(X excl. Use)	
Energy and auxilliary inputs, metal working factory {RER}	(X excl. Use)						
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	(X excl. Use)						
Electricity, low voltage {FR}		X					
Silver {GLO}			X			X	
Zinc {GLO}			X				
Molybdenum {RER}			X				
Copper, cathode {GLO}			X				
Electronics, for control units {RER}			X				
Water, deionised {Europe without Switzerland}, market for water				(X excl. Use)			
Water, deionised {Europe without Switzerland}, water production				(X excl. Use)			
Oxygen, liquid {RER}, industrial gases production, cryogenic air separation				(X excl. Use)			
Magnesium {GLO}					X		
Tungsten, metallic {GLO}					X		X
Magnesium-alloy, AZ91 {RER}					X		
Building, hall, steel construction {CH}					X		
Electricity, low voltage {RER}						(X excl. Use)	
Iron-nickel-chromium alloy {RER}							X
Nickel, 99.5% {GLO}							X
LCS2: Manufacturing							
Electricity, high voltage {BR-North-eastern grid}	(X excl. Use)	X			X		X

Processes per life cycle stage	Climate change[31]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Building, hall, steel construction {CH}	(X excl. Use)				(X excl. Use)		(X excl. Use)
Electricity, medium voltage {FR}	(X excl. Use)	X					
MAIT processes					(X excl. Use)		(X excl. Use)
LCS3: Distribution							
Diesel, low-sulfur {RER}	(X excl. Use)	(X excl. Use)			(X excl. Use)		(X excl. Use)
LCS4: Use stage							
Sodium perchlorate {GLO}, sodium perchlorate production	X	X	X	X	X	X	X
Hazardous waste, for incineration {Europe without Switzerland}	X	X			X	X	X
Sodium perchlorate {GLO}, market for sodium perchlorate production	X	X	X		X	X	X
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	X	X			X	X	X
Hydrogen, gaseous, methanol reforming, propellant {French Guiana}	X				X		
Electricity, high voltage {BR-North-eastern grid}	X	X			X		X
Nitrogen, liquid {RER}	X	X		X	X	X	X
Heat, district or industrial, natural gas {RER}	X	X					
Heat, central or small-scale, other than natural gas {RoW}	X	X					X
Liquid storage tank, chemicals, organics {RoW}	X	X			X	X	X
Methanol {GLO}	X	X					X
Heat, district or industrial, natural gas {FR}	X	X			X		
Ammonia, anhydrous, liquid {RER}	X	X					
Butadiene {RER}		X					
Distribution network, electricity, low voltage {GLO}			X				

Processes per life cycle stage	Climate change[31]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Eutrophication, freshwater	Acidification
Chemical factory, organics {GLO}			X				
Oxygen, liquid {FG}				X			
Sulfuric acid {RER}					X		X
Launch emissions DelraV10.6 (MEO)	X[34]						X
LCS5: End of Life stage							
LCS5 was not assessed							

Table 37. List of most relevant processes per most relevant impact category for Uncrewed launch services from Earth to Space sub-category, per reference ΔV12 (indicated with „X").

Processes per life cycle stage	Climate change[35]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Acidification
LCS1: Raw material acquisition and pre-processing						
Aluminium, primary, liquid {GLO}	X	X		(X excl. Use)	X	X
Electricity, medium voltage {DE}	X	X				X
Electricity, medium voltage {FR}	X	X		(X excl. Use)	X	X
Cobalt {GLO}	X	X	X	X	X	X
Acrylonitrile {GLO}	X	X		(X excl. Use)	X	X
Steel, chromium steel 18/8 {RER}	X	X	X		X	X
Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}	X	X			X	X
Aluminium, cast alloy {RER}	X		X	(X excl. Use)	X	X
Oxygen, liquid {RER}, market for	X	X		(X excl. Use)		X
Tin plated chromium steel sheet, 2 mm {GLO}	X		X		X	X
Electricity, medium voltage {RER}	X[36] (X excl. Use)[37]					

[34] Applies only when climate change impact from launch and re-entry emissions from propellant use is **included**.
[35] The most relevant processes when including and excluding climate change impact from launch and re-entry emissions from propellant use are the same, unless otherwise indicated.
[36] Applies only when climate change impact from launch and re-entry emissions from propellant use is **excluded.**
[37] Applies only when climate change impact from launch and re-entry emissions from propellant use is **included**.

Processes per life cycle stage	**Climate change[35]**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**	**Particulate matter**	**Acidification**
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	(X excl. Use)				X	X
Laser machining, metal, with YAG-laser, 500W power {RER}	(X excl. Use)		X	(X excl. Use)		X
Aluminium, wrought alloy {GLO}	(X excl. Use)				X	
Energy and auxilliary inputs, metal working factory {RER}	(X excl. Use)					
Electricity, medium voltage {NL}	(X excl. Use)					
Electricity, low voltage {FR}		X				
Silver {GLO}			X			
Zinc {GLO}			X			
Molybdenum {RER}			X			
Electronics, for control units {RER}			X			
Copper, cathode {GLO}			X			
Water, deionised {Europe without Switzerland}, market for water				(X excl. Use)		
Water, deionised {Europe without Switzerland}, water production				(X excl. Use)		
Nitrogen, liquid {RER}				(X excl. Use)		
Oxygen, liquid {RER}, industrial gases production, cryogenic air separation				(X excl. Use)		
Iron-nickel-chromium alloy {RER}				(X excl. Use)		X
Magnesium {GLO}					X	
Magnesium-alloy, AZ91 {RER}					X	
Tungsten, metallic {GLO}					X	X
Nickel, 99.5% {GLO}						X
LCS2: Manufacturing						
Electricity, high voltage {BR-North-eastern grid}	(X excl. Use)	(X excl. Use)			X	X
Electricity, medium voltage {FR}	(X excl. Use)	X				
Building, hall, steel construction {CH}	(X excl. Use)				(X excl. Use)	(X excl. Use)
MAIT processes					(X excl. Use)	(X excl. Use)
LCS3: Distribution						
Diesel, low-sulfur {RER}	(X excl. Use)	X			(X excl. Use)	(X excl. Use)
LCS4: Use stage						
Sodium perchlorate {GLO}, sodium perchlorate production	X	X	X	X	X	X

Processes per life cycle stage	Climate change[35]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Acidification
Hazardous waste, for incineration {Europe without Switzerland}	X	X			X	X
Electricity, high voltage {BR-North-eastern grid}	X	X			X	X
Hydrogen, gaseous, methanol reforming, propellant {French Guiana}	X				X	
Liquid storage tank, chemicals, organics {RoW}	X	X			X	X
Heat, central or small-scale, other than natural gas {RoW}	X	X			X	X
Sodium perchlorate {GLO}, market for sodium perchlorate production	X	X	X		X	X
Launch emissions DeltaV12 (GTO)	X[38]					X
Aluminium, primary, ingot {IAI Area, EU27 & EFTA}	X	X			X	X
Methanol {GLO}	X	X			X	X
Nitrogen, liquid {RER}	X	X		X		X
Heat, district or industrial, natural gas {RER}	X	X				
Heat, district or industrial, natural gas {FR}	X	X				
Ammonia, anhydrous, liquid {RER}	X					
Kerosene {RoW}		X				
Diesel, low-sulfur {RER}		X				
Natural gas, high pressure {FR}		X				
Distribution network, electricity, low voltage {GLO}			X			
Liquid storage tank, chemicals, organics {RoW}			X			
Oxygen, liquid {FG}				X		
Sulfuric acid {RER}					X	X
Transport, freight, sea, tanker for liquid goods other than petroleum						X

[38] Applies only when climate change impact from launch and re-entry emissions from propellant use is **included**.

Processes per life cycle stage	Climate change[35]	Resource use, fossils	Resource use, minerals and metals	Water use	Particulate matter	Acidification
and liquefied natural gas, heavy fuel oil {GLO}						

4.4 Most relevant direct elementary flows

[the list shall be provided based on the final results of the PEF studies of the representative product(s). Provide one list per sub-category, if appropriate.]

Due to limited data availability, the most relevant direct elementary flows are not identified at this stage.

5. Life cycle inventory

All newly created datasets shall be EF compliant.

[The PEFCR shall indicate if sampling is allowed. If the Technical Secretariat allows sampling, the PEFCR shall describe the sampling procedure as described in the PEF method and contain the following sentence:]

In case sampling is needed, it shall be conducted as specified in this PEFCR. However, sampling is not mandatory and any user of this PEFCR may decide to collect the data from all the plants or farms, without performing any sampling.

[This section will be completed after the open consultation.]

5.1 List of mandatory company-specific data

[This section will be completed after the open consultation.]

[The Technical Secretariat shall here list the processes to be modelled with mandatory company-specific data (i.e. activity data and direct elementary flows). Note that the direct elementary flows listed shall be aligned with the nomenclature used by the most recent version of the EF reference package124.]

Process A

[Provide a short description of process A. List all the activity data and direct elementary flows that shall be collected and the default datasets of the sub-processes linked to the activity data within process A. Use the table below to introduce minimum one example in the PEFCR. In case not all processes are introduced here, the full list of all processes shall be include in an excel file.]

Table: Data collection requirements for mandatory process A

Requirements for data collection purposes			Requirements for modelling purposes								Re-marks
Activity data to be collec-ted	Specific require-ments (e.g. frequency, measure-ment standard, etc.)	Unit of measu-re	Default dataset to be used	Dataset source (i.e. node)	UUID	TiR	TeR	GeR	P	DQR	
Inputs:											
[E.g.: yearly electri-city use]	[E.g.: 3 year average]	[E.g. kWh/year]	[E.g.: Electricity grid mix 1kV-60kV/EU28+3]	[Link to appropriate node of the Life Cycle Data Network. The 'data stock' shall also be specified]	[E.g.: 0af0a6a8-aebc-4eeb-99f8-5ccf2304b99d]	[E.g 1.6]					
Outputs:											
...	...	...	...	...	...	...					

Available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[List all the emissions and resources that shall be modelled with company-specific information (most relevant foreground elementary flows) within process A.]

Table B. 6. Direct elementary flow collection requirements for mandatory process A

Emissions/resources	Elementary flow	UUID	Frequency of measurement	Default measurement method[125]	Remarks

[125] Unless specific measurements/methods are foreseen in a country-specific legislation.

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See excel file named '[Name PEFCR_version number] - Life cycle inventory' for the list of all company-specific data to be collected.

See excel file named '[Name PEFCR_version number] - Life cycle inventory' for the list of all company-specific data to be collected.

5.2 List of processes expected to be run by the company

[This section will be completed after the open consultation.]

[The processes listed in this section shall be additional to the ones listed as mandatory company-specific data. No repetition of processes or data is allowed. In case there are no further processes expected to be run by the company, please state 'There are no further processes expected to be run by the company in addition to those listed as mandatory company-specific data.']

The following processes are expected to be run by the user of the PEFCR:

- Process X
- Process Y
- …

Process X:

[Provide a short description of process 'x'. List the activity data and direct elementary flows that shall be collected as a minimum, and the datasets of the sub-processes linked to the activity data within process 'x'. Indicate the unit of measurement, how to

measure and any other characteristic that could help de user. Note that the direct elementary flows listed shall be aligned with the nomenclature used by the most recent version of the EF reference package126 . Use the table below to introduce minimum one example in the PEFCR. In case not all processes are introduced here, the full list of all processes shall be include in an excel file.]

Table 38: Data collection requirements for process X

Table B. 7. Data collection requirements for process X

Requirements for data collection purposes			Requirements for modelling purposes								Re-marks
Activity data to be collec-ted	Specific require-ments (e.g. frequency, measure-ment standard, etc.)	Unit of measu-re	Default dataset to be used	Dataset source (i.e. node and data stock)	UUID	TiR	TeR	GeR	P	DQR	
Inputs:											
[E.g.: yearly electri-city	[E.g.: 3 year average]	[E.g. kWh/ year]	[E.g.: Electricity grid mix 1kV-	[Link to appropriate node of the	[E.g.: 0af0a6a8-aebc-	[E.g 1.6]					

Available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

use]			60kV/EU28+3]	Life Cycle Data Network. The 'data stock' shall also be specified]	4eeb-99f8-5ccf2304b99d]						

Requirements for data collection purposes			Requirements for modelling purposes								Re-marks
Outputs:											
…	…	…	…	…	…	…					

Table B. 8. Direct elementary flow collection requirements for process X

Emissions/resources	Elementary flow	UUID	Frequency of measurement	Default measurement method[127]	Remarks

See excel file named '[Name PEFCR_version number] - Life cycle inventory' for the list of all processes expected to be in situation 1.

5.3 Data quality requirements

The data quality of each dataset and the total PEF study shall be calculated and reported. The calculation of the DQR shall be based on the following formula with four criteria:

$$DQR = \frac{TeR+GeR+TiR+P}{4}$$

[Equation 1]

where TeR is technological representativeness, GeR is geographical representativeness, TiR is time representativeness, and P is precision. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and related level of uncertainty. The next sections provide tables with the criteria to be used for the semi-quantitative assessment of each criterion.

[The PEFCR may specify more stringent data quality requirements and specify additional criteria for the assessment of data quality. The PEFCR shall report the formulas to be used for assessing the DQR of i) company-specific data (equation 20 of Annex I), ii) secondary datasets (equation 19 of Annex I), iii) PEF study (equation 20 of Annex I).]

5.3.1 Company-specific datasets

The DQR shall be calculated at the level-1 disaggregation, before any aggregation of sub-processes or elementary flows is performed. The DQR of company-specific datasets shall be calculated as following:

- Select the most relevant activity data and direct elementary flows: most relevant activity data are the ones linked to sub-processes (i.e. secondary datasets) that account for at least 80% of the total environmental impact of the company-specific dataset, listing them from the most contributing to the least contributing one. Most relevant direct elementary flows are defined as those direct elementary flows contributing cumulatively at least with 80% to the total impact of the direct elementary flows.

- Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and each most relevant direct elementary flow. The values of each criterion shall be assigned based on Table B.9.
  - Each most relevant direct elementary flow consists of the amount and elementary flow naming (e.g. 40 g carbon dioxide). For each most relevant elementary flow, the user of the PEFCR shall evaluate the 4 DQR criteria named TeR-EF, TiR-EF, GeR-EF, PEF. For example, the user of the PEFCR shall evaluate the timing of the flow measured, for which technology the flow was measured and in which geographical area.
  - For each most relevant activity data, the 4 DQR criteria shall be evaluated (named TeR-AD TiR-AD, GeR-AD, PAD) by the user of the PEFCR.
  - Considering that the data for the mandatory processes shall be company-specific, the score of P cannot be higher than 3, while the score for TiR, TeR, and GeR cannot be higher than 2 (The DQR score shall be ≤1.5).

- Calculate the environmental contribution of each most relevant activity data (through linking to the appropriate sub-process) and each most relevant direct elementary flow to the total sum of the environmental impact of all most-relevant activity data and direct elementary flows, in % (weighted, using all EF impact categories). For example, the newly developed dataset has only two most relevant activity data, contributing in total to 80% of the total environmental impact of the dataset:
    - Activity data 1 carries 30% of the total dataset environmental impact. The contribution of this process to the total of 80% is 37.5% (the latter is the weight to be used).
    - Activity data 2 carries 50% of the total dataset environmental impact. The contribution of this process to the total of 80% is 62.5% (the latter is the weight to be used).
- Calculate the TeR, TiR, GeR and P criteria of the newly developed dataset as the weighted average of each criteria of the most relevant activity data and direct elementary flows. The weight is the relative contribution (in %) of each most relevant activity data and direct elementary flow calculated in step 3.
- The user of the PEFCR shall calculate the total DQR of the newly developed dataset using Equation B.2, where $\overline{TeR}$,$\overline{TiR}$,$\overline{GeR}$,$\overline{P}$ are the weighted average calculated as specified in point (4).

$$DQR = \frac{\overline{Te_R}+\overline{Ge_R}+\overline{Ti_R}+\overline{P}}{4}$$ [Equation 2]

Table B. 9. How to assess the value of the DQR criteria for datasets with company-specific information [Note that the reference years for criterion TiR may be adapted by the TS; more than one table may be included in the PEFCR].

Rating	P_{EF} and P_{AD}	TiR_{EF} and TiR_{AD}	TeR_{EF} and TeR_{AD}	GeR_{EF} and GeR_{AD}
1	Measured/calculated and externally verified	The data refers to the most recent annual administration period with respect to the EF report publication date	The elementary flows and the activity data explicitly depict the technology of the newly developed dataset	The activity data and elementary flows reflect the exact geography where the process modelled in the newly created dataset takes place
2	Measured/calculated and internally verified, plausibility checked by reviewer	The data refers to maximum 2 annual administration periods with respect to the EF report publication date	The elementary flows and the activity data are a proxy of the technology of the newly developed dataset	The activity data and elementary flows partly reflect the geography where the process modelled in the newly created dataset takes place
3	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data refers to maximum three annual administration periods with respect to the EF report publication date	Not applicable	Not applicable
4-5	Not applicable	Not applicable	Not applicable	Not applicable

P_{EF}: Precision for elementary flows; P_{AD}: Precision for activity data; TiR_{EF}: Time Representativeness for elementary flows; TiR_{AD}: Time representativeness for activity data; TeR_{EF}: Technology representativeness for elementary flows; TeR_{AD}: Technology representativeness for activity data; GeR_{EF}: Geographical representativeness for elementary flows; GeR_{AD}: Geographical representativeness for activity data.

5.4 Data needs matrix (DNM)

All processes required to model the product and outside the list of mandatory company-specific data shall be evaluated using the Data Needs Matrix (see Figure 11 and Figure 12). The DNM shall be applied to evaluate which data is needed and shall be used within the modelling, depending on the level of influence the user of the PEFCR (company) has on the specific process. The simplified DNM shall be applied (see Figure 11) when following the horizontal rules, or when no list of most relevant processes is identified in the sub-category. The full DNM shall be applied (see Figure 12) by those sub-categories where the list of most relevant processes is identified.

The following three cases are found in the DNM and are explained below:

- **Situation 1:** the process is run by the company applying the PEFCR;
- **Situation 2:** the process is not run by the company applying the PEFCR but the company has access to (company-)specific information;
- **Situation 3:** the process is not run by the company applying the PEFCR and this company does not have access to (company-)specific information.

		Data requirements
Situation 1: process run by the company	Option 1	Provide company-specific data (both activity data and direct emissions) and create a company-specific dataset (DQR≤1.5). Calculate DQR of the dataset following the rules in Section 4.6.5.2.
Situation 2: process not run by the company but with access to company-specific information	Option 1	Provide company-specific data and create a company-specific dataset (DQR≤1.5). Calculate DQR of the dataset following the rules in Section 4.6.5.2.
	Option 2	Use an EF compliant secondary dataset and apply company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0). Recalculate DQR of the dataset used (see Section 4.6.5.6).
Situation 3: process not run by the company and without access to company-specific information	Option 1	Use an EF compliant secondary dataset in aggregated form (DQR≤3.0). Recalculate DQR of the dataset if the process is most-relevant (see Section 4.6.5.7).

Figure 11. DNM to be used on horizontal level or when no most relevant processes are identified in the sub-categories.

		Most relevant process	Other process
Situation 1: process run by the company using the PEFCR	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5)[129] Calculate the DQR values (for each criterion + total)	
	Option 2		Use default secondary dataset in PEFCR, in aggregated form (DQR≤3.0) Use the default DQR values
Situation 2: process not run by the company using the PEFCR but with access to company-specific information	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5) Calculate the DQR values (for each criterion + total)	
	Option 2	Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0)* Re-evaluate the DQR criteria within the product specific context	
	Option 3		Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0)* Use the default DQR values.
Situation 3: process not run by the company using the PEFCR and without access to company-	Option 1	Use default secondary data set in aggregated form (DQR≤3.0) Re-evaluate the DQR criteria within the product specific context	
	Option 2		Use default secondary data set in aggregated form (DQR≤4.0) Use the default DQR values

*Figure 12. DNM to be used by the sub-categories where the most relevant processes have been identified. *Disaggregated datasets shall be used.*

5.4.1 Processes in situation 1

For each process in situation 1 there are two possible options:

- The process is in the list of most relevant processes as specified in the PEFCR or is not in the list of most relevant process, but still the company wants to provide company-specific data (option 1);
- The process is not in the list of most relevant processes and the company prefers to use a secondary dataset (option 2).

Situation 1/Option 1
For all processes run by the company and where the user of the PEFCR applies company-specific data. The DQR of the newly developed dataset shall be evaluated as described in section B.5.3.1.

Situation 1/Option 2
For the non-most relevant processes only, if the user of the PEFCR decides to model the process without collecting company-specific data, then the user shall use the secondary dataset listed in the PEFCR together with its default DQR values listed here.

If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the metadata of the original dataset.

5.4.2 Processes in situation 2

When a process is not run by the user of the PEFCR, but there is access to company-specific data, then there are three possible options:

- The user of the PEFCR has access to extensive supplier-specific information and wants to create a new EF compliant dataset (Option 1);
- The company has some supplier-specific information and want to make some minimum changes (Option 2);
- The process is not in the list of most relevant processes and the company wants to make some minimum changes (Option 3).

Situation 2/Option 1
For all processes not run by the company and where the user of the PEFCR applies company-specific data, the DQR of the newly developed dataset shall be evaluated as described in section B.5.3.1

Situation 2/Option 2
The user of the PEFCR shall use company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets, starting from the default secondary dataset provided in the PEFCR.
Please note that the PEFCR lists all dataset names together with the UUID of their aggregated dataset. For this situation, the disaggregated version of the dataset is required.

The user of the PEFCR shall make the DQR context-specific by re-evaluating TeR and TiR using the table(s) B.11. The criteria GeR shall be lowered by 30%[130] and the criteria P shall keep the original value.

In situation 2, option 2 it is proposed to lower the parameter GeR by 30% in order to incentivise the use of company-specific information and reward the efforts of the company in increasing the geographic repres

Situation 2/Option 3

The user of the PEFCR shall apply company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets, starting from the default secondary dataset provided in the PEFCR.

Please note that the PEFCR lists all dataset names together with the UUID of their aggregated dataset. For this situation, the disaggregated version of the dataset is required.

In this case, the user of the PEFCR shall use the default DQR values. If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the original dataset.

Table 39: How to assess the value of the DQR criteria when secondary datasets are used

	TiR	TeR	GeR
1	The EF report publication date happens within the time validity of the dataset	The technology used in the EF study is exactly the same as the one in scope of the dataset	The process modelled in the EF study takes place in the country the dataset is valid for
2	The EF report publication date happens not later than 2 years beyond the time validity of the dataset	The technologies used in the EF study are included in the mix of technologies in scope of the dataset	The process modelled in the EF study takes place in the geographical region (e.g. Europe) the dataset is valid for
3	The EF report publication date happens not later than 4 years beyond the time validity of the dataset	The technologies used in the EF study are only partly included in the scope of the dataset	The process modelled in the EF study takes place in one of the geographical regions the dataset is valid for
4	The EF report publication date happens not later than 6 years beyond the time validity of the dataset	The technologies used in the EF study are similar to those included in the scope of the dataset	The process modelled in the EF study takes place in a country that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement.
5	The EF report publication date happens later than 6 years after the time validity of the dataset	The technologies used in the EF study are different from those included in the scope of the dataset	The process modelled in the EF study takes place in a different country than the one the dataset is valid for

5.4.3 Processes in situation 3

If a process is not run by the company using the PEFCR and the company does not have access to company-specific data, there are two possible options:

- It is in the list of most relevant processes (situation 3, option 1);
- It is not in the list of most relevant processes (situation 3, option 2).

Situation 3/Option 1
In this case, the user of the PEFCR shall make the DQR values of the dataset used context-specific by re-evaluating TeR, TiR and GeR, using the table(s) provided. The criteria P shall keep the original value.

Situation 3/Option 2
For the non-most relevant processes, the user of the PEFCR shall apply the corresponding secondary dataset listed in the PEFCR together with its DQR values.

If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the original dataset.

5.5 Datasets to be used

This PEFCR lists the secondary datasets to be applied by the user of the PEFCR in section 0 and Annex XX [Data collection template is still under development]. Whenever a dataset needed to calculate the PEF profile is not among those listed in this PEFCR, then the user shall choose between the following options (in hierarchical order):

- Use an EF compliant dataset available on one of the nodes of the Life Cycle Data Network;
- Use an EF compliant dataset available in a free or commercial source;
- Use another EF compliant dataset considered to be a good proxy. In such case this information shall be included in the ‘limitations‘ section of the PEF report;
- Use an ILCD-EL compliant dataset as proxy. These datasets shall be included in the ‘limitations‘ section of the PEF report. A maximum of 10% of the single overall score may be derived from ILCD-EL compliant datasets. The nomenclature of the elementary flows of the dataset shall be aligned with the EF reference package used in the rest of the model;
- If no EF compliant or ILCD-EL compliant dataset is available, it shall be excluded from the PEF study. This shall be clearly stated in the PEF report as a data gap and validated by the PEF study and PEF report verifiers.

5.6 How to calculate the average DQR of the study

To calculate the average DQR of the PEF study, the user of the PEFCR shall calculate separately the TeR, TiR, GeR and P for the PEF study as the weighted average of all most relevant processes, based on their relative environmental contribution to the total single overall score. The calculation rules explained in section 4.6.5.8 of Annex I of the PEF method shall be used.

5.7 Allocation rules

[The PEFCR shall define which allocation rules shall be applied by the user of the PEFCR and how the modelling/ calculations shall be made. In case economic allocation is used, the calculation method on how to derive the allocation factors shall be fixed and prescribed in the PEFCR. The following template shall be used:]

Allocation shall be applied only when sub-division is not feasible. For example, when two payloads deliver two different services, the payloads can be directly linked to the service provided. However, the single platform serving both payloads will need to be allocated over both services provided.

The following allocations shall be followed when applying this PEFCR. Allocation modelling rules are listed in Table 40:

1. In case the spacecraft delivering the service (as described by the FU) also delivers other service types, it is required to allocate the spacecraft platform (and all related inputs and outputs) to the specific service in scope. Figure 13 presents a schematic example. For example: the Eutelsat 5 West B satellite launched in 2020 carries a payload for its own video broadcasting services and the GEO-3 payload of the European Geostationary Navigation Overlay Service (EGNOS).

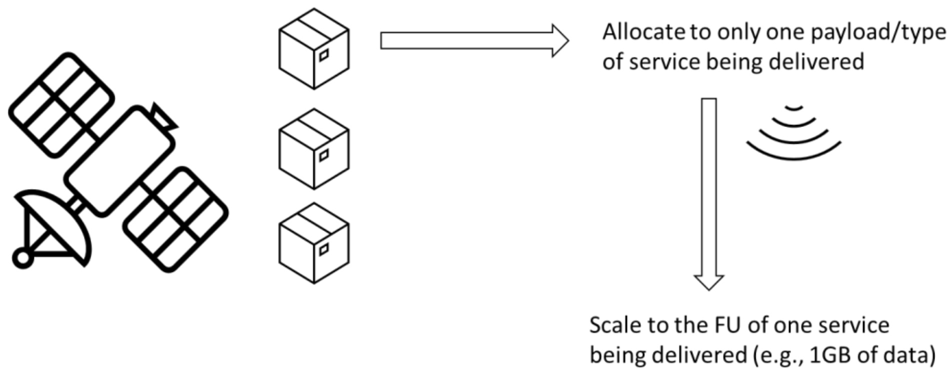

Figure 13. Schematic example of allocation and scaling (using the reference flow) of a satellite-platform.

Note: For Software-defined Satellites (SDS), no allocation between the different services shall be applied. The user of the PEFCR shall, for simplicity, model the satellite assuming 100% delivery of the service in scope of the study.

2. In case (ground) infrastructure delivers support to multiple spacecrafts or services, it is required to allocate the infrastructure to the specific use in scope of the study (e.g, cleanroom use, storage facility, launch site, SCC/MCC, datacenter), a physical allocation approach shall be used. The physical allocation unit to be used is process specific and described together with the modelling requirements of that dataset in Section 0.

   For example: in the case Flexsat satellites that are able to provide simultaneously video broadcasting and connectivity services, the associated Earth station will have to be properly split between those 2 distinct services.

3. In case the launcher, used to launch the spacecraft to space, carries multiple payloads, a mass allocation shall be used. The spacecraft integration and testing in launcher, the launch activities, launcher propellant, and the launcher shall be allocated to the spacecraft based on the mass carried by the launcher.

4. In case the kickstage as part of the launcher is used to both (i) release the spacecraft and (ii) engine for in-space transport, the amount of ΔV shall be used to allocate the impact over both functions. In case of a multiple launch, the fraction of the kickstage needs to be further allocated over the payloads launched using mass allocation as described in point 4. above. See Section 5.10 for more details on the modelling of the kickstage.

Table 40. Allocation modelling rules.

Nr.	Process	Allocation rule (in hierarchical order)	Modelling instructions	Allocation factor
1	All processes linked to the spacecraft production, distribution, use and end of life	(1) If the space services carry the same "WHAT" in their FU: "What" of the FU shall be used as basis of the allocation. (2) If the services delivered have a different "What" in their FU: mass shall be used: (Mass of equipment delivering the FU) / (total mass of all equipment delivering all service types of the spacecraft).	All processes linked to the spacecraft production, distribution, use and end of life shall be allocated to the service in scope	Company specific values
2	All supporting ground infrastructure	(1) If the supported space services carry the same "WHAT" in their FU: this shall be used as basis of the allocation. (2) If the supported services have a different "What" in their FU: the time using the supporting ground infrastructure shall be used.	All processes linked to the supporting ground infrastructure (as indicated in the system boundary diagram) shall be allocated using the FU or time as a basis. See Section 0 for process specific requirements.	Company specific values.
3	All activities linked to one launcher (incl. propellant, transport, emissions,…)	The total launched payload mass.	The amount of spacecraft being launched as % of the total launched payload for this specific launch is used to allocate	Company specific values
4	Kickstage	The amount of ΔV shall be used to allocate the impact over the functions delivered.	Kickstage manufacturing, distribution, use and EOL shall be allocated to the life cycle it peforms the function for, using the amount of ΔV related.	Company specific values

5.7.1 Earth Observation Services Allocation

Table 41 presents the specified allocation rules if either the spacecraft or the supporting ground infrastructure is delivering multiple services.

Table 41: Allocation rules for Earth observation services

Nr.	Process	Allocation rule	Modelling instructions	Allocation factor
1	All processes linked to the spacecraft production, distribution, use and end of life	(Mass of payload equipment delivering the FU) / (total mass of all payload equipment delivering all service types of the spacecraft)	All processes linked to the spacecraft production, distribution, use and end of life shall be allocated based on this mass fraction	Company specific

5.7.2 Positioning, Navigation and Timing Services Allocation

Table 42 presents the specified allocation rules if either the spacecraft (Nr.1) or the supporting ground infrastructure (Nr. 2) is delivering multiple PNT services. Only open Service (OS) for civilian users (free positioning service) are in scope of this PEFCR. Allocation between multiple PNT services will be necessary in case the spacecraft and supporting ground infrastructure also deliver one of the following services: High Accuracy Service (HAS) with improved position for authorized users; Public Regulated Service (PRS) which is an encrypted service for government use; and/or Search and Rescue (SAR) to help locate distress signals worldwide. This allocation shall be done after allocation between sub-categories.

Table 42: Allocation rules for PNT services between multiple PNT services provided

Nr.	Process	Allocation rule	Modelling instructions	Allocation factor
1	All processes linked to the payload equipment production, distribution, use and end of life	(Power of payload equipment delivering the FU) / (total power of payload equipment for all PNT services provided)	All processes linked to the payload equipment production, distribution, use and end of life shall be allocated based	Company specific

			on the power of payload fraction	
2	All supporting ground infrastructure	Time using the supporting ground infrastructure / total time the supporting ground infrastructure is being used	All processes linked to the supporting ground infrastructure (as indicated in the system boundary diagram) shall be allocated using time as a basis.	Company specific

A default allocation factor for the allocation to Open Services is 75%. This estimate is generated by combining expert insights with information published by the European Space Agency in its Annual Reports, reports published by the European Commission on the development and application of the Galileo program, publications of the European GNSS Agency and Market reports and Industry analyses.

5.7.3 Satellite Video Services Allocation

Table 43 presents the specified allocation rules if the spacecraft (Nr.1) is delivering multiple services related to satellite video services. In case satellites deliver both video and connectivity services, and the assumed split between the two is estimated before launch, the allocation shall be performed based on the estimated split of Mbps per service type delivered. Only if the split is not known beforehand, an assumption of 100% service delivery for either video or connectivity services shall be made. Since the functional unit is per Mbps delivered, the environmental impact between both approaches stays the same. If the satellite however delivers multiple services not being video and connectivity services, meaning if the functional unit is not shared (here in Mbps) the horizontal rules shall apply, and the allocation shall be made based on time.

In case the satellite in scope is a so called Software-defined Satellite (SDS), the user shall, for simplicity, assume 100% of video service delivery over its full life time.

Table 43. Allocation rules for satellite video services.

Nr.	Process	Allocation rule	Modelling instructions	Allocation factor
1	All processes linked to the spacecraft production,	(Mbps of equipment delivering the FU) / (total Mbps of all equipment delivering	All processes linked to the spacecraft production,	Company specific

	distribution, use and end of life	all service types of the spacecraft)	distribution, use and end of life shall be allocated using Mbps (or time).	

5.7.4 Satellite Connectivity Services Allocation

Table 44 presents the specified allocation rules if the spacecraft is delivering multiple services related to satellite communication. In case satellites deliver both video and connectivity services, and the assumed split between the two is estimated before launch, the allocation shall be performed based on the estimated split of Mbps per service type delivered. Only if the split is not known beforehand, an assumption of 100% service delivery for either video or connectivity services shall be made. Since the functional unit is per Mbps delivered, the environmental impact between both approaches stays the same. If the satellite however delivers multiple services not being video and connectivity services, meaning if the functional unit is not shared (here in Mbps) the horizontal rules shall apply.

In case the satellite in scope is a so called Software-defined Satellite (SDS), the user shall, for simplicity, assume 100% of video service delivery over its full life time.

Table 44. Allocation rules for satellite connectivity services.

Nr.	Process	Allocation rule	Modelling instructions	Allocation factor
1	All processes linked to the spacecraft production, distribution, use and end of life	(Mbps of equipment delivering the FU) / (total Mbps of all equipment delivering all service types of the spacecraft)	All processes linked to the spacecraft production, distribution, use and end of life shall be allocated using Mbps (or time).	Company specific

5.7.5 In-Space Transport Services Allocation

Table 45 presents the specified allocation rules if either the servicer spacecraft or the supporting ground infrastructure is delivering multiple services.

Table 45: Allocation rules for in-space transport services

Nr.	Process	Allocation rule	Modelling instructions	Allocation factor
1	All processes linked to the servicer spacecraft production, distribution, use and end of life	(Mass of equipment delivering the transport service) / (total mass of all equipment delivering all service types of the servicer spacecraft, such as refuelling or repairing)	All processes linked to the spacecraft production, distribution, use and end of life shall be allocated based on this mass fraction	Company specific
2	All supporting ground infrastructure	the time using the supporting ground infrastructure shall be used: (time using the supporting ground infrastructure/ total time the supporting ground infrastructure is being used.	All processes linked to the supporting ground infrastructure (as indicated in the system boundary diagram) shall be allocated using the FU or time as a basis.	Company specific

In the case a kick stage is used that aids both the launcher and in-space transport, allocation may be required. If the kickstage aids in the launch activity by providing ΔV, part of the kickstage shall be allocated to the launcher. See section 5.10 on the modelling of the kickstage.

5.7.6 Uncrewed launch services from Earth to space allocation

In the case a kick stage is used, the functions it provides need to be evaluated. If it is fully used to launch a payload to a larger ΔV then the kick stage is accounted to the launcher life cycle. If it has multiple functions between the launcher and the in-space transport then allocation needs to be applied. See section 5.10 on the modelling of the kickstage.

No further allocation related to multiple functions has been identified. The FU of the uncrewed launch services from Earth to space is defined per kg of payload and it is independent of the amount of units of cargo sent in orbit. For instance, if the payload includes multiple satellites, the allocation of the impact of the launcher and the launching activity to the satellites is considered in the relevant satellite subcategories.

5.8 Electricity modelling

5.8.1 Electricity mix to be used

The following electricity mix shall be used in hierarchical order:

- Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if:
    - available, and
    - the set of minimum criteria to ensure the contractual instruments are reliable is met.
- The supplier-specific total electricity mix shall be used if:
    - available, and
    - the set of minimum criteria to ensure the contractual instruments are reliable is met.
- The 'country-specific residual grid mix, consumption mix' shall be used. Country-specific means the country in which the life cycle stage or activity occurs. This may be an EU country or non-EU country. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in (a) and (b).
- As a last option, the average EU residual grid mix, consumption mix (EU+EFTA), or region representative residual grid mix, consumption mix, shall be used.

5.8.2 Electricity at the use stage

In the PEF recommendation, the use stage is modelled using the consumption grid mix, as it is impossible to know which electrcitiy product is used by an average consumer. However, in this PEFCR the use stage is mostly not at the consumer side. Therefore, also the use stage follows the general modelling rules as presented in section 5.8 with exception of the user equipment.

The electricity use of the user equipment shall be modelled with the consumption grid mix.

5.8.3 Set of minimum criteria to ensure contractual instruments from suppliers

The environmental integrity of the use of supplier-specific electricity mix depends on ensuring that contractual instruments (for tracking) **reliably and uniquely convey claims to consumers**. Without this, the PEF lacks the accuracy and consistency necessary to drive product/ corporate electricity procurement decisions and accurate consumer (buyer of electricity) claims. Therefore, a set of **minimum criteria** that relate to the integrity of the contractual instruments as reliable conveyers of environmental footprint information has been identified. They represent the minimum features necessary to use supplier-specific mix within PEF studies.

A supplier-specific electricity product/ mix may only be used if the user of the PEF method ensures that the contractual instrument meets the criteria specified below. If contractual instruments do not meet the criteria, then country-specific residual electricity consumption-mix shall be used in the modelling.

The list of criteria below is based on the criteria of the GHG Protocol Scope 2 Guidance133–. A contractual instrument used for electricity modelling shall:

Criterion 1 – Convey attributes

- Convey the energy type mix associated with the unit of electricity produced.
- The energy type mix shall be calculated based on delivered electricity, incorporating certificates sourced and retired (obtained or acquired or withdrawn) on behalf of its customers. Electricity from facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the environmental attributes of the country residual consumption mix where the facility is located.

Criterion 2 – Be a unique claim

- Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.
  133 *World Resources Institute (WRI) and World Business Council for Sustainable Development WBCSD (2015): GHG Protocol Scope 2 Guidance. An amendment to the GHG Protocol. Corporate Standard*
- Be tracked and redeemed, retired, or cancelled by or on behalf of the company (e.g. by an audit of contracts, third party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).

Criterion 3 – Be as close as possible to the period to which the contractual instrument is applied

[The Technical Secretariat may provide more information following the PEF method]

5.8.4 Modelling 'country-specific residual grid mix, consumption mix'

Datasets for residual grid mix, consumption mix, per energy type, per country and per voltage are made available by data providers.

If no suitable dataset is available, the following approach should be used:

Determine the country consumption mix (e.g. X% of MWh produced with hydro energy, Y% of MWh produced with coal power plant) and combine them with LCI datasets per energy type and country/region (e.g. LCI dataset for the production of 1MWh hydro energy in Switzerland).

Activity data related to non-EU country consumption mix per detailed energy type shall be determined based on:

- Domestic production mix per production technologies;
- Import quantity and from which neighbouring countries;
- Transmission losses;
- Distribution losses;
- Type of fuel supply (share of resources used, by import and / or domestic supply).

These data may be found in the publications of the International Energy Agency (IEA (www.iea.org).

Available LCI datasets per fuel technologies. The LCI datasets available are generally specific to a country or a region in terms of:

- fuel supply (share of resources used, by import and/ or domestic supply);
- energy carrier properties (e.g. element and energy contents);
- technology standards of power plants regarding efficiency, firing technology, flue-gas desulphurisation, NOx removal and de-dusting.

5.8.5 Electricity allocation rules

[The PEFCR shall define which physical relationship shall be used by PEF studies: (i) to subdivide the electricity consumption among multiple products for each process (e.g. mass, number of pieces, volume…) and (ii) to reflect the ratios of production/ratios of sales between EU countries/regions when a product is produced in different locations or sold in different countries. Where such data are not available, the average EU mix (EU+EFTA), or region representative mix, shall be used. The following template shall be used...]

Electricity follows the same allocation rules as the allocation of the specific process being modelled. See Section 5.7 and Section 0 for the detailed allocation rules.

A specific electricity type may be allocated to one specific product in the following conditions:

- If the production (and related electricity consumption) of a product occurs in a separate site (building), the energy type physical related to this separated site may be used.
- If the production (and related electricity consumption) of a product occurs in a shared space with specific energy metering or purchase records or electricity bills, the product-specific information (measure, record, bill) may be used.

- If all the products produced in the specific plant are supplied with a publically available PEF study, the company wanting to make the claim shall make all PEF studies available. The allocation rule applied shall be described in the PEF study, consistently applied in all PEF studies connected to the site and verified. An example is the 100% allocation of a greener electricity mix to a specific product.

5.8.6 On-site electricity generation

If on-site electricity production is equal to the site own consumption, two situations apply:

- No contractual instruments have been sold to a third party: the own electricity mix (combined with LCI datasets) shall be modelled.
- Contractual instruments have been sold to a third party: the ‘country-specific residual grid mix, consumption mix’ (combined with LCI datasets) shall be used.

If electricity is produced in excess of the amount consumed on-site within the defined system boundary and is sold to, for example, the electricity grid, this system may be seen as a multifunctional situation. The system will provide two functions (e.g. product + electricity) and the following rules shall be followed:

1. If possible, apply subdivision. Subdivision applies both to separate electricity productions or to a common electricity production where you may allocate based on electricity amounts the upstream and direct emissions to your own consumption and to the share you sell out of your company (e.g. if a company has a windmill on its production site and exports 30% of the produced electricity, emissions related to 70% of produced electricity should be accounted in the PEF study).
2. If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution134.

Subdivision is considered as not possible when upstream impacts or direct emissions are closely related to the product itself.

5.9 Climate change modelling

The impact category ‘climate change’ shall be modelled considering three sub-categories:

- **Climate change – fossil:** This sub-category includes emissions from peat and calcination/carbonation of limestone. The emission flows ending with '(fossil)' (e.g., 'carbon dioxide (fossil)' and 'methane (fossil)') shall be used, if available.

- **Climate change – biogenic:** This sub-category covers carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of biomass by means of its transformation or degradation (e.g. combustion, digestion, composting, landfilling) and CO_2 uptake from the atmosphere through photosynthesis during biomass growth – i.e. corresponding to the carbon content of products, biofuels or aboveground plant residues, such as litter and dead wood. Carbon exchanges from native forests[135] shall be modelled under sub-category 3 (incl. connected soil emissions, derived products, residues). The emission flows ending with '(biogenic)' shall be used.

  A simplified modelling approach shall be used when modelling foreground emissions. Only the emission 'methane (biogenic)' is modelled, while no further biogenic emissions and uptakes from atmosphere are included. If methane emissions can be both fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining fossil methane.

- **Climate change – land use and land use change**: This sub-category accounts for carbon uptakes and emissions (CO_2, CO and CH_4) originating from carbon stock changes caused by land use change and land use. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions). For native forests, all related CO_2 emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forest[136] and residues), while their CO_2 uptake is excluded. The emission flows ending with '(land use change)' shall be used.

  For land use change, all carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI 2011) and the supplementary document PAS2050-1:2012 (BSI 2012) for horticultural products. PAS 2050:2011 (BSI 2011): 'Large emissions of GHGs can result as a consequence of land use change. Removals as a direct result of land use change (and not as a result of long-term management practices) do not usually occur, although it is recognized that this could happen in specific circumstances. Examples of direct land use change are the conversion of land used for growing crops to industrial use or conversion from forestland to cropland. All forms of land use change that result in emissions or removals are to be included. Indirect land use change refers to such conversions of land use as a consequence of changes in land use elsewhere. While GHG emissions also arise from indirect land use change, the methods and data requirements for calculating these emissions are not fully developed. Therefore, the assessment of emissions arising from indirect land use change is not included.

The GHG emissions and removals arising from direct land use change shall be assessed for any input to the life cycle of a product originating from that land and shall be included in the assessment of GHG emissions. The emissions arising from the product shall be assessed on the basis of the default land use change values provided in PAS 2050:2011 Annex C, unless better data is available. For countries and land use changes not included in this annex, the emissions arising from the product shall be assessed using the included GHG emissions and removals occurring as a result of direct land use change in accordance with the relevant sections of the IPCC (2006). The assessment of the impact of land use change shall include all direct land use change occurring not more than 20 years, or a single harvest period, prior to undertaking the assessment (whichever is the longer). The total GHG emissions and removals arising from direct land use change over the period shall be included in the quantification of GHG emissions of products arising from this land on the basis of equal allocation to each year of the period137.

- Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out, no emissions from land use change should be included in the assessment.
- Where the timing of land use change cannot be demonstrated to be more than 20 years, or a single harvest period, prior to making the assessment (whichever is the longer), it shall be assumed that the land use change occurred on 1 January of either:
  - the earliest year in which it can be demonstrated that the land use change had occurred; or
  - 136 Following the instantaneous oxidation approach in IPCC 2013 (Section 2).
  - 137 In case of variability of production over the years, a mass allocation should be applied.
  - on 1 January of the year in which the assessment of GHG emissions and removals is being carried out.

The following hierarchy shall apply when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvest period, prior to making the assessment (whichever is the longer):

- where the country of production is known and the previous land use is known, the GHG emissions and removals arising from land use change shall be those resulting from the change in land use from the previous land use to the current land use in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012);
- where the country of production is known, but the former land use is not known, the GHG emissions arising from land use change shall be the estimate of

average emissions from the land use change for that crop in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012);

- where neither the country of production nor the former land use is known, the GHG emissions arising from land use change shall be the weighted average of the average land use change emissions of that commodity in the countries in which it is grown. Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used. Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied. Data sources, location and timing of land use change associated with inputs to products shall be reported.' [end of quote from PAS 2050:2011]

Soil carbon storage shall not be modelled, calculated and reported as additional environmental information.

The sum of the three climate change sub-categories shall be reported.

[To be completed still.]

[If climate change is selected as a relevant impact category, the PEFCR shall (i) always request to report the total climate change as the sum of the three sub-indicators, and (ii) for the sub-indicators 'Climate change – fossil', 'Climate change – biogenic' and 'Climate change - land use and land use change', request separate reporting for those contributing more than 5% each to the total score.]

[Choose the right statement]

The sub-category 'Climate change-biogenic' shall be reported separately.
[OR]
The sub-category 'Climate change-biogenic' shall not be reported separately.
The sub-category 'Climate change-land use and land transformation' shall be reported separately.
[OR]
The sub-category 'Climate change-land use and land transformation' shall not be reported separately.

5.10 Modelling of the kickstage

The kickstage is an additional small stage on top of the launcher and modelled as a subsystem in Section 6.1.2. It can perform three different functions linked to three different services (and thus life cycles):

1. To launch with larger ΔV
2. To reduce time to reach destination orbit (for the spacecraft)

3. To perform in-space transport
4. Multiple use between launcher and IST. The kickstage aids in the launch activity by providing ΔV, part of the kickstage shall be allocated to the launcher.

The impacts of the kickstage shall be accounted to the life cycle it performs the function for:

1. To launch with larger ΔV: accounted to the launcher life cycle
2. To reduce time to reach destination orbit: accounted to the spacecraft
3. To perform in-space transport: accounted to the IST life cycle
4. Multiple use between launcher and IST: fraction of ΔV shall be used to allocate the kickstage to the launcher and the IST services. See also Section 5.7.

[During the PEF-RP studies, no data was available about fraction of ΔV for case 4 (kickstage with multiple use between launcher and IST). The kickstage is therefore assumed to have the same ΔV for launcher and IST, and allocation is done based on propellant use during launch and IST instead. We suggest to include the following rule in a future iteration of the PEFCR, do you agree?
„If ΔV of the launcher and IST are the same or not know, use propellant use instead for the allocation."]

5.11 Modelling reusable packaging and materials

When materials or packaging are being reused, the *reuse rate shall be determined and the modelling in the different life cycle stages shall be adjusted.*

5.11.1 The reuse rate

The reuse rate is the number of times a material is *re-used. This is also often called trip rates, reuse time or number of rotations. This may be expressed as the absolute number of reuse or as % of reuse rate.*

For example: a reuse rate of 80% equals 5 reuses.
Number of reuse = *1/(100%−(% reuse rate))*

The number of reuses applied here refers to the total number of uses during the life of the material. It includes both the first use and all of the following reuses.

The reuse rate shall be calculated using supply chain-specific data. Returnable glass bottles are used as an example but the calculations also apply for another company-owned reusable material:

- Use supply-chain-specific data, based on accumulated experience over the lifetime of the previous glass bottle pool. This is the most accurate way of calculating the reuse rate of bottles for the previous bottle pool and is a proper estimate for the current bottle pool. The following supply chain-specific data is collected.

- Number of bottles filled during the bottle pool's lifetime (#Fi)
- Number of bottles at initial stock plus purchased over the bottle pool's lifetime (#B)
- Reuse rate of the bottle pool = # Fi/#B
- The net glass use (kg glass/l beverage) = $\frac{\#B \times (\text{kg glass/bottle})}{\#Fi}$

5.11.2 Reusable launchers

In the case of reusable launchers, some stages can be landed/recovered and refurbished to be reused (e.g., a core stage of a launcher). The refurbishment results in a product with the original product specifications, meaning the launcher stage provides the same function. In this situation, the product lifetime shall be included in the FU and reference flow (see section 3.3).

A launcher stage is composed of subsystems that are composed of equipment. As defined in section 3.2.6, reusability is defined per stage as:

- **Expendable stage**: non-reusable stage
- **Partially reusable stage**: includes change of subsystems; i.e., ***some*** subsystems are reused with the replacement of some equipment, while some subsystems are non-reusable and are fully replaced.
- **Fully reusable stage**: includes only inspections and change of some equipment (e.g., new lighters for the engines); i.e., ***all*** subsystems are reused, and some equipment is reused, while some equipment is non-reusable and is replaced.

In the case of a reusable launcher stage, the reuse rate (as number of reuses) needs to be provided at the:

1. Stage level,
2. Subsystem level, and
3. Equipment level.

The number of reuses of equipment cannot exceed the number of reuses of the subsystem it belongs to. The number of reuses of a subsystem cannot exceed the number of reuses of the stage it belongs to. Section 5.11.3 provides an example on the application of number of reuses in reusable launcher stages.

Defining the number of reuses
Determining the number of reuses for a reusable launcher stage is a complex process. Therefore, the number of reuses shall be defined and three scenarios shall be reported upon:

1. Business case;
2. Expendable (non-reusable: i.e., reuse number is set to 1);
3. Default number of reuses.

The business case shall be reported as the main **PEF profile**. The scenarios of the expendable and the default number of reuses shall be provided as **additional technical information** (see Section 3.6.6).

The business case affects how the launcher is designed to withstand a specific number of reuses. Company-specific data shall be used for defining the business case.

The number of reuses based on a business case is complex to justify, especially in the case that there hasn't been any first flight for a reusable launcher. Considering the uncertainty, and to allow comparability among reusable launchers, an expendable version and a reusable launcher with a default number of reuses shall also be modelled.

The default number of reuses is defined as 10. This default number is applied at the stage, subsystem and equipment level. The user of the PEFCR should use 10 as default number of reuses, unless their business case number reuses is lower than 10. In this case, the default number of reuses shall be equal to the reuses defined in the business case for the stage, subsystem and equipment level.

The following formulas summarize how to calculate the impact of a **partially reusable launcher stage** (as defined in section 3.2.6):

$$Impact\ [Launcher\ reusable\ stage] =$$

$$= \frac{Impact\ [Reusable\ stage - Subsystem\ input]}{Stage\ reuses\ (\#)} + Impact\ [Reusable\ stage\ Refurbishment] +$$

$$+ \sum \frac{Impact\ [Reusable\ Subsystem_k - Equipment\ input]}{Subsystem_k reuses\ (\#)} +$$

$$+ Impact\ [Reusable\ subsystem_k\ Refurbishment] + \sum Impact\ [Expendable\ Susbsystem_l] +$$

$$+ \sum_k \frac{Impact\ [Reusable\ Equipment_m]}{Equipment_m reuses\ (\#)} +$$

$$+ Impact\ [Reusable\ equipment_m\ Refurbishment] + \sum_k Impact\ [Expendable\ Equipment_n]$$

Where:
$k = number\ of\ reusable\ subsystems\ in\ a\ reusable\ stage$
$l = number\ of\ expendable\ subsystems\ in\ a\ reusable\ stage$
$m = number\ of\ reusable\ equipment\ per\ reusable\ subsystem\ of\ a\ reusable\ stage$
$n = number\ of\ expendable\ equipment\ per\ reusable\ subsystem\ of\ a\ reusable\ stage$

The first part of the equation, i.e.,

$$\frac{Impact\ [Reusable\ stage - Subsystem\ input]}{Stage\ reuses\ (\#)} + Impact\ [Reusable\ stage\ Refurbishment]$$

is interpreted as:
The '*Impact [Reusable stage – Subsystem input]'* includes the impact from all activities for a launcher stage production minus the impact of all activities form the production of its subsystem inputs. This is then divided by the number of stage reuses. The impact of the activities from the refurbishment of the reusable stage (which is defined per one launch – see section 6.2.14 for launcher stage refurbishment) is then added to the formula. The impact of the production of subsystems that was subtracted from the impact of the stage production is then calculated in the second part of the formula, following a similar logic (see section 6.1.19 in the case reusable subsystem or equipment refurbishment).

For a **fully reusable stage** (as defined in Section 3.2.6), there are no expendable subsystems, and the number of subsystem reuses equals the number of stage reused thus:

$$\sum Expendable\ Susbsystem_l = 0\ (for\ a\ fully\ reusable\ stage)$$

And

$$Stage\ reuses\ (\#) = Subsystem\ reuses\ (\#)$$

5.11.3 How to apply and model the 'reuse rate'

The number of times a material is reused affects the product's environmental profile at different life-cycle stages. The following five steps explain how the user shall model the different life-cycle stages with reusable materials.

1. Raw material acquisition: the reuse rate determines the quantity of material consumed during the entire product life time. The raw material consumption shall be calculated by dividing the actual weight (e.g., equipment) by the number of reuse. For example, a 1 l glass bottle weighs 600 grams and is reused 10 times (reuse rate of 90%). The raw material use per litre is 60 grams (= 600 grams per bottle / 10 reuses). Example for launchers provided below.
2. Transport to the product factory (where the material is used): The reuse rate determines the quantity of transport that is needed per product life time. The transport impact shall be calculated by dividing the one-way trip impact by the number of times the material is reused. Example for launchers provided below.
3. Transport from product factory to final use and back: in addition to the transport needed during distribution, the return transport shall also be taken into account.
4. At the product factory (see section 6.1.19 and 6.2.14): once the used product is returned to the product factory, energy, resource and material use shall be taken into consideration for the cleaning, repairing and refurbishment (if applicable).
5. At end of life: the reuse rate determines the quantity of material (per entire product life cycle) to be treated at end of life. The amount of material treated shall be calculated by dividing the actual weight of the material by the number of times it was reused.

Example for a partially reusable launcher stage

This example refers to steps 1 and 2 from the list above. Assuming a stage_1 of a launcher that is fully reusable and is composed of subsystem_1 and subsystem_2. Subsystem_1 is composed of equipment_1 and equipment_2. Subsystem_2 is composed of equipment_3 and equipment_4. The number of reuses of stage_1 as a whole, the number of reuses for subsystem_1 and subsystem_2, and the number or reuses of equipment_1, equipment_2, equipment_3 and equipment_4 shall be provided. Assuming the following number of reuses*:

- stage_1: 5 times,
- subsystem_1: 5 times,
- subsystem_2: 2 times,
- equipment_1: 5 times,
- equipment_2: 3 times,
- equipment_3: 2 times,
- equipment_4: 1 times (i.e., it is expendable, only used once).

**Number of reuses includes both the first use and all of the following reuses (see section 5.11.1).*

Considering the number of reuses, the **scaling factors** of the reusable stage and its subsystems and equipment, for one launch, are defined as:

- stage_1 = 1/5=0.2: affects all activities of LCS2 of production of launcher, except of its subsystems inputs (*defined in the next two bullet points*);
- subsystem_1 = 1/5=0.2: affects all activities of LCS1 of production of subsystem_1, except of its equipment inputs;
- subsystem_2 = 1/2=0.5: affects all activities of LCS1 of production of subsystem_2, except of its equipment inputs (*defined in the next four bullet points*);
- equipment_1 = 1/5=0.2: affects all activities of LCS1 equipment_1 production;
- equipment_2 = 1/3=0.33: affects all activities of LCS1 equipment_2 production;
- equipment_3 = 1/2=0.5: affects all activities of LCS1 equipment_3 production;
- equipment_4 = 1: since equipment_4 is expendable, its scaling factor equals one, meaning the full impact is considered; it affects all activities of LCS1 equipment_4 production.

The refurbishment activities (step 4 from the list above) are defined per one launch. The refurbishment of a reusable stage is included in LCS2. The refurbishment of its subsystems or equipment is included in LCS1 (see system boundary in section 3.4.2, as well as sections 6.1.19 and 6.2.14).

For a **fully reusable launcher stage**, all its subsystems are reused. In this case, the number of reuses of the reusable launcher stage and its subsystems should be equal. However, certain equipment can have a lower number of reuse.

5.12 Modelling of transport[39]

The following transport activities shall be included in the life cycle:

(i) Transport of material and components to the manufacturing facilities of equipment (and back in case of re-use) (LCS1),

(ii) Transport of equipment, materials, packaging, GSE and auxiliaries to the manufacturing facilities of subsystems (and back in case of re-use) (LCS1),

(iii) Transport of subsystems, packaging, auxiliaries and GSE to the manufacturing facilities of spacecrafts and launchers. In case defaults are allowed and company-specific information is missing, the modelling requirements of this section apply (and back in case of re-use) (LCS2),

(iv) Transport to the launch site of the spacecraft, launcher, propellant and GSE (LCS3). This transport shall be modelled with company-specific information.

If the country of origin is known together with the transport mode:

- For road: the adequate distance shall be determined using https://www.ecotransit.org/en/emissioncalculator/
- For ship and plane: the adequate distance shall be determined using https://www.searates.com/services/distances-time/ and https://co2.myclimate.org/en/flight_calculators/new. An additional 1000 km by truck (>32 t, EURO 4) shall be added for the sum of distances from harbour/airport to factory outside and inside Europe.

For point (i), (ii) and (iii): if no company-specific information is available the following default scenario shall be used:

- For suppliers located in Europe: 130 km by truck (>32 t, EURO 4) + 240 km by train (average freight train) + 270 km by ship (barge).
- For suppliers located outside of Europe: 1000 km by truck (>32 t, EURO 4, for the sum of distances from harbour/airport to factory outside and inside Europe) + 18 000 km by ship (transoceanic container) or 10 000 km by plane (cargo).
- If it is not known whether the supplier is located within or outside Europe: the transport shall be modelled as if the supplier was located outside of Europe.

More information on the default datasets to be used (including their default utilisation ratio and return trip) can be found in Annex XX [under development].

5.13 Modelling building infrastructure

Building infrastructures in the life cycle of spacecrafts and launchers might be relevant due to its low use rate (for example manufacturing facility, clean room or launch site). Therefore, in this PEFCR, most infrastructure is included in the system boundaries and

[39] Copied from the PEF recommendation

shall be modelled (see Figure 9 and Figure 10 on system boundaries). The following modelling hierarchy shall be followed when modelling building infrastructure:

1. If data allows, infrastructure should be modelled by measuring the total amount of concrete, steel, wood or other materials used in the construction, while considering the default lifetime of 50 years.
2. If time and data is limited, the type of building and building size shall be used together with the following default dataset:
   - Concrete building (in m3)
   - Steel building (in m3)
3. If the type of building is not know, a steel building shall be chosen for the modelling.

[To be evaluated if this is possible with the available EF database]

5.14 Default lifetimes

For a large number of datasets default lifetimes have been introduced, to ensure consistency in the modelling. Table 46 presents the default lifetimes to be used for the most common infrastructures used in the life cycle of space activities.

Table 46. Default lifetimes

Infrastructure	**Lifetime to be used**
Ground support equipment	10 years
IT and RF equipment (such as network, data center, servers, modems, transmitters and hubs)	10 years
Cleanroom	30 years
Antenna and antenna pad	30 years
End user equipment	15 years
Buildings (such as manufacturing facility, office building, storage building, ground receiving station)	50 years

[Input is welcome during the open consultation on any missing infrastructure or justification for other numbers to be used.]

5.15 Launch and re-entry emissions

5.15.1 Launch emissions

Launch emissions can be theoretically calculated based on three factors:

1. Propellant type;
2. Trajectory: longitude, latitude, altitude and time;

3. Engine parameters: mixture ratio (fuel/oxidizer), efficiency (nozzle size), chamber pressure, equilibrium or frozen emissions

Within this PEFCR only the first two factors are taken into account to calculate the launch emissions. Engine parameters are excluded so far due to limited calculation means.

A launch emissions and re-entry emissions from propellant use (see next section for re-entry emissions) calculation model is provided as an Excel Annex. The model is developed by Jan-Steffen Fischer, University of Stuttgart, Institute of Space Systems (Fischer, 2025) as part of this PEFCR. It includes emissions form the use of various propellants including afterburning emissions. Users shall provide the mass of emitted propellant from a launcher stage and/or booster at 6 different altitudes ranges (from 0 to 100 km). The emission calculation formulas as well as the altitude variations, are based on literature data, using the publications from (James, et al., 2021; Barker, Marais, & McDowell, 2024; Fischer , Winterhoff, & Fasoulas, Launch Emission Assessment Tool (LEAT), 2025).

Excel Annex 4.3: Launch emissions and re-entry emissions from propellant use shall be used to calculate the launch emissions and re-entry emissions from propallent use (see next section for re-entry emissions) related to the mass of emitted propellant per defined altitude interval.

- For PEF studies on spacecrafts the mass of emitted propellant per altitude interval shall be calculated considering the mission specific propellant type and launch trajectory.
- For PEF studies on launchers the mass of emitted propellant per altitude interval be calculated considering the launcher specific propellant type and the default trajectory defined per ΔV. [The description of the default trajectory to be used will be added in the next version of the PEFCR].

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

5.15.2 Re-entry emissions

Re-entry emissions derive from (i) propellant use and (ii) the burn-up process with the remnants falling to Earth (also named „Demise emissions”).

- Emissions from propellant use are affected by trajectory, type and amount of propellant. Engine parameters also play a role but are excluded so far due to limited calculation means (as for launch emissions, Section 5.15.1).
- Demise emissions are affected by the trajectory, type of material being burned, and the burn-up rate (% surviving mass from total mass). Note for reusable launcher stages, the advanced heat shields result in minimal emissions from burn-up.

For propellant emissions, within this PEFCR only the propellant type and amount are taken into account to calculate the re-entry emissions. Due to limited scientific knowledge, today a simple complete stochiometric combustion approach has been considered, without altitude effects. No intermediate species (such as OH, CO or H2) are taken into account. A calcluation model for re-entry emissions from propellant use – e.g., of reusable launchers –is developed by Jan-Steffen Fischer, University of Stuttgart, Institute of Space Systems (Fischer, 2025) as part of this PEFCR and provided in Excel Annex 4.3: Launch emissions and re-entry emissions from propellant use. Users shall provide the mass of emitted propellant per altitudes interval (from 1 to 100 km).

- For PEF studies on spacecrafts the mass of emitted propellant shall be calculated considering the mission specific propellant type and re-entry trajectory.
- For PEF studies on launchers the mass of emitted propellant shall be calculated considering the launcher specific propellant type and the default trajectory defined per ΔV. [The description of the default trajectory to be used will be added in the next version of the PEFCR].

For demise emissions, a calculation model is developed by Jan-Steffen Fischer, University of Stuttgart, Institute of Space Systems (Fischer, 2025) as part of this PEFCR and provided in Annex 4.4. Users shall provide the mass of emitted material per altitudes interval (from 100 to 1 km).

- For PEF studies on spacecrafts the mass of emitted material shall be calculated considering the mission specific material type, the burn-up rate and re-entry trajectory.
- For PEF studies on launchers the mass of emitted material shall be calculated considering the launcher specific material type, the burn-up rate and default re-entry trajectory. [The description of the default trajectory to be used will be added in the next version of the PEFCR].

[How to calculate the burn-up rate, and thus the amount of material to be emitted, is still under discussion. The recommended tool shall be freely accessible by all stakeholders using the PEFCR. Is it acceptable that users of the PEFCR use their own tool or specific calculation requirements are needed? Input during the open consultation is welcome.]

[IMPORTANT NOTE: Demise emissions are currently excluded in the first PEF-RP. Therefore, the re-entry emissions only cover propellant use from reusable launchers]

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

5.15.3 Launch and re-entry emission impact assessment

As launch and re-entry emissions are known to be highly relevant and altitude dependent, special attention is given to their coverage by the EF impact assessment methodology. Table 47 indicates the modelling of the different emissions using EF4.0 flow list. For those substances modelled with EF4.0, only the lower altitude emissions are considered in the modelling, being 0-15km.

Table 47. Launch and re-entry emissions modelled with EF4.0. Note that only lower altitudes of 0-15km are considered.

<table>
<tr><th>Emissions and altitude</th><th>EF 4.0 flow name to be used</th><th>EF impact categories covered</th></tr>
<tr><td>CO 0-15km</td><td>carbon monoxide, fossil</td><td>Photochemical ozone formation, human health
Ecotoxicity, freshwater
Ecotoxicity, freshwater inorganics
Human toxicity, non-cancer inorganics
Human toxicity, non-cancer</td></tr>
<tr><td>Cl 0-15km</td><td>Not Available</td><td></td></tr>
<tr><td>HCl 0-15 km</td><td>Hydrochloric acid</td><td>Ecotoxicity, freshwater|inorganics
Ecotoxicity, freshwater</td></tr>
<tr><td>H2O 0-15 km</td><td>Not Available</td><td></td></tr>
<tr><td>Al2O3 0-15 km</td><td>Not Available</td><td></td></tr>
<tr><td>TiO2 0-15 km</td><td>Not Available</td><td></td></tr>
<tr><td>Fe2O3</td><td>Iron oxide (Fe2O3)</td><td>Human toxicity, non-cancer|inorganics
Human toxicity, non-cancer</td></tr>
<tr><td>NOx 0-15 km</td><td>Nitrogen oxide</td><td>Photochemical ozone formation, human health
Particulate matter
Acidification
Eutrophication, terrestrial
Eutrophication, marine</td></tr>
<tr><td>MgO</td><td>Not Available</td><td></td></tr>
<tr><td>Black carbon 0-15 km</td><td>Not Available</td><td></td></tr>
</table>

For climate change, most impacts from launch and re-entry emissions happen at higher altitude. As the current EF footprint approach doesn’t capture higher altitude effects, all climate change impacts from all launch and re-entry emissions shall be calculated separately (outside the EF footprint results) using the excel Annex. Table 48. GWP100 (in CO_2 equivalents) for launch and re-entry emissions to be used to calculate the climate change impacts separately Effects in the troposphere (using the 0-15 km intervals) are characterized using the standard IPCC values (IPCC, 2014), while the effects from higher altitude emissions are characterized with values taken from (D.S. Lee, 2021).

Table 48. GWP100 (in CO_2 equivalents) for launch and re-entry emissions to be used to calculate the climate change impacts separately. Grey cells indicate substances missing in EF4.0.*

Altitude interval	CO2 [min-max]	CO [min-max]	H2O [min-max]	NOx [min-max]	BC [min-max]
0-5 km	1-1	1.6-7.6		[-238]-[-11]	100-1700
5-15 km	1-1	1.6-7.6		[-238]-[-11]	100-1700
15-35 km	1		0.06	114	1166
35-50 km	NA	NA	NA	NA	NA
50-75 km	NA	NA	NA	NA	NA
75-100 km	NA	NA	NA	NA	NA

*These values are in line with the European Commission report: Updated analysis of the non-CO2 climate impacts of aviation and potential policy measures pursuant to EU Emissions Trading System Directive Article 30(4), https://eur-lex.europa.eu/resource.html?uri=cellar:7bc666c9-2d9c-11eb-b27b-01aa75ed71a1.0001.02/DOC_3&format=PDF

The benchmark results shall be reported in two ways:

1. Excluding climate change emissions and impacts from launch and re-entry emissions, as presented in Table 48.
2. Including climate change emissions and maximum impacts from launch and re-entry emissions, as presented as maximum range in Table 48.

5.16 Modelling of end of life and recycled content

[This section will be completed after the open consultation.]

The end of life of products used during the manufacturing, distribution, retail, the use stage or after use shall be included in the overall modelling of the life cycle of the products. Overall, this should be modelled and reported at the life cycle stage where the waste occurs. This section provides rules on how to model the end of life of products as well as the recycled content.

The circular footprint formula (CFF) is used to model the end of life of products as well as the recycled content and is a combination of 'material + energy + disposal', i.e.:

Material
$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy $$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal $$(1-R_2-R_3) \times E_D$$

With the following parameters

A: allocation factor of burdens and credits between supplier and user of recycled materials.

B: allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.

Qsin: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.

Qsout: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.

Qp: quality of the primary material, i.e. quality of the virgin material.

R1: it is the proportion of material in the input to the production that has been recycled from a previous system.

R2: it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.

R3: it is the proportion of the material in the product that is used for energy recovery at EoL.

Erecycled (Erec): specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.

ErecyclingEoL (ErecEoL): specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.

Ev: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.

E*v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.

EER: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).

ESE,heat and ESE,elec: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.

ED: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.

XER,heat and XER,elec: the efficiency of the energy recovery process for both heat and electricity.

LHV: lower heating value of the material in the product that is used for energy recovery.

[Within the respective sections, the following parameters shall be provided in the PEFCR:

- *All A values to be used shall be listed in the PEFCR, together with a reference to the PEF method and part C of Annex II. In case specific A values cannot be determined by the PEFCR, the PEFCR shall prescribe the following procedure for its users:*
    - *Check in part C of Annex II the availability of an application-specific A value which fits the PEFCR,*
- *If an application-specific A value is not available, the material-specific A value in part C of Annex II shall be used,*
- *If a material-specific A value is not available, the A value shall be set equal to 0.5.*
    - *2) All quality ratios (Qsin, Qsout/Qp) to be used.*
    - *3) Default R1 values for all default material datasets (in case no company-specific values are available), together with a reference to the PEF method and part C of Annex II. They shall be set to 0% when no application-specific data is available.*
    - *4) Default R2 values to be used in case no company-specific values are available, together with a reference to the PEF method and part C of Annex II.*
    - *5) All datasets to be used for Erec, ErecEoL, Ev, E*v, EER, ESE,heat and ESE,elec, ED]*

[Default values for all parameters shall be listed in a table in the section of the appropriate life cycle stage. Furthermore, the PEFCR shall clearly describe for each parameter if only defaults can be used or also company-specific data, following the overview in section A.4.2.7. of Annex II]

Modelling recycled content (if applicable)

[If applicable the following text shall be included:]

The following part of the circular footprint formula is used to model the recycled content:
$(1-R_1)E_V+R_1\times(A\times E_{recycled}+(1-A)E_V\times \frac{Q_{Sin}}{Q_p})$

The R1 values applied shall be supply-chain specific or default as provided in the Table XX *[under development],* in relation with the DNM. Material-specific values based on supply market statistics are not accepted as a proxy and therefore shall not be used. The applied R1 values shall be subject to PEF study verification.

When using supply-chain specific R1 values other than 0, traceability throughout the supply chain is necessary. The following guidelines shall be followed when using supply-chain specific R1 values:

- The supplier information (through e.g., statement of conformity or delivery note) shall be maintained during all stages of production and delivery at the converter;
- Once the material is delivered to the converter for production of the end products, the converter shall handle information through their regular administrative procedures;
- The converter for production of the end products claiming recycled content shall demonstrate through its management system the [%] of recycled input material into the respective end product(s).
- The latter demonstration shall be transferred upon request to the user of the end product. In case a PEF profile is calculated and reported, this shall be stated as additional technical information of the PEF profile.
- Company-owned traceability systems may be applied as long as they cover the general guidelines outlined above.

[Industry systems may be applied as long as they cover the general guidelines outlined above. In that case, the text above may be replaced by those industry specific rules. If not, they shall be supplemented with the general guidelines above.]

6. Life cycle stages

Section 6.1 to 0 presents the description of the life cycle stages on horizontal level of this PEFCR. The life cycle stages “Raw material acquisition and pre-processing” and “Manufacturing” cover both spacecrafts and launchers, this is indicated in the title of the section. For the life cycle stages “Distribution”, “Use”, and “End of life” a clear split between spacecrafts and launchers is made through separate sub-sections.

While all the horizontal requirements are also valid for the different sub-categories, certain sub-categories may provide additional or more stringent requirements. These are identified in the horizontal rules and specified per sub-category in Section 6.6.

[Any feedback on suggested defaults, further clarifications or missing information is highly welcome during the open consultation.]

6.1 Raw material acquisition and pre-processing stage (for spacecrafts and launchers)

[The PEFCR shall list all technical requirements and assumptions to be applied by the user of the PEFCR. Furthermore, it shall list all processes taking place in this life cycle stage (according to the model of the RP), following the table provided below (transport in separate table). The table may be adapted by the TS as appropriate (e.g. by including relevant parameters of the circular footprint formula).]

The life cycle stage “Raw material acquisition and pre-processing” includes all activities related to the production of all equipment and subsequent subsystems that are needed for the spacecraft/launcher flight models and for all test models. It starts from the production of materials and auxiliaries, the manufacturing/assembling/integration/testing (MAIT) of equipment, the production and storage of all subsystems on site, till the transport to the manufacturing site. The development of test models, additional spare parts as well as refurbishment activities shall be included in this life cycle stage. See section 5.11 for more details on modelling reusable parts.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used to model the raw material acquisition and pre-processing.

6.1.1 Production of equipment

The production of equipment shall include the amounts of the following activities:

- Materials and components required;
- Ground support equipment (incl. maintenance)
- Cleanroom use (excl. MAIT processes);

- Office use;
- Staff travel (e.g., to suppliers);
- External testing;
- MAIT processes;
- Inbound transport of each material, component and GSE required;
- Waste generated during production.

All other activities shall be excluded from the calculations. Packaging of materials and components, production and packaging of auxiliaries, packaging of equipment, storage of equipment, the use of manufacturing facility (workshop), materials and components used for the first test models, and staff commuting shall not be modelled.

[The inclusion of GSE will be further evaluated during the RP and supporting studies. Based on its relevance and data availability, its need for modelling will be reconsidered. The exclusions above are valid for the modelling of equipment, when default data as well as company-specific data is used. After the supporting studies, further exclusions might be added if no data is available.]

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The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default equipment datasets, as listed in ANNEX XX [we are still working on the excel file], should be used. If only company-specific information is available on the amounts of materials and components for an equipment listed in ANNEX XX, the default dataset shall be modified by only adapting the amounts of materials and components. If the required equipment is not available in ANNEX XX, Section 5.5 shall be followed.

If equipment is being reused, the additional energy and resource used for refurbishment shall be included in this life cycle stage (see section 6.1.19). The impact of the original equipment shall be calculated by dividing impact of the activities listed above by its reuse rate. More detailed modelling requirements are provided in section 5.11.

The sections below (6.1.3 - 6.1.18) explain the detailed modelling rules for each of the required input activities.

6.1.2 Production of subsystems

The production of subsystems shall include the amounts of the following activities:

- Equipment required;
- Materials required;
- Auxiliaries consumed;
- Ground support equipment (incl. maintenance);
- Cleanroom use (excl. MAIT processes);
- Manufacturing facility (excl. MAIT processes);

- Office use;
- Staff travel;
- Staff commuting;
- External testing;
- MAIT processes;
- Waste generated during production;
- Packaging of the subsystem;
- Storage of the subsystem on-site (outside cleanroom);
- Inbound transport of each equipment, material, packaging, auxiliary and GSE required;
- Outbound transport of subsystem to manufacturing site of spacecraft/launcher.

All other activities shall be excluded from the calculations. Packaging of equipment, materials and auxiliaries shall not be modelled.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default equipment datasets, as listed in ANNEX XX [under development], shall be used. If only company-specific information is available on the amounts of materials and equipment for a subsystem listed in ANNEX XX, the default dataset shall be modified by only adapting the amounts of materials and components. If the required subsystem is not available in ANNEX XX, Section 5.5 shall be followed.

If subsystems are being reused, the additional energy and resource for refurbishment shall be included in this life cycle stage (see section 6.1.19). The impact shall be calculated by dividing the impact of the activities listed above excluding equipment (their reuse is covered in the previous section) by its reuse rate. More detailed modelling requirements are provided in section 5.11.

The sections below (6.1.3 - 6.1.18) explain the detailed modelling rules for each of the required input activities.
Details on how to allocate the impact of the kickstage, based on its function, can be found in Section 5.10.

6.1.3 Packaging of the spacecraft

The packaging of spacecraft, that is needed for transport to the launch site, shall be included in the modelling (also named transport GSE). The type (such as containers) and amount needed, as well as used auxiliaries shall be modelled with company-specific information.

If packaging is being reused, the additional energy and resource used for cleaning or repairing shall be included in this life cycle stage. The raw material consumption of reusable packaging shall be calculated by dividing the actual weight of the packaging by the reuse rate. More detailed modelling requirements are provided in section 5.11.

6.1.4 Packaging of the launcher

The packaging of the launcher refers to the packaging of the different launcher stages and/or boosters. The packaging of the launcher is needed for transporting the launcher to the launch site. It shall be included in the modelling (also named transport GSE). Specific containers are used for the different launcher stages. Often, these containers need to be pressurized, potentially using gases such as helium, nitrogen or just air. The type and amount of material needed per launcher stage and booster, as well as used auxiliaries shall be modelled with company-specific information.

If packaging is being reused, the additional energy and resource used for cleaning or repairing shall be included in this life cycle stage. The raw material consumption of reusable packaging shall be calculated by dividing the actual weight of the packaging by the reuse rate. More detailed modelling requirements are provided in section 5.11.

6.1.5 Auxiliaries

Auxiliaries refer to additional materials and substances (such as solvents and liquid nitrogen) needed during the production process of equipment / sub-systems, testing activities, cleanroom or storage.

Annex XX of this PEFCR provides a list of default Auxiliaries that may be used during the modelling. In case the auxiliary required is not included in Annex XX, section 5.5 shall be used for further guidance. [List of auxiliaries is under development]

6.1.6 Ground support equipment (incl. maintenance)

Ground support equipment (GSE) is specifically developed to handle the equipment and subsystems being developed. It includes the tools necessary to perform the manufacturing, assembling, integration and internal test activities. It covers both mechanical and electrical GSE equipment. Transport GSE refers to the packaging used for subsystems, the spacecraft or the launcher and is discussed in section 6.1.3, 6.1.4 and 0

GSE is usually built off-site and transported to its use site. The modelling of GSE (incl. maintenance) shall include the amounts of the following activities:

- Materials and components required (including spares);
- Energy use for production;
- Transport of the GSE to its use site;
- Auxiliaries for maintenance;
- Office use.

The amounts and exact materials needed when modelling the GSE should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default dataset(s) on Mechanical GSE and

Electronical GSE (available for spacecrafts and launchers), as provided in ANNEX XX [under development] of the PEFCR.

[Shall other GSEs be considered, such as fluidic or optical? Any input on data is more than welcome]

If a certain GSE is used multiple times within the same life cycle, it should only be accounted for once. If a certain GSE is re-used by different spacecrafts/launchers, it can be allocated to the specific product in scope in two ways (in hierarchical order):

(i) by dividing the GSE model by the number of products (missions) it is used for during its lifetime, if this is known. Or,
(ii) by dividing the number of years the GSE is used for the product in scope, by its default lifetime.

A default lifetime of 10 years shall be used, unless there are justified reasons to deviate (e.g., the lifetime of 10 years already passed). This shall be justified when performing the study.

6.1.7 Cleanroom use

The cleanroom is a controlled environment facility, in which manufacturing, assembling, integration and testing procedures and storage take place. The cleanroom can be used on the level of equipment or subsystem (spacecraft or launcher). The modelling of the cleanroom facility shall include the amounts of the following activities (excluding MAIT processes):

- Electricity use (for ventilation and environmental control such as heating, cooling, humidity control);
- Natural gas use;
- Water use;
- Direct emissions;
- Use of personal protective equipment;
- Auxiliaries (e.g., chemicals for cleaning or refrigerants for air conditioning);
- Use of filters;
- Ground transformation;
- Building infrastructure.

All other inputs shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the cleanroom use. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX [under development], for an overview of most common auxiliaries used in cleanroom use and their related emissions. *[Input is requested on the main emissions and amounts of the main auxiliaries used.]*

The lifetime for cleanroom infrastructure to be considered is 30 years.
The operation hours are to be considered 7 days a week, 24h a day, 365 days a year.

When using company-specific data, the cleanroom use shall be allocated to the specific equipment (or subsystem) using the duration of occupation and area occupied. The following inputs are needed:

1. The total annual consumption of electricity, gas, water, personal protective equipment, auxiliaries, and filters.
2. The total annual direct emissions. If these are not available, use Table XX [Under development].
3. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
4. The total duration of occupation shall reflect how long the equipment (or sub-system) is actively used in the cleanroom (in hours).
5. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area (in m^2). In case the equipment (or subsystems) simultaneously occupying the cleanroom are very similar in size, the number of pieces handled in the cleanroom may be used rather than the occupied area.

The cleanroom is then allocated to the specific equipment (or subsystem): For example, all above mentioned inputs of the cleanroom are divided by 365 days a year and 24 hours a day, divided by total cleanroom area (incl. hallways) (in m^2), and lastly multiplied with occupied area (m^2) (+5%) and occupation time (hours) used for the specific equipment (or sub-system).

If no company-specific information is available for small cleanrooms (ceiling height ≤ 4.5m), one of the two default cleanroom datasets shall be used (presented in Annex XX). They are differentiated on the level of pressure standards (ISO-classes), (i) ISO 6-8 for high to moderate cleanliness, and (ii) ISO 5 for very high cleanliness (See Table 49). To allocate the default cleanroom dataset to the specific equipment (or subsystem), the duration and area size occupied shall be used[40]. For larger cleanrooms (ceiling height ≥4.5m) company specific data shall be used in the modelling.

[It has been requested to provide a default dataset also for larger cleanrooms. However, it is difficult to create a default for large rooms as linear scaling doesn't hold. It will be evaluated after the PEF-RP modelling, if a default can be provided or if it shall be modelled with company specific data. Inputs during the open consultation are welcome.]

[40] See description 4. And 5. On how to measure duration and occupied area.

*Table 49. Default cleanroom datasets, with their specific volume and area size. The default datasets for cleanrooms are expressed in m2*hour.*

ISO Class	Ceiling Height (m)	Size (m^3)	Area (m^2)	Use Cases
ISO 6-8 (high to moderate cleanliness)	≤ 4.5 m	Medium (450 m^3)	100 m^2	Equipment MAIT - Small satellites MAIT
ISO 5 (very high cleanliness)	≤ 4.5 m	Medium (450 m^3)	100 m^2	High precision or sensitive equipment; Optical instruments manufacturing

Cleanrooms have different levels of pressure standards (ISO-classes), vary in application, purpose, and thereby also in size. Cleanrooms can range from ISO 8 (basic cleanliness) to ISO 5 (very high cleanliness), and ceiling heights range from 3m for equipment and small satellites, up to 12m for special use cases such as tall satellites.

- A cleanroom up to or below 4.5m ceiling height is considered the most frequent use case, for which default datasets are provided in ANNEX XX. For cleanrooms with a ceiling height greater than 4.5m, company-specific information shall be used to model the cleanroom.
- The cleanrooms ISO 8 (basic cleanliness,≤100,000,000 per m^3), ISO 7 (moderate cleanliness, ≤10,000,000 per m^3), and ISO 6 (high cleanliness, ≤1,000,000 per m^3) are assumed to use HEPA (High-Efficiency Particulate Air or High Efficiency Particulate Arresting) filters, designed to remove at least 99.95 % of particulates of size 0.3 µm. Some can reach higher levels of efficiency. The lifetime of HEPAs are 10 years. It is assumed that the impacts of filtering air scales linearly for this filter with volume of air and its electricity usage. The ISO 5 cleanroom (very high cleanliness, ≤100,000 per m3) is considered different to the other cleanrooms and requires a better filter, namely a high-efficiency HEPA, or a ULPA (Ultra-Low Particulate Air) filter, which are even more efficient and remove 99.999 % of particles of size 0.12 µm. ULPAs are denser and require more energy and/or more cross-section to work. The lifetime of ULPAs are 5-8 years. The usage of ISO 8-6 cleanrooms is considered more common, than an ISO 5 cleanroom. Therefore the two default datasets have been created based on their use cases.

Note: The activities for cleanroom, office use and manufacturing facility may be modelled as a single aggregated dataset in case it is too difficult to split the numbers. [In the second draft PEFCR it will be evaluated if both options can be presented in the hotspot results. Inputs are welcome]

6.1.8 Manufacturing facility

The manufacturing facility for the subsystem shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Ground transformation;
- Building infrastructure.

All other inputs shall be excluded from the calculations. Note, the amounts needed for MAIT processes are modelled separately under “MAIT processes”.

The lifetime for manufacturing facility to be considered is 50 years.
The operation of the manufacturing facility to be considered is 7 days a week, 24h a day, 365 days a year.

When using company-specific data, the use of manufacturing facility shall be allocated to the specific subsystem, using the duration of occupation and the occupied area.

1. Electricity, gas and water use shall be measured and collected for one year. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
2. The total duration of occupation shall reflect how long the equipment (or sub-system) actively uses the manufacturing facility.
3. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area.

In case the subsystems simultaneously occupying the manufacturing facility are very similar in size, the number of pieces handled in the facility may be used rather than the occupied area.

The manufacturing facility is then allocated to the specific equipment (or subsystem): For example, the total annual consumption (and all activities as defined above) of the manufacturing facility can be divided by 365 days*24hours (being the annual total amount of hours) and the total area of the manufacturing facility, and then be multiplied with duration of occupation and area of occupied for the specific equipment (or sub-system).

If no company-specific information is available on the manufacturing facility, the default datasets in Annex XX (under development) shall be used. To allocate the default manufacturing dataset to the specific equipment (or subsystem), the duration and area size occupied shall be used.

Note: The activities for cleanroom, office use and manufacturing facility may be modelled as a single aggregated dataset in case it is too difficult to split the numbers. [In the second draft PEFCR it will be evaluated if both options can be presented in the hotspot results. Inputs are welcome]

6.1.9 Office use

The office work includes all related office activities required for the equipment (or subsystem), such as research and development, legal activities, or sales. The modelling of the office use shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Ground transformation;
- Building infrastructure (building of the office).

All other inputs shall be excluded from the calculations.

The lifetime for office infrastructure to be considered is 50 years.
The use time of the office is calculated based on the number of working hours per day and number of working days/year. In case no company-specific information is available, 8h/day and 220 working days/year shall be considered.

When using company-specific data, the office use shall be allocated to the specific equipment (or subsystem) using the amount of man*hours spent on the equipment (or subsystem). The following inputs are needed:

1. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
2. The annual consumption of gas, water and electricity shall be measured
3. The total office operation per year (in total man*hours): based on # hours/day * # working days/year * total amount of staff.
4. The amount of man*hours dedicated to the specific equipment (or subsystem): based on # hours/day * total working days working on the equipment (sum of all staff working on the equipment or subsystem).

The office use is then allocated to the specific equipment (or subsystem): For example, the total annual consumption (including all activities as defined above) of the office building can be divided by 30 man * 8h *220 working days (being the annual total amount of manhours) and multiplied with 80 man*hours (being the amount of manhours dedicated to a certain equipment).

If no company-specific information is available on the required input amounts, the default dataset presented in Annex XX [excel file under development] shall be used. To allocate the default office dataset to the specific equipment (or subsystem), also here the number of man*hours spend shall be used.

IMPORTANT: In most cases, the number of man*hours within a project are spend in the office and cleanroom. The number of workhours shall be correctly split between the cleanroom use and office use, this to avoid any double counting. In case the man*hours solely spend in the office is not known, a default value shall be used. 70 %

of all project man*hours shall be allocated to office use. [Any input on this default allocation value is welcome during the open consultation.]

Note: The activities for cleanroom, office use and manufacturing facility may be modelled as a single aggregated dataset in case it is too difficult to split the numbers. [In the second draft PEFCR it will be evaluated if both options can be presented in the hotspot results. Inputs are welcome]

6.1.10 Staff travel

Staff travel includes the travelling (business related) of employees (i) to supplier sites, to test and verify the equipment or subsystem being used or for any programmatic/contractual reasons, (ii) between own production sites, and (iii) for on-site progress or review meetings (e.g. with ESA). Staff travel can be done by car, train or plane. Company-specific information should be used on the travelling mode and distance used per travel, in combination with the following transport datasets:

- Car: Transport, passenger car, diesel, RER
- Train: Transport, train, passenger, electric, RER
- Plane: Transport, aircraft, passenger, long-haul, business class, global average; Transport, aircraft, passenger, short-haul, economy class, Europe.

[The list of these datasets will be updated once the exact dataset names are clear.] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

In case no company-specific information is available the user of the PEFCR shall use the default scenario provided below (see Table 50) together with 7% of the defined man*hours of the office use specific to the equipment (or sub-system). Divide the 7% of the total man*hours in office specific to the equipment (or sub-system) by 8hrs/day to obtain total travel days for the equipment (or sub-system). Apply the default scenario of Table 50 by multiplying amount of staff travel days with the scenario.

Table 50. Default scenario for staff travel (per day) to be used in case of no company-specific information.

Distance	Ratio	Transport mode
Short trip in EU (round) – 500 km	50%	75% Car; 25% Train
Medium trip in EU (round) – 2000 km	30%	20% Train; 80% Plane (short haul)
Long trips in EU (round) – 4000 km	10%	Plane 100% (short haul)

Long trips intercontinental (round) - 15000 km	10%	Plane 100% (long haul)

[The 7% of manhours and the travel scenario will be further evaluated after the RP-results and supporting studies. Suggestions are highly welcome].

6.1.11 Staff commuting

Staff commuting includes the travelling of employees to and from the office or manufacturing facility (incl. internal test facilities), throughout the manufacturing, assembling, integration and internal testing activities. Company-specific information should be used on the travelling mode and distance used per employee, in combination with the following transport datasets:

- Car: Transport, passenger car, diesel, RER
- Train: Transport, train, passenger, electric, RER
- Bus: transport, bus, passenger, diesel, RER
- Bike/foot: No impact shall be modelled.

[The list of these datasets will be updated once the exact dataset names are clear.] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

To allocate the amount of transport to the specific equipment (or subsystem) the nr of commuting days shall be calculated. This may be based on the total amount of man*hours spend on the project, excluding the working days for teleworking and divided by the # hours/day. If the amount of teleworking is not known the default amount of 20% shall be considered.

In case no company-specific information is available, the default commuting scenario as presented below shall be used (Table 51).

Table 51. Staff commuting default scenario, values per working day (return trip).

Transport mode	Distance	Ratio
Transport by car, diesel	40 km/commute	60%
Transport by train	40 km/commute	15%
Transport by bus, diesel	20 km/commute	15%
Transport by bike/foot	10 km/commute	10%

More information on the default datasets to be used can be found in Annex XX [under development].

[The assumptions will be re-evaluated using the data collected for the PEF-RPs]

6.1.12 External testing activities

The external testing activities cover the different tests required for the equipment (and subsystem), that are performed at an external testing facility. The modelling of the external testing shall include the amounts of the following activities:

- Facility or cleanroom use;
- Use of auxiliaries (e.g., liquid N2 for TVAC test);
- Transport of equipment or subsystems to external testing facilities (and back);
- Energy use
- Water use
- Direct emissions generated during the testing activities;
- Waste generated during testing.

All other inputs shall be excluded from the calculations. The inclusion of facility refers to the overall building where the external test is performed. The materials used to build specific testing rooms (e.g., TVAC room) are excluded, while the activities within the testing room are included.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the testing activity. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX, for an overview of most common auxiliaries used and their related emission factors. *[We aim for emission factors of the main auxiliaries used. Inputs are welcome. This will be added in the default datasets.]*

While most inputs will be test-specific, the manufacturing facility or cleanroom use will need to be allocated to the specific testing activity. To allocate to the specific test, the corresponding rules of allocation apply (see sections 0 and 6.1.7).

If no company-specific information is available, a default dataset shall be selected. More information on the default datasets can be found in Annex XX [Under development]. Default datasets on the following tests are available:

- Mechanical test, incl. shock / structural;
- Thermal test;
- TVAC test;
- EMC test;
- Proof pressure test;
- Material test (also called non-destructive inspection, to evaluate fatigue, fracture, etc.);
- Functional test (e.g., complete life cycle test for engines).

For those tests where size matters, multiple sizes are available [Under development]. The functional test shall be used as default in case the required test is not available in the dataset list.
To allocate the test activity to the specific equipment (or subsystem), the time of testing shall be used [The unit of the testing datasets will be based on time].

[The following tests have not been included: Dimensional and geometric control, laser surface treatment for cleaning the surface. Input of default data or justification for the need of other default tests is highly welcome during the open consultation]

6.1.13 MAIT processes

For all MAIT processes the amounts of energy use, water use as well as the type and amount of direct emissions shall be included in the modelling:

- Electricity: More guidance on the modelling of the direct electricity use on site can be found in Section 5.8.
- The modelling of water use shall be regional specific using the flows as provided in EF xx.
- The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the MAIT process. If this is not available, as a minimum the emissions related to Auxiliary use shall be included in the modelling. See Table 52, for an overview of most common auxiliaries used in MAIT processes and their related emission factors. [Inputs and suggestions on how to define default values are highly welcome.]

Table 52. Auxiliaries and related emissions (mainly solvents related).

Auxiliary	Emission (substance name)	Emission factor (%)

If no company-specific information is available on the amounts of energy, water use and direct emissions, default values shall be used as presented in Annex XX [under development].

[Equipment and subsystem specific data will be collected for MAIT processes. Then it will be evaluated how much data is received, how many data gaps we have, and if we can created averages on (i) Mechanical equipment MAIT process, (ii) Electronical equipment AIT process, (iii) Mechanical Subs. MAIT process, and (iv) Electronical Subs. MAIT process. Inputs and suggestions are highly welcome.]

6.1.14 Waste generated during production

The waste generated during the production of equipment and subsystems shall be included in the modelling using material-specific loss rates. In case no company-specific information is available, the default loss rates per manufacturing process and material input of Table 53 shall be used:

Table 53. Default loss rates

Manufacturing process	Material	Equipment/subsystem	Default loss rate (%)
E.g. conventional machining	Aluminium		90%
…			
[Will be filled in after the open consultation]			

These loss rates shall be included in the modelling at three levels:

- The amount of materials and components required: by multiplying the input amounts with the respective loss rates as [1+(loss rate/100)].
- For cleanroom use, external testing, direct energy and water use during manufacturing, assembling, integration and internal testing: shall be based on the total amount of materials and components required including the loss rates.
- For the waste generated: by using the loss rates to calculate the amounts of waste generated. Once the amounts of waste are quantified, the emissions related to the respective waste treatments shall be included in the modelling.

To model the end of life treatment, the Circular Footprint Formula (CFF) shall be used, as explained in detail in Section 5.13. The end of life parameters to be used at equipment level are presented in Table 54.

Table 54: End of life parameters for the waste generated during the manufacturing, assembling, integration and internal testing of the equipment.

Materials/components	A	R_2	R_3	E_{recEOL}	E^*_V

Table 55: End of life parameters for the waste generated during the manufacturing, assembling, integration and internal testing of the sub-systems.

Equipments	A	R_2	R_3	E_{recEOL}	E^*_V

[To be defined after the open consultation.]

6.1.15 Packaging of the subsystems

The packaging of subsystems (such as containers, also named transport GSE) shall be included in the modelling. The type and amount of material needed, as well as used auxiliaries should be modelled with company-specific information.

If packaging is being reused, the additional energy and resource used for cleaning or repairing shall be included. The raw material consumption of reusable packaging shall be calculated by dividing the actual weight of the packaging by the reuse rate. More detailed modelling requirements are provided in section 5.10.

In case no company-specific information is available, the user of the PEFCR shall use the following defaults: XXX

[Based on the PEF-RP assessments and supporting studies, it will be evaluated if packaging of subsystems should be included or falls under the cut-off. If included, default values on amounts, type and reuse rates shall be agreed upon.]

6.1.16 Storage of the subsystem on site (outside cleanroom)

The on-site storage of produced subsystems is often done in a separate room or container. When modelling the storage, the user of this PEFCR shall include the amounts of the following activities:

- Electricity use;
- Natural gas use (for heating or pressure);
- Water use;
- Building infrastructure;
- Direct emissions;
- Auxiliaries (such as desiccants or liquid nitrogen).

All other activities shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the storage. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX, for an overview of most common auxiliaries used and their related emission factors. *[We aim for emission factors of the main auxiliaries used. Inputs are welcome. This will be added in the default datasets.]*

The lifetime for the storage infrastructure shall be 50 years.
The hours of storage to be considered are 7 days a week, 24h a day, 365 days a year.
To allocate the storage use to the specific subsystem the time and volume occupied shall be used.

The amounts of the different activities required for storing the subsystem should be based on company-specific information. In case no company-specific information is available, the user of the PEFCR shall use the default dataset as available in Annex XX [under development].

In the case that storage occurs in the cleanroom (modelled in Section 6.1.7), and there is no additional storage outside the cleanroom, storage of subsystem on-site (as prescribed here) shall be neglected to avoid double counting.

6.1.17 Inbound transport

Inbound transport includes all transport of materials to the respective sites for producing equipment and sub-systems. If transport happens in multiple trajects, all trajects shall be included. When inbound transport is modelled, it shall be modelled separately for each input material required (e.g, packaging, materials, equipment). Company-specific information on the transport mode, the distance per transport mode, utilisation ratios (loading factors) for truck transport and empty return modelling for truck transport should be used if available.

If no company-specific information is available, detailed information on default transport distances and datasets to be used can be found in section 5.12.

6.1.18 Outbound transport

The transport of subsystems and packaging to the manufacturing site of the spacecraft or launcher shall be modelled in this life cycle stage. If transport happens in multiple trajects, all trajects shall be included. Company-specific information on the transport mode, the distance per transport mode, utilisation ratios for truck transport and empty return modelling for truck transport shall be used.

[Based on the PEF-RP and supporting studies, the contribution and feasibility will be evaluated. Afterwards it will be decided if defaults need to be provided.]

6.1.19 Refurbishment of reusable equipment or subsystems

This activity includes the refurbishment of reusable equipment and subsystems. It shall include the amounts of the following activities.
For equipment:

- Materials and components required;
- Ground support equipment (incl. maintenance)
- Cleanroom use (excl. MAIT processes);
- Office use;
- Staff travel (e.g., to suppliers);
- External testing;
- MAIT processes;
- Inbound transport of each material, component and GSE required;
- Waste generated during production.

For subsystems:

- Materials required;
- Auxiliaries consumed;
- Ground support equipment (incl. maintenance);
- Cleanroom use (excl. MAIT processes);
- Manufacturing facility (excl. MAIT processes);
- Office use;
- Staff travel;
- Staff commuting;
- External testing;
- MAIT processes;
- Waste generated during production;
- Packaging of the subsystem;
- Storage of the subsystem on-site (outside cleanroom);
- Inbound transport of each equipment, material, packaging, auxiliary and GSE required;
- Outbound transport of subsystem to manufacturing site of spacecraft/launcher.

All other activities shall be excluded from the calculations.

The amounts of the different activities should be modelled with company-specific data. The refurbishment of equipment or subsystems is modelled for one launch.

The refurbishment of the spacecraft/launcher as a whole is included in the manufacturing stage (6.2.14). The change of equipment or subsystems that takes place during refurbishment falls under lifetime extension and is included in the FU and reference flow (more information can be found in sections 3.3.6 and 5.11.2). More detailed modelling requirements are provided in section 5.11.

The sections above (6.1.3 - 6.1.18) explain the detailed modelling rules for each of the required input activities.

6.2 Manufacturing stage (for spacecrafts and launchers)

[The PEFCR shall list all technical requirements and assumptions to applied by the user of the PEFCR. Furthermore, it shall list all processes taking place in this life cycle stage, according to the table provided below. The table may be adapted by the TS as appropriate (e.g. by including relevant parameters of the circular footprint formula).]

The life cycle stage "Manufacturing" includes all activities directly related to the manufacturing of the spacecraft or launcher. It starts from the arrival of the subsystems at the manufacturing site. It includes the necessary storage onsite (before and after manufacturing), all activities needed to manufacture the spacecraft or launcher and the final storage till the spacecraft or launcher leaves the manufacturing gate.

The manufacturing of spacecrafts or launchers required for testing or spares, as well as refurbishment activities shall be included in this life cycle stage. See section 5.11 for more details on modelling reusable parts.

The transport of subsystems to the manufacturing site shall be modelled under the previous life cycle stage, while the transport of auxiliaries and ground support equipment, specific to MAIT of spacecrafts or launchers shall be included in this life cycle stage.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used for the manufacturing stage.

6.2.1 Production of the spacecraft or launcher

The production of the spacecraft or launcher shall include the amounts of the following activities:

- Subsystems required;
- Auxiliaries consumed;
- Ground support equipment (incl. maintenance)*;
- Cleanroom use (excl. MAIT processes);
- Manufacturing facility (excl. MAIT processes);
- Office use;
- Staff travel;
- Staff commuting;
- External testing*;
- MAIT processes;
- Waste generated during production;
- Packaging materials for the final product;
- Storage and maintenance on site of subsystems or final products;
- Refurbishment of launcher stages (for reusable launcher stages)

All other activities shall be excluded from the calculations.

*Beside the ground support equipment (including maintenance and transport) and the external testing, all activities and required amounts are considered manufacturing-related and therefore shall be modelled with mandatory company-specific data (as also listed in Section 5.1).

If spacecrafts or launchers are (partly) being reused, the additional energy and resources for refurbishment shall be included in this life cycle stage (see section 6.2.14). The impact shall be calculated by dividing the impact of the activities listed above excluding subsystems (their reuse is covered in the previous section) by its reuse rate. More detailed modelling requirements are provided in section 5.11.

For launchers, this section refers to the manufacturing of the different launcher components. Therefore, in this life cycle stage, the term “launcher” specifically refers to its different launcher stages and boosters. These components are assembled at the launch site, where they are also integrated with the spacecraft.

The sections below (6.2.2 till 6.2.13) explain the detailed modelling rules for each of the required input activities.

6.2.2 Auxiliaries

Auxiliaries refer to additional materials and substances (such as solvents and liquid nitrogen) needed during the production process of equipment / sub-systems, testing activities, cleanroom or storage.

Annex XX of this PEFCR provides a list of default auxiliaries that may be used during the modelling. In case the auxiliary required is not included in Annex XX, section 5.5 shall be used for further guidance. [List of auxiliaries is under development]

6.2.3 Transport of auxiliaries and ground support equipment

Transport of the ground support equipment and auxiliaries shall be included in the modelling. Company-specific information on the transport mode (such as truck, aircraft or ship) and the distance per transport mode should be used if available. For truck transport, the utilization ratio (loading rate) and empty return modelling should be company-specific if available.

If no company-specific information is available, detailed information on default transport distances and datasets to be used can be found in section 5.12.

6.2.4 Ground support equipment (including maintenance)

The ground support equipment (GSE) is specifically developed to handle the spacecraft or launcher being developed. It includes the tools necessary to perform the manufacturing, assembling, integration and internal test activities. It covers both mechanical and electrical GSE equipment. Transport GSE refers to the packaging used for the spacecraft or the launcher and is discussed in section 6.1.3 and 6.1.4.

GSE is usually built off-site and transported to its use site. The modelling of GSE (incl. maintenance) shall include the amounts of the following activities:

- Materials and components required (including spares);
- Energy use for production;
- Transport of the GSE to its use site;
- Auxiliaries for maintenance;
- Office use.

The amounts and exact materials needed when modelling the ground support equipment for subsystems should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default dataset on (i) Mechanical GSE or Electronical GSE for spacecrafts or (ii) Mechanical GSE or Electronical GSE for launchers (ANNEX XX) [under development].

If a certain GSE is used multiple times within the same mission, it should only be accounted for once. If a certain GSE is re-used by different missions, it can be allocated to a specific mission in two ways (in hierarchical order):

(i) by dividing the GSE model by the number of missions it is used for during its lifetime, in case this is known. Or,
(ii) by dividing the number of years the GSE is used for the mission, by the default lifetime.

A default lifetime of 10 years shall be used, unless there are justified reasons to deviate (e.g., the lifetime of 10 years already passed). This shall be justified when performing the study.

6.2.5 Cleanroom use

The cleanroom is a controlled environment facility, in which manufacturing, assembling, integration and testing procedures and storage of the spacecraft or launcher takes place. The modelling of the cleanroom facility shall include the amounts of the following activities (excluding MAIT processes):

- Electricity use (for ventilation and environmental control such as heating, cooling, humidity control);
- Natural gas use;
- Water use;
- Direct emissions;
- Use of personal protective equipment;
- Auxiliaries (e.g., chemicals for cleaning or refrigerants for air conditioning);
- Use of filters;
- Ground transformation;
- Building infrastructure.

All other inputs shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the cleanroom use. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX [under development], for an overview of most common auxiliaries used in cleanroom use and their related emissions. *[Input is requested on the main emissions and amounts of the main auxiliaries used.]*

The modelling of the cleanroom and allocation of the cleanroom use to the spacecraft (/launcher) shall be based on company-specific data. The lifetime for cleanroom infrastructure to be considered is 30 years. The operation hours are to be considered 7 days a week, 24h a day, 365 days a year.

When using company-specific data, the cleanroom use shall be allocated to the spacecraft or launcher using the duration of occupation and area occupied[41]. The following inputs are needed:

1. The total annual consumption of electricity, gas, water, personal protective equipment, auxiliaries, and filters.
2. The total annual direct emissions. If these are not available, use Table XX [Under development].
3. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
4. The total duration of occupation shall reflect how long the spacecraft (or launcher) actively used the cleanroom (in hours).
5. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area.

The cleanroom is then allocated to the specific spacecraft or launcher: For example, all above mentioned inputs of the cleanroom are divided by 365 days a year and 24 hours a day, divided by total cleanroom area (incl. hallways) (in m^2), and lastly multiplied with occupied area (m2) (+5%) and occupation time (hours) of the spacecraft or launcher.

In this life cycle stage, the activities for cleanroom, office use and manufacturing facility shall be modelled separately.

6.2.6 Manufacturing facility

The manufacturing facility for the spacecraft (/launcher) shall include the amounts of the following activities (excluding MAIT processes):

- Electricity use;
- Gas use;
- Water use;
- Ground transformation;
- Building infrastructure (building of the manufacturing facility).

All other inputs shall be excluded from the calculations. Note, the amounts needed for MAIT processes are modelled separately under “MAIT processes”.

The lifetime for manufacturing facility to be considered is 50 years.
The operation of the manufacturing facility is considered to be 7 days a week, 24h a day, 365 days a year.

[41] As is provided in the contract.

The use of manufacturing facility shall be allocated to the specific spacecraft or launcher, using the duration of occupation and the area occupied.

1. Electricity, gas and water use shall be measured and collected for one year. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
2. The total duration of occupation shall reflect how long the equipment (or sub-system) actively uses the manufacturing facility.
3. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area.

The manufacturing facility is then allocated to the specific spacecraft or launcher: For example, the total annual consumption (and all activities as defined above) of the manufacturing facility can be divided by 365 days*24hours (being the annual total amount of hours) and the total area of the manufacturing facility, and then be multiplied with duration of occupation and area of occupied for the specific spacecraft (/launcher).

In this life cycle stage, the activities for cleanroom, office use and manufacturing facility shall be modelled separately.

6.2.7 Office use

The office work includes all related office activities required for the spacecraft or launcher, such as research and development, legal activities, or sales. The modelling of office use shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Ground transformation;
- Building infrastructure (building of the office).

All other inputs shall be excluded from the calculations.

The lifetime for office infrastructure to be considered is 50 years.
The use time of the office is calculated based on the number of working hours per day and number of working days/year.

The office use shall be allocated to the specific spacecraft or launcher using the amount of man*hours spent on the mission. The following inputs are needed:

1. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
2. The annual consumption of gas, water and electricity shall be measured
3. The total office operation per year (in total man*hours): based on # hours/day * # working days/year * total amount of staff.
4. The amount of man*hours dedicated to the spacecraft or launcher: based on # hours/day * total working days working on the spacecraft or launcher (sum of all staff working on the spacecraft).

The office use is then allocated to the specific spacecraft or launcher: For example, the entire office use dataset (including all activities as defined above) can be divided by 30 man * 8h *220 working days (being the annual total amount of manhours) and multiplied with 80 man*hours (being the amount of manhours dedicated to the spacecraft).

IMPORTANT: In most cases, the number of man*hours within a project are spend in the office and cleanroom. The number of workhours shall be correctly split between the cleanroom use and office use, this to avoid any double counting. In case the man*hours solely spend in the office is not known, as default 70 % of all project man*hours shall be allocated to office use. [We welcome any feedback on this % during the open consultation]

In this life cycle stage, the activities for cleanroom, office use and manufacturing facility shall be modelled separately.

6.2.8 Staff travel

Staff travel includes the travelling (business related) of employees (i) to supplier manufacturing sites, to test and verify the component/equipment/sub-system being used or for any programmatic/contractual reasons, (ii) between own production sites, and (iii) for on-site progress or review meetings (e.g; to ESA). Staff travel can be done by car, train or plane. Company-specific information shall be used on the travelling mode and distance used per travel, in combination with the following transport datasets:

- Car: Transport, passenger car, diesel, RER
- Train: Transport, train, passenger, electric, RER
- Plane: Transport, aircraft, passenger, long-haul, business class, global average; Transport, aircraft, passenger, short-haul, economy class, Europe.

[The list of these datasets will be updated once the exact dataset names are clear.] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

6.2.9 Staff commuting

Staff commuting includes the travelling of employees to and from the office or manufacturing facility (incl. internal test facilities), throughout the manufacturing, assembling, integration and internal testing activities. Company-specific information shall be used on the travelling mode and distance used per employee, in combination with the following transport dataset:

- Car: Transport, passenger car, diesel, RER
- Train: Transport, train, passenger, electric, RER
- Bus: Transport, bus, passenger, diesel, RER
- Bike/foot: No impact shall be modelled.

[The list of these datasets will be updated once the exact dataset names are clear.] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

To allocate the amount of transport to the specific equipment (or subsystem) the nr of commuting days shall be calculated. This may be based on amount of man*hours collected for office use, excluding the working days for teleworking and divided by the # hours/day.

6.2.10 External testing

The external testing activities cover the different tests required for spacecraft or launcher, that are performed at an external testing facility. The modelling of the external testing shall include the amounts of the following activities:

- Facility or cleanroom use;
- Use of auxiliaries (e.g., liquid N2 for TVAC test);
- Transport of equipment or subsystems to external testing facilities (and back);
- Energy use
- Water use
- Direct emissions generated during the testing activities;
- Waste generated during testing.

All other inputs shall be excluded from the calculations. The inclusion of facility refers to the overall building where the external test is performed. The materials used to build specific testing rooms (e.g., TVAC room) are excluded, while the activities within the testing room are included.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the testing activity. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX, for an overview of most common auxiliaries used and their related emission factors. [We aim for emission factors of the main auxiliaries used. Inputs are welcome. This will be added in the default datasets.]

While most inputs will be test-specific, the manufacturing facility or cleanroom use will need to be allocated to the specific testing activity. To allocate to the specific test, the corresponding rules of allocation apply (see sections 6.2.6 and 6.2.5).

If no company-specific information is available, a default dataset shall be selected. More information on the default datasets can be found in Annex XX]. Default datasets on the following tests are available:

- Mechanical test, incl. shock / structural;
- Thermal test;
- TVAC test;
- EMC test;
- Proof pressure test;

- Material test (also called non-destructive inspection, to evaluate fatigue, fracture, etc.);
- Functional test (e.g., complete life cycle test for engines).

For those tests where size matters, multiple sizes are available [Under development]. The functional test shall be used as default in case the required test is not available in the dataset list.
To allocate the test activity to the specific equipment (or subsystem), the time of testing shall be used [The unit of the testing datasets will be based on time].

[The following tests have not been included so far: Dimensional and geometric control, laser surface treatment for cleaning the surface. Input during the open consultation is welcome.]

6.2.11 MAIT processes

For all MAIT processes at spacecraft or launcher level, the amounts of energy use, water use as well as the type and amount of direct emissions shall be included in the modelling using company-specific information:

- Electricity use: More guidance on the modelling of the direct electricity use on site can be found in section 5.8.
- The modelling of water use shall be regional specific using the flows as provided in the EF reference package.
- The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the MAIT process. If this is not available, as a minimum the emissions related to Auxiliary use shall be included in the modelling. See Table 52, for an overview of most common auxiliaries used in MAIT processes and their related emission factors.

[We like to come up with emission factors for the main auxiliaries used. Inputs are welcome].

6.2.12 Waste generated during production

The waste created from using auxiliaries during spacecraft or launcher production shall be included in the modelling using the Circular Footprint Formula (CFF) as explained in detail in Section 5.13. The end of life parameters to be used are presented in Table 56.

Table 56: End of life parameters for the wasted auxiliaries during spacecraft manufacturing.

Auxiliaries	A	R_2	R_3	E_{recEOL}	E^*_V

[To be discussed and defined after the open consultation]

6.2.13 Storage on-site

The on-site storage of manufactured spacecrafts or launchers is often done in a separate room or container. When modelling the storage, the user of this PEFCR shall use company-specific information for the amounts of the following activities:

- Electricity use;
- Natural gas use (for heating or pressure);
- Water use;
- Building infrastructure;
- Direct emissions;
- Auxiliaries (such as desiccants or liquid nitrogen).

All other activities shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the storage. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX, for an overview of most common auxiliaries used and their related emission factors. [We aim for emission factors of the main auxiliaries used. Inputs are welcome during the open consultation. This will be added in the default datasets.]

The lifetime for the storage infrastructure shall be 50 years.
The hours to be considered are 7 days a week, 24h a day, 365 days a year.
To allocate the storage use to the spacecraft, the time and volume occupied shall be used.

6.2.14 Refurbishment of reusable spacecrafts or launchers

This activity includes the refurbishment of the reusable spacecrafts or launchers. It shall include the amounts of the following activities:

- Auxiliaries consumed;
- Ground support equipment (incl. maintenance)*;
- Cleanroom use (excl. MAIT processes);
- Manufacturing facility (excl. MAIT processes);
- Office use;
- Staff travel;
- Staff commuting;
- External testing*;
- MAIT processes;
- Waste generated during production;
- Packaging materials for the final product;
- Storage and maintenance on site of subsystems or final products;
- Refurbishment of launcher stages (for reusable launcher stages)

All other activities shall be excluded from the calculations.

*Beside the ground support equipment (including maintenance and transport) and the external testing, all activities and required amounts are considered manufacturing-related and therefore shall be modelled with mandatory company-specific data (as also listed in section 5.1).

All activities and required amounts are considered manufacturing-related and therefore shall be modelled with mandatory company-specific data (as also listed in Section 5.1). The refurbishment is modelled for one launch.

The change of equipment or subsystems that takes place during refurbishment falls under lifetime extension and is included in the FU and reference flow (more information can be found in sections 3.3.6 and 5.11.2).

The sections above (6.2.2 till 6.2.13) explain the detailed modelling rules for each of the required input activities.

6.3 Distribution stage

According to the PEF method “the distribution stage includes the transport from factory gate to storage, storage activities and transport to final client”. Within the context of Space-based activities this is translated as the transport of the product delivering the final service, being the spacecraft (or launcher) from the manufacturing gate till it is ready to provide its service (to the user) in space, such as linking data to Earth or in the case of launchers, transporting a payload in orbit. This life cycle stage includes the testing activities before going into operation.

The waste of products during distribution shall be included in the modelling.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

6.3.1 Distribution stage: spacecraft

For the spacecraft, the distribution stage includes the transport from the manufacturing stage to the launch site, the launch activity and movement till destination orbit (for all flight models and test models required). We foresee two options where (i) the launcher releases the spacecraft at destination orbit and (ii) where the spacecraft is released earlier and moves without the launcher to the destination orbit. For the latter, the system boundary diagram (presented in Figure 9) presents the option of either using an in-space transport service or spacecraft propellant. Both will be considered in the rules below but shall be put to zero in case it doesn’t take place.

6.3.1.1 Transport to the launch site

Transport of the spacecraft, launcher and the required GSE to the launch site shall be included in the modelling. Transport shall be modelled each individually with company-specific information on transport modes and locations, while using further guidelines provided in Section 5.12.

In case unique transport vehicles are developed, company-specific data shall be used for modelling the transport mode instead of default datasets on the transport mode. This shall include the material used, the energy used, as well as office use for engineering.

6.3.1.2 Spacecraft integration and testing in launcher

Spacecraft integration and testing includes all activities needed to prepare the spacecraft for launch. Upon arrival on the launch site the launch campaign takes place, there is spacecraft preparation for its integration and encapsulation into the launcher and associated verifications and final preparation, including the fuelling activities of the launcher. The amounts of the following activities shall be included:

- Spacecraft;
- Launcher;
- Launcher propellant use (incl. fuelling activities and leakage);
- Cleanroom use;
- Integration and testing at the launch site;
- Office use;
- Staff travel to launch site;
- Ground support equipment (incl. maintenance);
- Waste;
- Transport from the integration facility to the launch pad.

All other activities shall be excluded from the calculations. Packaging, auxiliaries, staff commuting and additional infrastructure (beside cleanroom, office use and GSE) shall not be modelled.

The amounts of the different activities required shall be modelled with company-specific information, except for office use, GSE, and transport to launch pad. For office use, GSE, and transport to launch pad company-specific information should be used. More details on the data needs, allocation requirements and defaults are provided in the sub-sections below.

The spacecraft integration and testing is modelled for one launch (except for the launcher). The allocation to the spacecraft being launched shall be made using the total launched mass (physical allocation). Meaning, the mass of spacecraft being launched as % of the total launched mass for this specific launch is used to allocate the “spacecraft integration and testing into launcher” to the spacecraft under study.

6.3.1.3 Launch activity

The launch activity includes all activities needed to launch and deliver the spacecraft to its destination orbit where it will provide its service. The amounts of the following activities shall be included:

- Spacecraft propellant use (if applicable)
- In-space transport (if applicable, see sub-category)
- Launch emissions from the launcher
- Spacecraft and mission control center (for LEOP)
- Launch ground activities
- Launch site and launch pad
- Re-entry and recovery of reusable launcher stages.

All other activities shall be excluded from the calculations. Auxiliaries, space traffic management shall not be modelled. Staff travel is already included in “Spacecraft integration and testing in launcher” and therefore excluded here.

The amount of spacecraft propellant and in-space transport (if applicable) shall be modelled with company-specific information. All other amounts for the different activities should be modelled with company-specific information. The Spacecraft and mission control center used for LEOP activities is modelled in two parts (i) the infrastructure and operations and (ii) the antenna and RF infrastructure (see sections 6.3.1.15 and 6.3.1.17). More details on the data needs, allocation requirements and defaults are provided in the sub-sections below.

The spacecraft and mission control center (for LEOP) is directly allocated to the single spacecraft using the LEOP time required for the mission. All other activities are modelled for a single launch and therefore need to be further allocated to the spacecraft. The allocation shall be made using the total launched payload mass for this specific spacecraft launch as physical basis. Meaning, the amount of spacecraft being launched as % of the total launched payload for this specific launch is used to allocate the “launch activity” to the spacecraft under study.

6.3.1.4 Launcher

This activity covers the life cycle of the packed launcher used to bring the spacecraft into orbit. It shall cover the following life cycle stages:

- Raw material acquisition and pre-processing
- Manufacturing
- End of life

The distribution of the launcher is included in section 6.3.1.1.
The use stage of the launcher is overlapping with this distribution stage, covered in sections 6.3.1.2 and 6.3.1.3, and therefore shall be excluded here.

Company-specific information should be used if available, following the detailed modelling requirements for the sub-category “uncrewed launch services from Earth to space”. In case no company-specific information is available, the default dataset (packed launcher, expressed in 1kg payload being launched, as in FU) provided in Annex XX [under development] shall be used.

6.3.1.5 Launcher propellant use

This activity covers the production, fuelling and use of launcher propellant (incl. leakage). The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production)
- Propellant storage on site
- Transport to launch site
- Fuelling activities (incl. emissions, auxiliaries and building infrastructure)

All other activities shall be excluded from the calculations. [Fuelling activities are currently included in this activity. It will be decided later if it is relevant to split it.]

The amount of propellant storage and fuelling activities depend on the type and amount of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of infrastructure auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure (GSE) and direct emissions.

The amount of propellant use depends on the maximum performance for which the launcher has been designed and shall be based on company-specific information. The launcher propellant is 100% linked to the specific launcher used, therefore: (i) If the launcher is modelled with company-specific information, also the “launcher propellant use” shall be modelled with company-specific information or (ii) if default data is used for the launcher, the corresponding default dataset on “launcher propellant use” shall be used (linked to the default launcher dataset) as provided in Annex XX.

6.3.1.6 Spacecraft propellant use

This activity covers the production, fuelling and use of spacecraft propellant. The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production)
- Propellant storage on site
- Transport to launch site
- Fuelling activities (incl. emissions, auxiliaries and infrastructure)

All other activities shall be excluded from the calculations. [Fuelling activities are currently included in this activity. It will be decided later if it is relevant to split it.]

Note that in-orbit emissions due to propellant use are not included in the modelling, as PEF only calculates the impacts on earth.

While the activities are the same as for launcher propellant use, the amounts and types might be totally different. The amount of propellant storage and fuelling activities depends on the amount and type of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of steel infrastructure (see Section 5.13), auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure (see Section 5.13) and direct emissions.

In case no company-specific information is available, the default dataset on spacecraft propellant use (per type of propellant) provided in Annex XX shall be used. [We aim to provide default datasets for the most common spacecraft propellants used.]

The total amount of spacecraft propellant use and the amount allocated to the distribution stage shall be based on company-specific information. The total amount of spacecraft propellant shall be allocated to three different parts of the spacecraft life cycle using company-specific data: (i) distribution stage, (ii) use stage and (iii) end of life. At the distribution stage (if applicable) the spacecraft propellant is used to transport the spacecraft from release orbit to destination orbit. The amount of propellant used for this movement shall be (i) zero if the launcher releases the spacecraft directly at destination orbit, or (ii) modelled with company-specific data.

6.3.1.7 Cleanroom use

The cleanroom is a controlled environment facility, in which manufacturing, assembling, integration and testing procedures and storage take place. The modelling of the cleanroom facility shall include the amounts of the following activities (excluding MAIT processes):

- Electricity use (for ventilation and environmental control such as heating, cooling, humidity control);
- Natural gas use;
- Water use;
- Direct emissions;
- Use of personal protective equipment;
- Auxiliaries (e.g., chemicals for cleaning or refrigerants for air conditioning);
- Use of filters;
- Building infrastructure.

All other inputs shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the cleanroom use. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX [under development], for an overview of most common auxiliaries used in cleanroom use and their related emission factors. *[Input is requested on the main emissions and amounts of the main auxiliaries used.]*

The lifetime for cleanroom infrastructure to be considered is 30 years.
The operation hours are to be considered 24h a day, 365 days a year.

The use of the cleanroom relates here to the spacecraft integration and testing, which is modelled for a single launch. Therefore, the cleanroom is here modelled for a single launch and allocated to the payload in section 6.3.1.2. When using company-specific data, the cleanroom use shall be allocated to the specific launch using the duration of occupation and area occupied during the entire integration and testing (including multiple payloads if applicable). The following inputs are needed:

1. The total annual consumption of electricity, gas, water, personal protective equipment, auxiliaries, and filters.
2. The total annual direct emissions. If these are not available, use Table XX [Under development].
3. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
4. The total duration of occupation shall reflect how long the launcher actively used the cleanroom (in hours).
5. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area (in m2).

The cleanroom is then allocated to the specific launch: For example, all above mentioned inputs of the cleanroom are divided by 365 days a year and 24 hours a day, divided by total cleanroom area (incl. hallways) (in m^2), and lastly multiplied with occupied area (m2) (+5%) and occupation time (hours) of the launch.

If no company-specific information is available for small cleanrooms (ceiling height ≤ 4.5m), one of the two default cleanroom datasets shall be used (presented in Annex XX). They are differentiated on the level of pressure standards (ISO-classes), (i) ISO 6-8 for high to moderate cleanliness, and (ii) ISO 5 for very high cleanliness (See Table 49). To allocate the default cleanroom dataset to the specific equipment (or subsystem), the duration and area size occupied shall be used[42]. For larger cleanrooms (ceiling height ≥4.5m) company-specific data shall be used in the modelling. See Section 6.1.7 for more instructions on allocating the default cleanroom datasets.

[It has been requested to provide a default dataset also for larger cleanrooms. However, it is difficult to create a default for large rooms as linear scaling doesn't hold. It will be evaluated after the PEF-RP modelling, if a default can be provided or if it shall be modelled with company specific data. Inputs during the open consultation are welcome.]

6.3.1.8 Integration and testing at the launch site

For all integration and testing processes the amounts of energy use, water use as well as the type and amount of direct emissions shall be included in the modelling:

[42] See description 4. And 5. On how to measure duration and occupied area.

- Electricity: More guidance on the modelling of the direct electricity use on site can be found in Section 5.8.
- The modelling of water use shall be regional specific using the flows as provided in EF xx.
- The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the process. If this is not available, as a minimum the emissions related to Auxiliary use shall be included in the modelling. See Table 52, for an overview of most common auxiliaries used in integration and testing processes and their related emission factors.

[Default emission factors for the main auxiliaries used will be developed after the PEF-RP modelling].

If no company-specific information is available on the input amounts required, the default dataset provided in Annex XX [under development] shall be used. The default dataset provided (per kwh spacecraft) shall be scaled to the needs, based on the power of the spacecraft being integrated.

6.3.1.9 Office use

The office work includes all related office activities required, such as research and development, legal activities, or sales. The modelling of office use shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Building infrastructure (building of the office).

All other inputs shall be excluded from the calculations.

The lifetime for office infrastructure to be considered is 50 years.
The use time of the office is calculated based on the number of working hours per day and number of working days/year. In case no company-specific information is available, 8h/day and 220 working days/year shall be considered.

When using company-specific data, the office use shall be allocated to the specific spacecraft using the amount of man*hours spent on the activity. The following inputs are needed:

1. The amount of building infrastructure shall be measured, and divided by its lifetime. See section 5.13 for more details.
2. The annual consumption of gas, water and electricity shall be measured
3. The total office operation per year (in total man*hours): based on # hours/day * # working days/year * total amount of staff.
4. The amount of man*hours dedicated to the activity: based on # hours/day *total working days working on the spacecraft (sum of all staff working on the spacecraft).

The office use is then allocated to the specific spacecraft: For example, the entire office use dataset (including all activities as defined above) can be divided by 30 man * 8h *220 working days (being the annual total amount of manhours) and multiplied with 80 man*hours (being the amount of manhours dedicated to the spacecraft).

If no company-specific information is available on the required input amounts, the default dataset presented in Annex XX [excel file under development] shall be used. To allocate the default office dataset to the specific activity in the distribution life cycle stage, the number of man*hours spend shall be used. In case no company-specific information is available on the amount of man*hours, a default of XX man*hours per launch shall be used. [The default man*hours to be used is still to be defined. Any inputs during the open consultation is welcome.]

6.3.1.10 Staff travel to launch site

Staff travel includes the business related travelling of employees (from the spacecraft producer) to the launch site to prepare the launch. Staff travel can be done by car, train or plane. Company-specific information shall be used on the travelling mode and distance used per travel, in combination with the following transport datasets:

- Car: Transport, passenger car, diesel, GLO
- Train: Transport, train, passenger, electric, GLO
- Plane: Transport, aircraft, passenger, long-haul, business class, global average; Transport, aircraft, passenger, short-haul, economy class, Europe.

[The list of these datasets will be updated once the exact dataset names are clear.] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

6.3.1.11 Ground support equipment (incl. maintenance)

The ground support equipment (GSE) is specifically developed to handle the spacecraft and launcher on the launch site. It includes the tools necessary to perform the integration and test activities. It covers both mechanical and electrical GSE equipment. Usually, it is built off-site and transported to its use site. The modelling of ground support equipment (incl. maintenance) shall include the amounts of the following activities:

- Materials and components required (including spares);
- Energy use for production;
- Transport of the GSE to its use site;
- Auxiliaries for maintenance;
- Office use.

All other inputs shall be excluded from the calculations.
The amounts and exact materials needed when modelling the ground support equipment should be based on company-specific information. In case no company-

specific information is available the user of the PEFCR shall use one of the default datasets provided in ANNEX XX [under development] of the PEFCR.

If a certain GSE is used multiple times for the same launch, it should only be accounted for once. If a certain GSE is re-used for different launchers, it shall be allocated to a specific launch by dividing the GSE model by the number of launches it is used for during its lifetime.

A default lifetime of 10 years shall be used, unless there are justified reasons to deviate (e.g., the lifetime of 10 years already passed). This shall be justified when performing the study.

6.3.1.12 Waste

All waste generated during spacecraft integration and testing (such as packaging materials) is collected and transported back to the country of origin of the spacecraft. There it shall be treated.

[Shall we include this in the modelling? If so, what are the different wastes, only packaging? Any suggestions/inputs during the open consultation are welcome]

6.3.1.13 Transport from the integration facility to the launch pad

Transport of the spacecraft and launcher to the launch pad shall be included in the modelling. Transport should be modelled with company-specific information on transport modes and distance if available. If not, the following defaults shall be used:

- Transport mode: XX
- Transport distance: XX

[This is probably very specific and difficult to provide defaults. However, its relevance might be very small and therefore not worth to request company-specific information. Based on the PEF-RP studies it will be decided if it is relevant to provide defaults on this.]

6.3.1.14 Launch emissions (from launcher)

Emissions taking place when the launcher lifts off and crosses the atmosphere shall be included in the modelling. The type and amount of launch emissions shall be calculated, depending on (i) the type and amount of launcher propellant used, (ii) as well as on the trajectory taken. See Section 5.15.1 for more details on the calculations.

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

6.3.1.15 Spacecraft and mission control centre (for LEOP)

The Launch and Early Orbit Phase (LEOP) is the phase after launch when critical operations are carried out by the Spacecraft and Mission Control Centre and the spacecraft is closely followed. LEOP start when the launch phase ends (meaning when the last stage of the launcher releases the spacecraft) and ends when it arrives at its operational orbit. It includes a wide range of operations to switch on all the sub-systems and prepare the deployment of the spacecraft at its final position or orbit. These activities are managed from the spacecraft and mission control centre (SCC/MCC), using a network of antennas. It operates continuously, provides multiple services and might control several spacecrafts simultaneously.

It is modelled in two parts:

1. SCC/MCC infrastructure and operations (LEOP): see section 6.3.1.16
2. Antenna (including pad) & RF equipment (LEOP): see section 6.3.1.17

Only a portion of the spacecraft and mission control centre is used by the specific spacecraft. The portion modelled shall be based on company-specific information on the time (# days) and the size and number of antenna required for the LEOP activities.

6.3.1.16 SCC/MCC infrastructure and operations (LEOP)

This section focusses solely on the SCC/MCC infrastructure & operations while the next section describes the rules for modelling the antenna & RF equipment to which the SCC/MCC is connected in order to deliver its service. The modelling of the SCC/MCC infrastructure & operations shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the operations only;
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the SCC/MCC as listed above.

The lifetime for the building infrastructure to be considered is 50 years, while for IT equipment a lifetime of 10 years shall be used.
The operation hours to be considered for SCC/MCC infrastructure & operations are 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for SCC/MCC infrastructure & operations is sufficient, as this is independent of the type, size and number of antennas connected during its service.

Only a portion of the SCC/MCC infrastructure & operations shall be used by the specific spacecraft, based on the duration of use. The portion of SCC/MCC infrastructure & operations used for in orbit related activities of the spacecraft (meaning, the amount of SCC/MCC used for the mission-related in orbit activities only) shall be based on company-specific information on the time (# days) required for the LEOP activities of the spacecraft.

The different inputs shall be measured and allocated using the following steps:
1. The total annual consumption of electricity, gas, water, auxiliaries and fuel for UPS shall be measured. Only the electricity use required for the SCC/MCC infrastructure & operations can be accounted for, the electricity use for the antenna needs to be considered separately.
2. The type and amount of all IT equipment, the UPS, and building infrastructure (see modelling details in Section 5.13) shall be measured, divided by their lifetime. The modem is considered as part of the SCC/MCC infrastructure & operations.
3. At this point the total service delivered by the SCC/MCC infrastructure & operations over one year shall be calculated using all spacecrafts served and the time (in days) for each. This leads to the total service delivered by the SCC/MCC station over one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the LEOP time (expressed in days) the spacecraft in scope is served by the SCC/MCC.

6.3.1.17 Antenna & RF equipment (LEOP)

The spacecraft and mission control centre (SCC/MCC) connects with one or more antennas & RF equipment in order to deliver its service during the LEOP time. It is assumed that the antenna can serve multiple spacecrafts, however it can’t serve multiple spacecrafts at the same time. It can only serve one spacecraft at any point in time. The modelling of the antenna and RF equipment shall include the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the antenna and RF equipment;
- RF equipment (transmitters, …), the modem is not considered as part of the RF equipment, but is considered to be part of the SCC/MCC infrastructure & operations;
- Antenna (incl. radome);
- Antenna pad (reinforced concrete foundation).

All other inputs shall be excluded from the calculations.

The lifetime for the antenna to be considered is 30 years, while for RF equipment (e.g., transmitters) a lifetime of 10 years shall be used.
The operation hours to be considered for the antenna & RF equipment are 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for the antenna & RF equipment is sufficient. A parabolic antenna is considered as the default type, which can be scaled by size (diameter of antenna).

Only a portion of the antenna & RF equipment shall be allocated to the specific spacecraft based on the duration of use, the number and size of antennas needed. The allocation of the antenna & RF equipment to LEOP activities (meaning, the amount of antenna used for the LEOP) shall be based on company-specific information on the time (# days), size and number of antennas required for the LEOP activities of the spacecraft.

The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, dedicated for the operation of the antenna & RF equipment, shall be measured.
2. The type, size and amount of the antenna and all RF equipment shall be measured, divided by their lifetime.
3. At this point the total service delivered by the antenna & RF equipment over one year shall be calculated using all spacecrafts served and the time for each (in #days). This leads to the total service delivered by the antenna & RF equipment in one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the LEOP time (expressed in days) and the size and number of antennas the spacecraft in scope communicates with.

6.3.1.18 Launch ground activities

The ground activities are launch site-specific and include all activities related to safety and security. They include sea measures with boats looking after security/safety and potentially catching some big falling dangerous objects, aerial measures to protect the launch against attacks or interference, terrestrial measures for safety/security reasons. The modelling of ground activities shall include the amounts of the following activities:

- Land, sea, air transport modes;
- Land, sea, air transport distances.

The launch ground activities are modelled for one launch. Company-specific information should be used. In case no company-specific information is available, the user of the PEFCR shall use the default datasets (expressed per one launch) provided in ANNEX XX of the PEFCR. [We aim to provide one default dataset for ground activities per launch site Kourou, Andøya Spaceport and Sutherland spaceport. This is under discussion and development. Inputs during the open consultation on the approach and potential data are welcome]

6.3.1.19 Launch site

The launch site covers the facility and all infrastructure needed to prepare and perform the launch. Often it includes a large area size, several buildings and offices, and launch pads. The modelling of the launch site shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Fuel use (generator);
- Building infrastructure (e.g. steel, concrete, roads, land used);
- Maintenance.

To allocate the activities to the specific launch in scope, the following allocation rules shall be used:

- If the electricity, gas, water and fuel use is collected on a yearly basis, their allocation to the specific launch shall be based on the average number of launches per year.
- The infrastructure related to the launch site shall be modelled following Section 5.13 and allocated based on the total number of launches in its entire lifetime. The lifetime for the infrastructure to be considered is 50 years.

The amounts needed when modelling the launch site should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default datasets provided in ANNEX XX [under development] of the PEFCR.

[Defaults should be provided for the most common launch sites for the European launch service providers. These are:

- Guiana Space Centre (Kourou, French Guiana)
- Andøya Spaceport (Andøya island, Norway)
- Sutherland spaceport (United Kingdom)]

6.3.1.20 Launch pad

The launch pad covers the launching infrastructure. The launch pads are either launcher-specific or flexible (meaning, they are used by multiple launchers). The modelling of the launch site shall include the amounts of the following activities:

- Building infrastructure (e.g. steel, concrete, roads, land used).

The infrastructure related to the launch pad shall be modelled following Section 5.13 and allocated to the launch based on the total number of reuse. Company-specific information on the number of reuse should be used. If this is not available, a default value of zero shall be used.

The amounts needed when modelling the launch pad should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default datasets provided per launch pad (expressed per one launch) in ANNEX XX [under development] of the PEFCR.

[Defaults should be provided for two types of launch pads: a small and a large launch pad. Only the Guiana Space Centre has both types available]

6.3.1.21 Re-entry and recovery of reusable launcher stages

More details on the modelling of re-entry and recovery when using reusable launchers can be found in section 6.4.2.3 and the related activities mentioned herein.

6.3.2 Distribution stage: launcher

For the launch services sub-category, the distribution stage includes the transport of the launcher stages and/or boosters from the manufacturing site to the launch site.

6.3.2.1 Transport to the launch site

Transport of the launcher stages and/or boosters to the launch site shall be included in the modelling using company-specific information on transport modes and locations, while using further guidelines provided in Section 5.12.

In case unique transport vehicles are developed, company-specific data shall be used to model the transport mode. This shall include the materials used, the energy used, as well as office use for engineering. [In case no company-specific information is available for the required input amounts, the default dataset that includes the special Ariane 6 transport mode Canopée shall be used, as listed in ANNEX XX – this is a nice to have if data are available].

6.4 Use stage

According to the PEF method, “the use stage describes how the product is expected to be used by the end user. This stage starts the moment the user uses the product until it leaves its place of use and enters the end of life (EoL) stage (e.g., final treatment). It includes all activities and products that are needed for proper use of the product (i.e. to ensure it performs its original function throughout its lifetime). Waste generated by using the product shall be part of the EoL stage”. Within the context of Space-based activities the use stage starts from the moment the spacecraft or launcher starts its operation until it reaches its end of life. For example, from the moment the spacecraft is operational in orbit and starts delivering its data till it reaches its service lifetime and moves to graveyard orbit. Testing activities before going actively in operation are part of the distribution stage.

According to the PEF recommendation, the PEFCR shall identify in the use stage those processes that are product dependent[43] and product independent[44]. The identified product independent processes are excluded from the system boundary. See more details in the sections below.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

The electricity mix to be used in the use stage of this PEFCR shall follow the modelling requirements explained in section 5.8.2.

6.4.1 Use stage: spacecraft

The use stage of the spacecraft includes all activities that are required to keep the spacecraft operational in orbit and have its service delivered (to Earth) during its entire service lifetime. It can be divided into two main phases: (1) the operation and control of the spacecraft while in orbit, and (2) the delivery of services from the spacecraft to Earth.

As a general allocation rule, allocating the use stage components to the functional unit shall be based on the Reference Flow calculation formula for each subcategory as documented in par. 3.3, i.e. using the denominator in the RF. This can either be based on the inventory expressed per year of use if the FU is expressed per year, or over the total design service lifetime if the FU is expressed as such. The sections below explain the modelling following different steps, depending on the time defined in the FU (per year or for total design service lifetime) the final calculation step might not be relevant.

6.4.1.1 Spacecraft in-orbit activity

The amounts of the following activities shall be included when modelling the spacecraft operations in orbit:

- Spacecraft propellant use;
- Spacecraft and mission control centre (SCC/MCC), distinguishing the (i) SCC/MCC infrastructure & operations and (ii) antenna & RF equipment.

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[43] **Product dependent processes** are directly or indirectly determined or influenced by the spacecraft or launcher design or are related to instructions for use. These processes depend on the spacecraft or launcher characteristics and therefore help differentiate two products. All instructions provided by the producer and directed towards the consumer (through labels, websites or other media) shall be considered product dependent.

[44] **Product independent processes** have no relationship with the way the spacecraft or launcher is designed or distributed. The impacts of the use stage process will remain the same for all spacecrafts or launchers in this product (sub-)category, even if the producer changes their characteristics. Therefore, they do not contribute to any form of differentiation between two products or might even hide the difference.

All other activities shall be excluded from the calculations. Note that in-orbit emissions due to propellant use are not included in the modelling, while emissions during manufacturing the propellant used are included in “spacecraft propellant use” (see Section 6.4.1.3). The Space traffic management (STM) is identified as an independent process and therefore excluded from the system boundary. STM activity can either take place in the same facility as the MCC or can be external. The STM delivers continuously data to SCC/MCC, which processes it further and therefore doesn’t vary depending on the mission.

The required amount of SCC/MCC infrastructure & operations, antenna & RF equipment and spacecraft propellant are modelled for the lifetime of one spacecraft with company-specific data. The allocation of the spacecraft to the FU is further explained in Section 3.3. The sections below explain the detailed modelling rules for each of the required input activities.

6.4.1.2 Spacecraft service delivery (if applicable)

The amounts of the following activities shall be included for the service delivery (if applicable for the product under study):

- Earth station(s) distinguishing the (i) Earth station infrastructure & operations and (ii) antenna & RF equipment.
- Ground communication network distinguishing the (i) core connectivity network and (ii) data centre;
- Equipment on the user side.

All other activities shall be excluded from the calculations.

The amounts of the different activities required shall be based on company-specific information. The following sections explain the detailed modelling rules for each of the required input activities.

6.4.1.3 Spacecraft propellant use

Spacecraft propellant is used to keep the spacecraft in its operational orbit and attitude during the use phase. This activity covers the production, fuelling and use of spacecraft propellant. While the production of propellant, storage and fuelling takes place on Earth, the related impacts linked to the amount of propellant used for orbit activities are allocate to this part of the life cycle. The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production)
- Propellant storage on site
- Transport to launch site
- Fuelling activities (incl. emissions, auxiliaries and cleanroom)

All other activities shall be excluded from the calculations. [Fuelling activities are currently included in this activity. It will be decided later if it is relevant to split it.]

Note that in-orbit emissions due to propellant use are not included in the modelling, as PEF only calculates the impacts on earth.

While the activities are the same as for launcher propellant use, the amounts and types might be totally different. The amount of propellant storage and fuelling activities depends on the amount and type of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of steel infrastructure (see Section 5.13), auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure (see Section 5.13) and direct emissions.

In case no company-specific information is available, the default dataset on spacecraft propellant use (per type of propellant) provided in Annex XX shall be used.
[We aim to provide default datasets for the most common spacecraft propellants used.]

The total amount of spacecraft propellant use and the amount allocated to the distribution stage shall be based on company-specific information. The total amount of spacecraft propellant shall be allocated to three different parts of the spacecraft life cycle using company-specific data: (i) distribution stage, (ii) use stage and (iii) end of life.

6.4.1.4 Spacecraft and mission control centre

The spacecraft and mission control centre (SCC/MCC) is the facility or network of facilities that manages the functionality of the spacecraft and the mission during its entire operation time in orbit. It operates continuously, provides multiple services and might control several spacecrafts simultaneously.

It is modelled in two parts:

1. SCC/MCC infrastructure & operations : see section 6.4.1.5
2. Antenna & RF equipment: see section 6.4.1.6

Only a portion of the spacecraft and mission control centre is used by the specific spacecraft. The portion modelled shall be based on company-specific information on the time (# days) and the size and type of antenna required for the operation service lifetime of the spacecraft.

6.4.1.5 SCC/MCC infrastructure & operations

The part of the SCC/MCC activities discussed in this section focusses solely on the SCC/MCC infrastructure & operations, the next section describes the rules for modelling the antenna & RF equipment to which the SCC/MCC is connected in order to deliver its service. The modelling of the SCC/MCC infrastructure & operations shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the operations only;
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the SCC/MCC as listed above.

The lifetime for the infrastructure to be considered is 50 years, while for IT equipment a lifetime of 10 years shall be used.
The operation hours to be considered for SCC/MCC infrastructure & operations are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for SCC/MCC infrastructure & operations is sufficient, as this is independent of the type, size and number of antennas connected during its service.

Only a portion of the SCC/MCC infrastructure & operations shall be used by the specific spacecraft, based on the duration of use. The portion of SCC/MCC infrastructure & operations used for in orbit related activities of the spacecraft (meaning, the amount of SCC/MCC used for the mission-related in orbit activities only) shall be based on company-specific information on the time (# days) required for the operation service lifetime of the spacecraft.

The different inputs shall be measured and allocated using the following steps:
1. The total annual consumption of electricity, gas, water, auxiliaries and fuel for UPS shall be measured. Only the electricity use required for the SCC/MCC infrastructure & operations can be accounted for, the electricity use for the antenna needs to be considered separately.
2. The type and amount of all IT equipment, the UPS, and building infrastructure (see modelling details in Section 5.13) shall be measured, divided by their lifetime. The modem is considered as part of the SCC/MCC infrastructure & operations.
3. At this point the total service delivered by the SCC/MCC infrastructure & operations over one year shall be calculated using all spacecrafts served and the time (in days) for each. This leads to the total service delivered by the SCC/MCC station over one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the (sum of non-continuous) time (expressed in days) the spacecraft in scope is served by the SCC/MCC per year of its use stage.

5. If the functional unit refers to the total design service life time of the spacecraft, as a last step the inputs per year of use need to be recalculated for the full design service life time.

6.4.1.6 Antenna & RF equipment

The spacecraft and mission control centre (SCC/MCC), resp. the Earth station, connects with one or more antennas & RF equipment to deliver its service during the entire operation time of the spacecraft in orbit. It is assumed that the antenna can serve multiple spacecrafts, however it cannot serve multiple spacecrafts at the same time. It can only serve one spacecraft at any point in time. [Is our assumption correct that an antenna can only serve one spacecraft at any point in time, and thus not multiple spacecrafts at the same time? Any input during the open consultation is welcome]
The modelling of the antenna and RF equipment shall include the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the antenna and RF equipment;
- RF equipment (transmitters, …), the modem is not considered as part of the RF equipment, but is considered to be part of the SCC/MCC infrastructure & operations;
- Antenna (incl. radome);
- Antenna pad (volume of reinforced concrete foundation).

All other inputs shall be excluded from the calculations.

The lifetime for the antenna to be considered is 30 years, while for RF equipment (e.g., transmitters) a lifetime of 10 years shall be used.
The operation hours to be considered for the antenna & RF equipment are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for the antenna & RF equipment is sufficient. A parabolic antenna is considered as the default type, which can be scaled by size (diameter of antenna).

Only a portion of the antenna & RF equipment shall be allocated to the specific spacecraft based on the duration of use, size and number of antennas needed. The allocation of the antenna pad, antenna & RF equipment to in orbit related activities of the spacecraft (meaning, the amount and size of antenna used for the mission-related in-orbit activities only) shall be based on company-specific information on the time (# days), size and number of antennas required for the operation service lifetime of the spacecraft.

The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, dedicated for the operation of the antenna & RF equipment, shall be measured.

2. The type, size and amount of the antenna (including pad) and all RF equipment shall be measured, divided by their lifetime.
3. At this point the total service delivered by the antenna & RF equipment over one year shall be calculated using all spacecrafts served and the time for each (in #days). This leads to the total service delivered by the antenna & RF equipment in one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2 for the antenna & RF equipment, related to step 3 are allocated to the spacecraft based on company-specific information on the (sum of non-continuous) time (expressed in days) and the size and number of antennas the spacecraft in scope uses per year of its use stage.
5. If the functional unit refers to the total design service life time of the spacecraft, as a last step the inputs per year of use need to be recalculated for the full design service life time.

6.4.1.7 Earth station

The Earth station(s) is part of the supporting ground infrastructure that communicates with the spacecraft during its use phase, when the spacecraft is delivering its service (for example, gate ways). It might serve several spacecrafts simultaneously.

It is modelled in two parts:

1. Earth station infrastructure & operations : see section 6.4.1.8
2. Antenna & RF equipment: see section 6.4.1.6

Only a portion of the Earth station is used by the specific spacecraft. The portion modelled shall be based on company-specific information on the time (# days) and the size and type of antenna required for the operation service lifetime of the spacecraft.

6.4.1.8 Earth station infrastructure & operations (if applicable)

The part of the Earth stations activities discussed in this section focusses solely on the Earth station infrastructure & operations, the rules for modelling the antenna & RF equipment to which the Earth station is connected in order to deliver its service is discussed in section 6.4.1.6. The modelling of the Earth station infrastructure & operations shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the operations only;
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the Earth station as listed above.

The lifetime for the infrastructure to be considered is 50 years, while IT materials (e.g., servers, and network) a lifetime of 10 years shall be used.
The operation hours are to be considered for Earth station are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default for the Earth station infrastructure & operations is sufficient as this is independent of the type, size and number of antennas connected during its service.

Only a portion of the Earth station infrastructure & operations shall be used by the specific spacecraft, based on the duration of use. The portion of the Earth station used for in orbit related activities of the spacecraft shall be based on company-specific information on the time (# days) required for the operation service lifetime of the spacecraft.

The Earth station(s) operates continuously and might communicate with several spacecrafts simultaneously. Therefore, its use shall be allocated to the specific spacecraft based on the portion of the Earth station infrastructure & operations that is dedicated to the spacecraft and the duration of use (expressed in spacecrafts*time). The allocation of the Earth station infrastructure & operations to the spacecraft shall be based on company-specific information on the time (# days) required from the Earth station. The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, gas, water, auxiliaries and fuel for UPS shall be measured. Only the electricity use required for the Earth station infrastructure & operations can be accounted for, the electricity use for the antenna needs to be considered separately.
2. The type and amount of all IT equipment, the UPS, and building infrastructure (see modelling details in Section 5.13) shall be measured, divided by their lifetime. The modem is considered as part of the Earth station infrastructure & operations.
3. At this point the total service delivered by the Earth station infrastructure & operations over one year shall be calculated using all spacecrafts served and the time (in days) for each. This leads to the total service delivered by the Earth station over one year, in spacecraft*days per year. If more than one spacecraft is served at a given time, the total spacecraft*days per year may exceed 365.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the (sum of non-continuous) time (expressed in days) the spacecraft in scope is served by the Earth station per year of its use stage.
5. If the functional unit refers to the total design service life time of the spacecraft, as a last step the inputs per year of use need to be recalculated for the full design service life time.

If the spacecraft communicates with several Earth stations, the modelling shall be performed for each Earth station and allocated to the spacecraft.

The modelling of the antenna(s) that are linked to the Earth station for the spacecraft under study, will be done as described in section 6.4.1.5.

6.4.1.9 Ground communication network

The ground communication network is part of the supporting ground infrastructure that communicates with the spacecraft during its use phase, when the spacecraft is delivering its service. It might serve several spacecrafts simultaneously.

It is modelled in two parts:

1. The core connectivity network: see section 6.4.1.10
2. Data centre: see section 6.4.1.11

Only a portion of the ground communication network is used by the specific spacecraft. The portion modelled shall be based on company-specific information on (i) the speed and distance for the core connectivity network and (ii) the Mb of data stored in the data centre.

6.4.1.10 Core connectivity network (if applicable)

The core connectivity network, part of the ground communication network, is the network that is used to interconnect different Earth station sites with each other, with the antennas or with data centres. It concerns both communication between ground stations via land lines and satellite communication. It includes cables and IT infrastructure used by operators.
The model of the core connectivity network shall include the amounts of the following activities:

- Electricity use (incl. maintenance);
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance);
- IT equipment used for the core connectivity network (e.g., cables (fibre), switches, amplifiers, servers);
- Communication via satellites (VSAT).

[Satellite communication between Earth stations is excluded so far and it is under discussion if this shall be excluded in the scope. We ask feedback on this during the open consultation]

All other inputs shall be excluded from the calculations, even though they might be part of the connectivity network. Connection cables between the core connectivity network and antenna, Earth station, data centres and dedicated buildings used by operators are excluded. Office use is implicitly included by the electricity use, natural gas use and water use as listed above.

The lifetime for IT materials (e.g., servers, and network) is considered to be 10 years. The operation hours are to be considered for the connectivity network are 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset is sufficient, independent of the orbit in which the spacecraft operates. This default dataset shall be scaled to the spacecraft specific connectivity network based on the Mbps capacity and the direct distance between Earth stations, data centres and antennas used for the spacecraft (per Mbps * km).

The connectivity network operates continuously. It might serve several spacecrafts simultaneously, which is implicitly taken into consideration by the Mbps linked to the network. Therefore, the use of the connectivity network shall be allocated to the specific spacecraft based on the portion of the connectivity network that is dedicated to the spacecraft's mission, based on the average throughput capacity of the network needed (expressed in Mbps). The allocation of the connectivity network to the spacecraft shall be based on company-specific information. The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, gas, water and auxiliaries shall be measured.
2. The type and amount of cables, all IT equipment (see modelling details in Section 5.13), divided by their lifetime.
3. At this point the total service delivered by the connectivity network over one year shall be calculated using the total distance of the connectivity network (direct distance between Earth stations, data centres and antennas, in km) and the total data rate capacity of the network (in Mbps) in one year. This leads to the total service delivered by the connectivity network over one year, in Mbps*km.
4. In case a default connectivity network is used (and no company-specific data are available for the steps 1-3), this default connectivity network shall be scaled to the spacecraft-specific connectivity network based on the Mbps capacity and the km of distance (per Mbps * km)
5. In case company-specific data are available for the connectivity network, the inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the minimum Mbps required for the service of the spacecraft.
6. If the functional unit refers to the total design service lifetime of the spacecraft, as a last step the inputs per year of use need to be recalculated for the full design service lifetime.

6.4.1.11 Data centre (if applicable)

In cases where data need to be processed and stored during the use phase of a spacecraft, the connectivity network also connects the Earth station(s) to data centres, as part of the ground communication network. A data centre mainly performs storage of the intermediate data before further processing. It includes dedicated IT infrastructure and dedicated cooling technologies.
The modelling of the data centre shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance);
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the Earth station as listed above.

The lifetime for the infrastructure to be considered is 50 years, while IT materials (e.g., servers, and network) a lifetime of 10 years shall be used.
The operation hours are to be considered for Earth station are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default for a data centre is sufficient. Scaling based on GB of data storage should allow to distinguish between less or more data intensive spacecrafts.

The data centre operates continuously and might serve several spacecrafts simultaneously. Therefore, its use shall be allocated to the specific spacecraft based on the portion of the data centre that is dedicated to the spacecraft (expressed in GB). The allocation of the data centre to the spacecraft shall be based on company-specific information on storage capacity required from the data centre. The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, gas, water, auxiliaries and fuel for UPS shall be measured.
2. The type and amount of all IT equipment, the UPS, and building infrastructure (see modelling details in Section 5.13) shall be measured, divided by their lifetime.
3. At this point the total service delivered by the data centre over one year shall be calculated using the total storage capacity of the data centre over one year. This leads to the total service delivered by the data centre over one year, in GB per year.

4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the storage capacity needed by the spacecraft in scope per year of its use stage.
5. If the functional unit refers to the total design service life time of the spacecraft, as a last step the inputs per year of use need to be recalculated for the full design service life time.

6.4.1.12 Equipment on the user side (if applicable)

Equipment might be necessary to deliver the service in scope of the study to its final user, such as beacons or antennas. This shall be included in the modelling when the size and type of equipment required depend on the service provider (as a product dependent process).

The modelling of the user equipment shall be modelled with the amounts for the following activities:

- Electricity use of the user equipment (user terminal and antenna);
- Size of Antenna

All other inputs shall be excluded from the calculations.

The amounts of the different activities required shall be based on company-specific information linked to the service provided as described in the FU and using the antenna default datasets provided in Annex XX [under development]. Table 57 indicates per sub-category the modelling requirements.

The user terminal and the antennas can have either a shared power supply, or separate power supplies. The electricity required shall be modelled for both the user terminal and its antenna, in case of separate power supplies.

The default lifetime of the user equipment is 15 years.

The electricity use of the user equipment shall be modelled with the consumption grid mix (see Section 5.8.2).

Table 57. User equipment per sub-category

Sub-category	**User equipment requirements**
Earth observation services	Not applicable.
Not Positioning, navigation and timing services	User equipment is out of scope. The signal can be picked up by many different receivers and the operator providing the open services cannot know who will use the signal.
Video services	Relevant in the analysis and shall be included in the modelling. See Section 6.6.3 for additional instructions on the user equipment for video.
Connectivity services	Relevant in the analysis and shall be included in the modelling. See Section 6.6.4

	for additional instructions on the user equipment for connectivity.
In-space transport services	Not applicable.
Uncrewed launch services from Earth to space	Not applicable.

6.4.2 Use stage: launcher

The launcher use stage involves two main activities:

1. **Launch campaign:** includes the integration of the launcher stages and boosters, the integration of the spacecraft into the launcher, the fuelling of the launcher and the testing;
2. **Launch event:** includes the launch activity and related launching emissions; the re-entry and recovery activities in the case of re-usable launchers that are aimed to be reused*, including the re-entry emissions are also included at this stage.

* *For re-usable launchers that re-enter the atmosphere for the last time (i.e., no further re-use), this is modelled under the end-of-life cycle stage of the launcher (see next section).*

Note that in this section on the launcher's use stage, and in the next section on its end-of-life stage, the term ‘**destination orbit’** refers to the various launcher stages, while ‘**altitude**’ refers specifically to the boosters. The functional unit defines the transport and **release** of a payload into orbit; this release is carried out by the upper stage of the launcher. Since a launcher consists of multiple stages, each reaching a distinct orbit, the term ‘destination orbit’ is used to reflect this variation. The term ‘release orbit’ is only used to express the final orbit the upper stage reaches to release a payload. In contrast, boosters do not reach orbit and are instead characterized by the ‘altitude’ they attain.

6.4.2.1 Launch campaign: launcher stages, boosters and spacecraft integration, fuelling and testing at the launch site

The launch campaign includes all activities needed to prepare the launcher for launch. Upon arrival on the launch site the so-called launch campaign takes place. The launcher stages and boosters are integrated. Furthermore, there is spacecraft preparation for its integration and encapsulation into the launcher and associated testing and final preparation, including the fuelling activities of the launcher. The spacecraft is the payload of the launcher and is outside the scope of this sub-category. The amounts of the following activities shall be included:

- Launcher propellant use (incl. fuelling activities and leakage);
- Cleanroom use;
- Integration and testing at the launch site;
- Office use;

- Staff travel to launch site;
- Staff commuting to launch site;
- Ground support equipment (incl. maintenance);
- Launch site;
- Waste;
- Transport from the integration facility to the launch pad.

All other activities shall be excluded from the calculations. Any auxiliaries and additional infrastructure (beside cleanroom, office use and GSE) shall not be modelled.

The amounts of the different activities required shall be modelled with company-specific information, except for office use and GSE. For office use and GSE, default information should be used. More details on the data needs, allocation requirements and defaults are provided in the sub-sections below. The launch campaign is modelled for one launch.

6.4.2.2 Launch activity

The launch activity includes all activities related to the launching of 1 kg of payload to a release orbit. The activity is performed by the launcher stages and the boosters. Launcher stages reach a destination orbit, while boosters only reach a specific altitude without reaching orbit. The amounts of the following activities shall be included:

- Launch emissions (from launcher);
- Launch ground activities;
- Flight safety centre;
- Antenna & RF equipment;
- Launch pad;
- Re-entry and recovery of reusable launcher stages.
- Water consumption.

All other activities shall be excluded from the calculations. Auxiliaries shall not be modelled. Staff travel is already included in “launch campaign“ and therefore excluded here.

Water consumption for the so-called ‘deluge’ is occurring during the lift-off. The net water use (water consumed minus water captured) shall be included. The modelling of water use shall be regional specific using the flows as provided in the EF reference package.

The amounts of launch emissions should be modelled with company-specific information. In case no company-specific information is available, the user of the PEFCR shall use values of the most common propellant types provided in Excel Annex 4.3: Launch emissions and re-entry emissions from propellant use.

All other amounts for the different activities should be modelled with company-specific information. More details on the data needs, allocation requirements and defaults are provided in the sub-sections below. The launch activity is modelled for one launch.

6.4.2.3 Re-entry and recovery of reusable launcher stages

This activity covers the re-entry emissions and the use of the flight safety centre related to the re-entry and recovery of reusable launcher stages. The amounts of the following activities shall be included:

- Flight safety centre for re-entry;
- Re-entry emissions from reusable launcher stages;
- Recovery vehicle (if applicable).

The amount of flight safety centre shall be modelled with company-specific information. If a special recovery vehicle is used to recover a reusable launcher stage (e.g., special barge), the amount shall be with company-specific information.

The amounts of re-entry emissions due to propellant burning, as well as due to burn-up from the friction of the heat shield with the atmosphere, should be modelled with company-specific information. In case no company-specific information is available, the user of the PEFCR shall use values of the most common propellant types provided in Excel Annex 4.3: Launch emissions and re-entry emissions from propellant use and most common materials in Excel Annex 4.4: Re-entry emissions from burn-up.

The refurbishment of launcher stages and the related use of building infrastructure/ cleanroom and MAIT processes is covered at the manufacturing stage (section 6.2.14). The change of subsystems and equipment is modelled in the FU and reference flow (see sections 3.3.6 and 5.11.2).

More details on the data needs, allocation requirements and defaults are provided in the sub-sections below.

6.4.2.4 Launcher propellant use

This activity covers the production, fuelling and use of launcher propellant (incl. leakage). The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production);
- Propellant storage on site;
- Transport to site;
- Fuelling activities (incl. emissions, auxiliaries and building infrastructure).

All other activities shall be excluded from the calculations.

The amount of propellant storage and fuelling activities depend on the type and amount of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of infrastructure (see Section 5.13), auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure (GSE) and direct emissions.

The amount of propellant use depends on the maximum performance for which the launcher has been designed and shall be based on company-specific information.

6.4.2.5 Cleanroom use

The cleanroom is a controlled environment facility, in which manufacturing, assembling, integration and testing procedures and storage take place. The modelling of the cleanroom facility shall include the amounts of the following activities (excluding MAIT processes):

- Electricity use (for ventilation and environmental control such as heating, cooling, humidity control);
- Natural gas use;
- Water use;
- Direct emissions;
- Use of personal protective equipment;
- Auxiliaries (e.g., chemicals for cleaning or refrigerants for air conditioning);
- Use of filters;
- Building infrastructure.

All other inputs shall be excluded from the calculations.

The modelling of direct emissions should be based on measured data, reflecting the amounts and type of emissions related to the cleanroom use. As a minimum the emissions related to Auxiliary use shall be included in the modelling. See TABLE XX [under development], for an overview of most common auxiliaries used in cleanroom use and their related emission factors.

The lifetime for cleanroom infrastructure to be considered is 30 years.
The operation hours are to be considered 24h a day, 365 days a year.

The use of the cleanroom relates here to the launch campaign, which is modelled for a single launch. Therefore, the cleanroom is here modelled for a single launch. When using company-specific data, the cleanroom use shall be allocated to the specific launch using the duration of occupation during the entire launch campaign. The following inputs are needed:

1. The total annual consumption of electricity, gas, water, personal protective equipment, auxiliaries, and filters.
2. The total annual direct emissions. If these are not available, use Table XX [under development].
3. The amount of building infrastructure shall be measured and divided by its lifetime. See section 5.13 for more details.

4. The total duration of occupation shall reflect how long the launcher actively used the cleanroom (in hours).
5. The area occupied shall be measured as the area of the pre-defined workstation + 5% to cover common area (in m2).

The cleanroom is then allocated to the specific launch: For example, all above mentioned inputs of the cleanroom are divided by 365 days a year and 24 hours a day, divided by total cleanroom area (incl. hallways) (in m^2), and lastly multiplied with the occupation time (hours) of the launch.

For larger cleanrooms (ceiling height ≥4.5m) company specific data shall be used in the modelling. See Section 6.1.7 for more instructions on allocating the default cleanroom datasets.

6.4.2.6 Integration, and testing at the launch site

- For all integration and testing processes the amounts of energy use, water use as well as the type and amount of direct emissions shall be included in the modelling:
- Electricity: More guidance on the modelling of the direct electricity use on site can be found in Section 5.8.
- The modelling of water use shall be regional specific using the flows as provided in the EF reference package.
- The modelling of direct emissions shall be based on measured data, reflecting the amounts and type of emissions related to the process. If this is not available, as a minimum the emissions related to Auxiliary use shall be included in the modelling. See Table 52, for an overview of most common auxiliaries used in integration and testing processes and their related emission factors.

6.4.2.7 Office use

The office work is launch site-specific and it includes all related office activities required. The modelling of office use shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Building infrastructure (building of the office).

All other inputs shall be excluded from the calculations.

The lifetime for office infrastructure to be considered is 50 years.
The use time of the office is calculated based on the number of working hours per day and number of working days/year. In case no company-specific information is available, 8h/day and 220 working days/year shall be considered.

When using company-specific data, the office use shall be allocated to the specific launcher using the amount of man*hours spent on the activity. The following inputs are needed:

1. The amount of building infrastructure shall be measured and divided by its lifetime. See section 5.13 for more details.
2. The annual consumption of gas, water and electricity shall be measured
3. The total office operation per year (in total man*hours): based on # hours/day * # working days/year * total amount of staff.
4. The amount of man*hours dedicated to the activity: based on # hours/day *total working days working on the spacecraft (sum of all staff working on the launcher).

If no company-specific information is available on the required input amounts, the default dataset presented in Annex XX [under development] shall be used. To allocate the default office dataset to the specific activity in the distribution life cycle stage, the number of man*hours spend shall be used. In case no company-specific information is available on the amount of man*hours, a default of XX man*hours [under development] per launch shall be used.

[The default man*hours to be used shall be evaluated based on the PEF-RP data collection.]

6.4.2.8 Staff travel to launch site

Staff travel includes the business related travelling of employees (from the launcher manufacturing) to the launch site to prepare the launch. Staff travel can be done by car, train or plane. Company-specific information shall be used on the travelling mode and distance used per travel, in combination with the following transport datasets:

- Car: Transport, passenger car, diesel, GLO
- Train: Transport, train, passenger, electric, GLO
- Plane: Transport, aircraft, passenger, long-haul, business class, global average; Transport, aircraft, passenger, short-haul, economy class, Europe.

[The list of these datasets will be updated once the exact dataset names are clear] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

6.4.2.9 Staff commuting to launch site

Staff commuting is launch site-specific and includes the travelling of employees to and from the office or launch facility, throughout the launch campaign and launch activity. Company-specific information shall be used on the travelling mode and distance used per employee, in combination with the following transport dataset:

  - Car: Transport, passenger car, diesel, GLO
  - Train: Transport, train, passenger, electric, GLO
  - Bus : Transport, bus, passenger, diesel, GLO

- Bike/foot: No impact shall be modelled.

[The list of these datasets will be updated once the exact dataset names are clear] If the exact transport mode (such as fuel and location) is known together with a suitable EF-compliant dataset is available, this should be used.

To allocate the amount of transport to the launch activity the number of commuting days shall be calculated. This shall be based on amount of man*hours collected for office use, excluding the working days for teleworking and divided by the # hours/day.

6.4.2.10 Ground support equipment (incl. maintenance)

The ground support equipment is specifically developed to handle the spacecraft and launcher on the launch site. It includes the tools necessary to perform the integration and test activities. Usually, it is built off-site and transported to its use site. The modelling of ground support equipment (incl. maintenance) shall include the amounts of the following activities:

- Materials and components required (including spares);
- Energy use for production;
- Transport of the GSE to its use site;
- Auxiliaries for maintenance;
- Office use.

All other inputs shall be excluded from the calculations.
The amounts and exact materials needed when modelling the ground support equipment shall be based on company-specific information.

If a certain GSE is used multiple times for the same launch, it should only be accounted for once. If a certain GSE is re-used for different launchers, it shall be allocated to a specific launch by dividing the GSE model by the number of launches it is used for during its lifetime.

A default lifetime of 10 years shall be used, unless there are justified reasons to deviate (e.g., the lifetime of 10 years already passed). This shall be justified when performing the study.

6.4.2.11 Waste

All waste generated during launcher stages, boosters and spacecraft integration and testing (such as packaging materials) is collected and transported back to the country of origin of the launcher. There it shall be treated.

6.4.2.12 Transport from the integration facility to the launch pad

Transport of the spacecraft and launcher to the launch pad shall be included in the modelling. Transport should be modelled with company-specific information on transport modes and distance if available. If not, the following defaults shall be used:

- Transport mode: XX
- Transport distance: XX

[This is probably very specific and difficult to provide defaults. However, its relevance might be very small and therefore not worth to request company-specific information. Based on the PEF-RP studies it will be decided if it is relevant to provide defaults on this.]

6.4.2.13 Launch emissions (from launcher)

Emissions taking place when the launcher lifts off and crosses the atmosphere shall be included in the modelling. The type and amount of launch emissions shall be calculated, depending on (i) the type and amount of launcher propellant used, (ii) as well as on the trajectory taken. See Section 5.15.1 for more details on the calculations.

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

6.4.2.14 Launch ground activities

The ground activities are launch site-specific and they include all activities related to safety and security. They include sea measures with boats looking after security/safety and potentially catching some big falling dangerous objects, aerial measures to protect the launch against attacks or interference, terrestrial measures for safety/security reasons.
The modelling of ground activities shall include the amounts of the following activities:

- Transport mode (land, sea, air);
- Transport distance.

Common EF datasets are used to model transport mode.

The launch ground activities are modelled per launch site for one launch. Company-specific information should be used. In case no company-specific information is available, the user of the PEFCR shall use the default datasets (launch site specific, expressed per launch) provided in ANNEX XX [under development] of the PEFCR.

6.4.2.15 Flight safety centre (for launch and re-entry)

The flight safety centre is the phase during launch to monitor the launch stages and/or boosters. It is also active during the re-entry of reusable launcher stages until they land.

The modelling of the flight safety centre shall include both the operation during launch as well as its maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance);
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use as listed above.

This section focusses solely on the Flight safety centre infrastructure and operations, while the next section describes the rules for modelling the antenna & RF equipment to which the Flight safety centre is connected in order to deliver its service

The lifetime for the infrastructure to be considered is 50 years, while for IT materials (e.g., servers, and network) a lifetime of 10 years shall be used.

The operation hours to be considered for the flight safety centre are the average operation hours per year and should be company specific. It shall be allocated to one launch or re-entry by dividing the yearly operation hours to the number of launches and re-entries supported by the flight safety centre yearly. In case no company-specific information is available, the user of the PEFCR shall use the default dataset (expressed per one launch or re-entry) provided in ANNEX XX [under development] of the PEFCR.

6.4.2.16 Antenna & RF equipment (Flight safety centre)

The launcher connects with one or more antennas & RF equipment in order to deliver its service. The antenna can serve one launch at a point of time. The modelling of the antenna and RF equipment shall include the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the antenna and RF equipment;
- RF equipment (transmitters, …), the modem is not considered as part of the RF equipment, but is considered to be part of the Flight safety centre infrastructure & operations;
- Antenna;

All other inputs shall be excluded from the calculations.

The lifetime for the antenna to be considered is 30 years, while for RF equipment (e.g., transmitters) a lifetime of 10 years shall be used.
The operation hours to be considered for the antenna & RF equipment are 24h a day, 365 days a year.

The amounts of the activities to be considered shall be based on the average operation hours per year and should be company specific. It shall be allocated to one launch or re-entry by dividing the yearly operation hours to the number of launches and re-entries supported by the antenna and RF equipment yearly. In case no company-specific information is available, the user of the PEFCR shall use the default dataset (expressed per one launch or re-entry) provided in ANNEX XX [under development] of the PEFCR. A parabolic antenna is considered as the default type, which can be scaled by size (diameter of antenna).

6.4.2.17 Launch site

The launch site covers the facility and all infrastructure needed to prepare and perform the launch. Often it includes a large area size, several buildings and offices, and launch pads. The modelling of the launch site shall include the amounts of the following activities:

- Electricity use;
- Gas use;
- Water use;
- Fuel use (generator);
- Building infrastructure (e.g. steel, concrete, roads, land used);
- Maintenance.

To allocate the activities to the specific launch in scope, the following allocation rules shall be used:

- If the electricity, gas, water and fuel use is collected on a yearly basis, their allocation to the specific launch shall be based on the average number of launches per year.
- The infrastructure related to the launch site shall be modelled following Section 5.13 and allocated based on the total number of launches in its entire lifetime. The lifetime for the infrastructure to be considered is 50 years.

The amounts needed when modelling the launch site should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default datasets per launch site (expressed per one launch) provided in ANNEX XX [under development] of the PEFCR.

[Defaults should be provided for the most common launch sites for the European launch service providers. These are:

- Guiana Space Centre (Kourou, French Guiana)
- Andøya Spaceport (Andøya island, Norway)
- Sutherland spaceport (United Kingdom)]

6.4.2.18 Launch pad

The launch pad covers the launching infrastructure. The launch pads are either launcher-specific or flexible (meaning, they are used by multiple launchers). The modelling of the launch site shall include the amounts of the following activities:

The infrastructure related to the launch pad shall be modelled following Section 5.13 and allocated to the launch based on the total number of reuse. Company-specific information on the number of reuse should be used. If this is not available, a default value of zero shall be used.

The amounts needed when modelling the launch pad should be based on company-specific information. In case no company-specific information is available the user of the PEFCR shall use the default datasets provided per launch pad (expressed per one launch) in ANNEX XX [under development] of the PEFCR.

[Defaults should be provided for two types of launch pads: a small and a large launch pad. Only the Guiana Space Centre has both types available]

6.4.2.19 Re-entry emissions (from reusable launcher stages)

The emissions taking place when the launcher re-enters the atmosphere (also called re-entry emissions) shall be included in the modelling. The type and amount of re-entry emissions shall be calculated, depending on (i) the type and amount of launcher propellant used, (ii) as well as on the trajectory taken. See Section 5.15.1 for more details on the calculations.

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

6.4.2.20 Recovery vehicle and transport to launch site

In case a special recovery vehicle is developed to recover a reusable launcher stage, company-specific data shall be used for modelling the transport mode instead of default datasets on the transport mode. This shall include the material used, the energy used, as well as office use for engineering per one re-entry.

Transport of the recover reusable launcher stage to the launch site shall be included in the modelling using company-specific information on transport modes and locations, while using further guidelines provided in Section 5.12.

6.5 End of life stage

The end-of-life stage begins when the product in scope and its packaging is discarded after its use and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). Within the context of Space-based activities this is translated as the deorbiting or controlled re-entry activities of the spacecraft or launcher after its service lifetime ended. In some cases, end of life treatment and refurbishment on Earth can take place, while in other cases the spacecraft stays in space and is moved to a graveyard orbit. In the case of launcher stages, they are not being send to a graveyard orbit, rather they passively stay in orbit.

As the end of life stage of a spacecraft and launcher are very different, they are further discussed in two different sub-sections.

Other waste (different from the product in scope) generated during the manufacturing, distribution, retail, use stage or after use shall be included in the life cycle of the product and modelled at the life cycle stage where it occurs.

6.5.1 End of life: spacecraft

For the spacecraft, the end-of-life stage starts once the spacecraft is no longer operational and ends when (i) put in the graveyard orbit, or (ii) burns during re-entry with its remains littered on Earth. Alternatively, the spacecraft could be brought back to Earth for EOL treatment. However, this doesn't happen yet in practice today and therefore is not further discussed in scope of this PEFCR. It includes the movement of the spacecraft to the graveyard orbit or the active re-entry activity, including all required ground equipment and related emissions. Once in graveyard orbit, any further activity (such as tracking activities of space domain awareness stations) are not included in the modelling and excluded from the system boundaries.

The spacecraft end-of-life activities are modelled for the spacecraft in scope. The allocation to the FU (meaning, the service delivered) shall be modelled using the allocation rules provided in Section 5.7.

6.5.1.1 Sending to graveyard orbit

Sending to graveyard orbit is one of the two end-of-life options after a spacecraft ended its service lifetime. It is the most common option for Spacecrafts active in MEO or GEO orbit. Spacecrafts in graveyard obit remain their indefinitely. They are regarded as dead objects and active monitoring is no longer performed. Once in graveyard orbit, the generic monitoring through space surveillance and tracking (from space domain awareness stations) is excluded from the system boundaries and not included in the modelling.

The movement of the spacecraft to graveyard orbit is included and modelled under this activity.. The modelling shall include the amounts of the following activities:

- Spacecraft propellant use (if applicable);
- IST vehicle use (if applicable, see sub-category);
- Spacecraft and mission control centre (SCC/MCC).

The required amount of spacecraft propellant and SCC/MCC shall be modelled with company-specific data. Please note that the Spacecraft and mission control centre is modelled in two parts (i) the infrastructure and operations and (ii) the antenna and RF infrastructure.

The following sections explain the detailed modelling rules for each of the required input activities.

6.5.1.2 Re-entry activity

Re-entry activity is one of the two end-of-life options after the spacecraft ended its service lifetime. It is the active movement of the spacecraft back to Earth and happens mainly for spacecraft located in the lower orbits. The modelling shall include the amounts of the following activities:

- Spacecraft propellant use (if applicable);
- IST vehicle use[45] (if applicable);
- Spacecraft and mission control centre (SCC/MCC);
- Re-entry emissions;
- End-of-life treatment on Earth (if applicable).

The required amount of spacecraft propellant, IST vehicle, SCC/MCC and re-entry emissions shall be modelled with company-specific data. Please note that the Spacecraft and mission control centre is modelled in two parts (i) the infrastructure and operations and (ii) the antenna and RF infrastructure. The following sections explain the detailed modelling rules for each of the required input activities.

6.5.1.3 Spacecraft propellant use

The spacecraft propellant is used for active re-entry activities or moving the spacecraft to the graveyard orbit. This activity covers the production, fuelling and use of spacecraft propellant. The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production)
- Propellant storage on site
- Transport to site
- Fuelling activities (incl. Emissions, auxiliaries and cleanroom)

[45] The IST sub-category does not cover this type of activity. Therefore, the horizontal modelling rules shall be used when modelling this part of the life cycle. Relevant aspects from the sub-categories may be used.

All other activities shall be excluded from the calculations. [Fuelling activities are currently included in this activity. It will be decided later if it is relevant to split it.] While the activities are the same as for launcher propellant use, the amounts and inputs might be totally different.

The amount of propellant needed for movement to graveyard or re-entry of the spacecraft shall be modelled with company-specific information. The amount of propellant storage and fuelling activities depend on the amount of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of steel infrastructure (see Section 5.13), auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure (see Section 5.13) and direct emissions.

In case no company-specific information is available, the default dataset on spacecraft propellant use (in tonne per type of propellant) provided in Annex XX [under development] shall be used. [The aim is to provide default datasets for the most common spacecraft propellants used.]

The total amount of spacecraft propellant shall be allocated to three different parts of the spacecraft life cycle using company-specific data: (i) distribution stage, (ii) use stage and (iii) end of life. At the end-of-life stage the spacecraft propellant is used to move the spacecraft to graveyard orbit or re-entry back to Earth. The amount of propellant used for this movement shall be modelled with company-specific data.

6.5.1.4 Spacecraft and mission control centre

The spacecraft and mission control centre (SCC/MCC) is the facility or network of facilities that manages the functionality of the spacecraft and the mission during its entire operation time in orbit. It operates continuously, provides multiple services and might control several spacecrafts simultaneously.

It is modelled in two parts:

1. SCC/MCC infrastructure & operations : see section 6.5.1.5
2. Antenna & RF equipment: see section 6.5.1.6

Only a portion of the spacecraft and mission control centre is used by the specific spacecraft. The portion modelled shall be based on company-specific information on the time (# days) and the size and type of antenna required for the operation service lifetime of the spacecraft.

6.5.1.5 SCC/MCC infrastructure & operations

This section focusses solely on the SCC/MCC infrastructure & operations, the next section describes the rules for modelling the antenna & RF equipment to which the

SCC/MCC is connected. The modelling of the SCC/MCC infrastructure & operations shall include its use time for re-entry and sending to graveyard, as well as maintenance, with the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the operations only;
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the SCC/MCC as listed above.

The lifetime for the infrastructure to be considered is 50 years, while for IT equipment a lifetime of 10 years shall be used.
The operation hours to be considered for SCC/MCC infrastructure & operations are 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for SCC/MCC infrastructure & operations is sufficient, as this is independent of the type, size and number of antennas connected during its service.

Only a portion of the SCC/MCC infrastructure & operations shall be used by the specific spacecraft, based on the duration of use for the end of life activities. The portion of SCC/MCC infrastructure & operations used, shall be based on company-specific information on the time (# days) required for the end of life activities.
The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, gas, water, auxiliaries and fuel for UPS shall be measured. Only the electricity use required for the SCC/MCC infrastructure & operations can be accounted for, the electricity use for the antenna needs to be considered separately.
2. The type and amount of all IT equipment, the UPS, and building infrastructure (see modelling details in Section 5.13) shall be measured, divided by their lifetime. The modem is considered as part of the SCC/MCC infrastructure & operations.
3. At this point the total service delivered by the SCC/MCC infrastructure & operations over one year shall be calculated using all spacecrafts served and the time (in days) for each. This leads to the total service delivered by the SCC/MCC station over one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the (sum of non-continuous) time (expressed in days) the spacecraft in scope is served for the re-entry or movement to graveyard orbit.

6.5.1.6 Antenna & RF equipment

The spacecraft and mission control centre (SCC/MCC) connects with one or more antennas & RF equipment in order to deliver its service. It is assumed that the antenna can serve multiple spacecrafts, however it can't serve multiple spacecrafts at the same time. It can only serve one spacecraft at any point in time. The modelling of the antenna and RF equipment shall include the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the antenna and RF equipment;
- RF equipment (transmitters, …), the modem is not considered as part of the RF equipment, but is considered to be part of the SCC/MCC infrastructure & operations;
- Antenna (incl. radome);
- Antenna pad (reinforced concrete foundation).

All other inputs shall be excluded from the calculations.

The lifetime for the antenna to be considered is 30 years, while for RF equipment (e.g., transmitters) a lifetime of 10 years shall be used.
The operation hours to be considered for the antenna & RF equipment are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [under development], shall be used. It is assumed that one default dataset for the antenna & RF equipment is sufficient. A parabolic antenna is considered as the default type, which can be scaled by size (diameter of antenna).

Only a portion of the antenna & RF equipment shall be allocated to the specific spacecraft based on the duration of use during re-entry or movement to graveyard orbit, the number and size of antennas needed. The allocation of the antenna & RF equipment (meaning, the amount of antenna used for the mission-related in-orbit activities only) shall be based on company-specific information on the time (# days), size and number of antennas required for the end of life activities.
The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, dedicated for the operation of the antenna & RF equipment, shall be measured.
2. The type, size and amount of the antenna and all RF equipment shall be measured, divided by their lifetime.
3. At this point the total service delivered by the antenna & RF equipment over one year shall be calculated using all spacecrafts served and the time for each (in #days). This leads to the total service delivered by the antenna & RF equipment in one year, in spacecraft*days per year.
4. The inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the time (expressed in days) and the size and number of antennas the spacecraft in scope requires for its end of life activities.

6.5.1.7 Re-entry emissions

The emissions taking place when the launcher re-enters the atmosphere (also called re-entry emissions) shall be included in the modelling. The type and amount of re-entry emissions shall be calculated, depending on (i) the type and amount of launcher propellant used, (ii) as well as on the trajectory taken. See Section 5.15.1 for more details on the calculations.

Although most of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information (see Section 3.7).

6.5.1.8 End-of-life treatment on Earth

In case the spacecraft returns back to Earth and is recovered. The end-of-life treatment of the remaining materials shall be modelled in this life cycle stage, by using the Circular Footprint Formula as further explained in Section 5.15.

In case (part of) the spacecraft is reused, all activities related to the refurbishment shall be accounted for in the raw material acquisition and pre-processing stage, and the manufacturing stage.

In case no company-specific information is available, the user of this PEFCR shall model as default no end-of-life treatment.

6.5.2 End of life: launcher

The launcher consists of multiple stages, and in some designs, includes boosters. The end-of-life phase for both stages and boosters begins once they are no longer operational, specifically, after they have exhausted their propellant used to reach a destination orbit (for stages) or a specific altitude (for boosters or a launcher lower stage).

Boosters and in some cases the lower stage of a launcher are only capable of reaching a certain altitude and cannot achieve orbit. Once their propellant is depleted, they fall back to Earth. Their EOL concludes when they impact land or ocean surfaces, contributing to litter.

(Upper) launcher stages, on the other hand, can either:

- Passively remain in orbit as space debris, or
- Actively or passively re-enter Earth’s atmosphere.

6.5.2.1 Stage or booster: Falling back to Earth

When boosters are used, they reach a designated altitude and then they fall back to Earth where they impact land or ocean and remain there as a litter. This can also be the case for the lower stage of a launcher that does not reach orbit. The modelling shall include the amounts of the following activities:

- Flight safety centre;
- Ground activities (e.g., planes/ships monitoring the area for the falling objects?)

Littering on Earth (ocean or terrestrial) is not modelled. It shall be reported upon as mass of littering on Earth in additional environmental information (section 3.7).

The required amount of flight safety centre and ground activities shall be modelled with company-specific data. The following sections explain the detailed modelling rules for each of the required input activities.

6.5.2.2 Launcher stage: Passively staying in orbit

Passively staying in orbit is one of the two end-of-life options after a launcher stage ended its service lifetime (i.e., consumed its propellant to reach a destination orbit/altitude). For launcher stages that reach orbit, they typically remain there passively. There are no designated graveyard orbits for launcher stages, and no tracking or monitoring takes place. Depending on their orbital parameters, these stages can stay in orbit for many years – even thousands of years in the case of past missions – before eventually re-entering the atmosphere and disintegrating. In some cases, a stage may use residual propellant to move into a different orbit and remain there passively. This manoeuvre is done either to avoid interference with active satellites or to shift into a lower, decaying orbit, ensuring that re-entry occurs within a shorter timeframe.

The potential movement of the launcher stage to a different orbit is modelled under this activity. The modelling shall include the amounts of the following activities:

- Launcher propellant use (if applicable);
- Flight safety centre.

The required amount of launcher propellant and flight safety centre shall be modelled with company-specific data. The following sections explain the detailed modelling rules for each of the required input activities.

6.5.2.3 Launcher stage: Re-entry activity

Re-entry activity is one of the two end-of-life options after the launcher stage ended its service lifetime (i.e., consumed its propellant to reach a destination orbit/altitude). It is the passive or active movement of the launcher back to Earth. The launcher partially burns-up during atmospheric re-entry and results in emissions from the burn-up process and the remnants falling to Earth.

The modelling shall include the amounts of the following activities:

- Launcher propellant use (if applicable);
- Flight safety centre;
- Re-entry emissions;
- End-of-life treatment on Earth (if applicable).

The amounts of all activities shall be modelled with company-specific data. The following sections explain the detailed modelling rules for each of the required input activities.

6.5.2.4 Launcher propellant use

The launcher propellant is used for active re-entry activities or moving the launcher to a different orbit to passively stay there. This activity covers the production, fuelling and use of launcher propellant (incl. leakage). The amounts of the following activities shall be included:

- Propellant production (incl. dedicated site production);
- Propellant storage on site;
- Transport to site;
- Fuelling activities (incl. emissions, auxiliaries and cleanroom).

All other activities shall be excluded from the calculations. [Fuelling activities are currently included in this activity. It will be decided later if it is relevant to split it.]

The amount of propellant needed for movement to a specific orbit or the re-entry of the launcher shall be modelled with company-specific information. The amount of propellant storage and fuelling activities depend on the amount of propellant used and shall be modelled as follow:

- Propellant storage on site is modelled through the amount of steel infrastructure auxiliaries and energy (for heating) needed per tonne of propellant used.
- Fuelling activities shall include energy use, auxiliaries, infrastructure and direct emissions.

The amount of propellant use depends on the release orbit at certain ΔV and shall be based on company-specific information.

6.5.2.5 Flight safety centre

The flight safety centre is the facility or network of facilities that monitors the launcher during the launching activity (incl. re-entry of re-usable launchers), as well as during its end-of-life (re-entry). It operates during the active movement of a launcher stage to a specific orbit, during active or passive re-entry of a launcher stage, as well as during tracking the boosters while falling back to Earth. The modelling of the flight safety centre shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance);

- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for flight safety centre as listed above.

This section focusses solely on the Flight safety centre infrastructure and operations, while the next section describes the rules for modelling the antenna & RF equipment to which the Flight safety centre is connected in order to deliver its service

The lifetime for the infrastructure to be considered is 50 years, while for IT materials (e.g., servers, and network) a lifetime of 10 years shall be used.

The operation hours to be considered for the flight safety centre are the average operation hours per year and should be company specific. It shall be allocated to one launch or re-entry by dividing the yearly operation hours to the number of launches and re-entries supported by the flight safety centre yearly. In case no company-specific information is available, the user of the PEFCR shall use the default dataset (expressed per one launch or re-entry) provided in ANNEX XX [under development] of the PEFCR.

6.5.2.6 Antenna & RF equipment (Flight safety centre)

The launcher connects with one or more antennas & RF equipment in order to deliver its service. The antenna can serve one launch at a point of time. The modelling of the antenna and RF equipment shall include the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the antenna and RF equipment;
- RF equipment (transmitters, …), the modem is not considered as part of the RF equipment, but is considered to be part of the SCC/MCC infrastructure & operations;
- Antenna (incl. radome);
- Antenna pad (reinforced concrete foundation).

All other inputs shall be excluded from the calculations.

The lifetime for the antenna to be considered is 30 years, while for RF equipment (e.g., transmitters) a lifetime of 10 years shall be used.
The operation hours to be considered for the antenna & RF equipment are 24h a day, 365 days a year.

The amounts of the activities to be considered shall be based on the average operation hours per year and should be company specific. It shall be allocated to one launch or re-entry by dividing the yearly operation hours to the number of launches and re-entries supported by the antenna and RF equipment yearly. In case no company-specific information is available, the user of the PEFCR shall use the default dataset (expressed per one launch or re-entry) provided in ANNEX XX [under development] of the PEFCR. A parabolic antenna is considered as the default type, which can be scaled by size (diameter of antenna).

6.5.2.7 Launch ground activities

The ground activities are launch site-specific and they include all activities related to safety and security. They include sea measures with boats looking after security/safety and potentially catching some big falling dangerous objects, aerial measures to protect the launch against attacks or interference, terrestrial measures for safety/security reasons.
The modelling of ground activities shall include the amounts of the following activities:

- Transport mode (land, sea, air);
- Transport distance.

Common EF datasets are used to model transport mode.

The launch ground activities are modelled per launch site for one launch. Company-specific information should be used. In case no company-specific information is available, the user of the PEFCR shall use the default datasets (expressed per one launch) provided in ANNEX XX [under development] of the PEFCR. One default dataset is provided per launch site.

6.5.2.8 Re-entry emissions

The emissions taking place when the launcher re-enters the atmosphere (also called re-entry emissions) shall be included in the modelling. There are two types of re-entry emissions: from propellant use and from the burn-up process with the remnants falling to Earth (littering).

Emissions from burn-up are affected by the

1. Trajectory;
2. Type of material being burned;
3. Burn-up rate (% surviving mass from total mass).

The trajectory, the type of material being burned and the burn-up rate shall be modelled with company-specific data. One trajectory is be defined per ΔV. The related **demise emissions from re-entry** are provided as a fixed number in kg of emissions per kg of launcher material being burned, see Excel Annex 4.4: Re-entry emissions from burn-up.

Similarly to launch emissions, re-entry emissions from propellant use are affected by:

1. Propellant type;
2. Trajectory: longitude, latitude, altitude and time;

3. Engine parameters: mixture ratio (fuel/oxidizer), efficiency (nozzle size), chamber pressure, equilibrium or frozen emissions

Within this PEFCR only the first two factors for re-entry emissions from propellant use are taken into account to calculate the emissions. Engine parameters are excluded so far due to limited calculation means.

The type and amount of propellant and the trajectory shall be modelled with company-specific data. One trajectory is defined per ΔV. The related **re-entry emissions from propellant use** are expressed per tonne of propellant and are provided as default in Excel Annex 4.3: Launch emissions and re-entry emissions from propellant use.

Although part of these emissions cannot be part of the PEF profile, due to gaps in the impact assessment methodology, they will be reported upon separately as additional environmental information.

[Demise emissions are not included in the PEF-RP calculations so far. This will be included in the second draft PEFCR]

6.5.2.9 End-of-life treatment on Earth

In case the launcher returns back to Earth and is recovered, the end-of-life treatment of the remaining materials shall be modelled in this life cycle stage, by using the Circular Footprint Formula as further explained in Section 5.15.

In case the recovered launcher is reused, all activities related to the refurbishment shall be accounted for in the raw material acquisition and pre-processing stage and the manufacturing stage.

In case no company-specific information is available, the user of this PEFCR shall model as default no end-of-life treatment.

6.6 Sub-category-specific modelling rules

This section discusses additional rules for sub-categories which deviate from the horizontal rules specified in sections 6.1 to 0.

6.6.1 Earth Observation Services

6.6.1.1 Raw material acquisition and pre-processing stage

As specified in 6.1.2, the manufacturing of subsystems shall include company-specific values for the amounts of auxiliaries consumed for the manufacturing, assembling, integration and testing of subsystems. The production of the auxiliaries can be modelled with default data in case no company-specific data is available.

6.6.1.2 Manufacturing stage

No deviations from horizontal rules.

6.6.1.3 Distribution stage

No deviations from horizontal rules.

6.6.1.4 Use stage

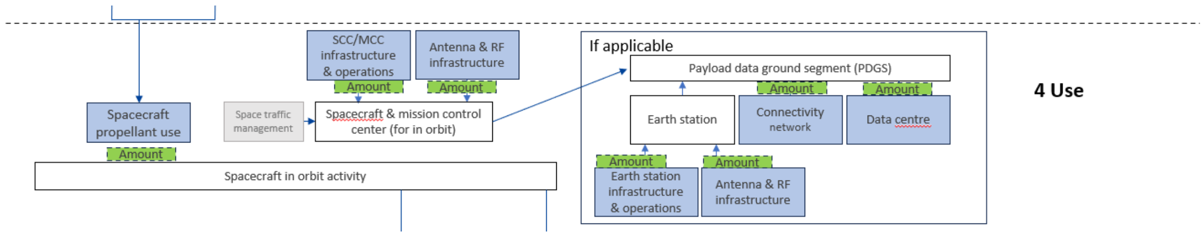

Figure 14 - System diagram of the use stage for EO-related services. [The proposed company-specific amounts and datasets are further evaluated after the open consultation.]

6.6.1.4.1 Payload Data Ground Segment (PGDS)

The amounts of the following activities shall be included for the payload data ground segment:

- Earth station(s) distinguishing the (i) Earth station infrastructure & operations and (ii) antenna & RF equipment.
- Ground communication network distinguishing the (i) core connectivity network and (ii) data centre;

All other activities shall be excluded from the calculations.

The amounts of the different activities required shall be based on company-specific information. The following sections explain the detailed modelling rules for each of the required input activities.

The modelling of the PDGS shall include both the operation of daily use as well as maintenance with the amounts of the following activities:

- Electricity use (incl. maintenance) dedicated for the operations only;
- Natural gas use;
- Water use;
- Auxiliaries (e.g., for maintenance)
- Fuel use (generator for Uninterruptible Power Source (UPS));
- IT equipment (computers, servers, routers, modem, cables (fibre), switches …);
- Building infrastructure.

All other inputs shall be excluded from the calculations. Office use is implicitly included by the electricity use, natural gas use and water use for the PDGS as listed above.

The lifetime for the infrastructure to be considered is 50 years, while IT materials (e.g., servers, and network) a lifetime of 10 years shall be used. The operation hours are to be considered for Earth station are 7 days a week, 24h a day, 365 days a year.

The amounts of the different activities required should be based on company-specific information. In case no company-specific information is available for the required input amounts, the default dataset, as listed in ANNEX XX [we are still working on the excel file], shall be used. It is assumed that one default for the PDGS is sufficient as this is independent of the type, size and number of antennas connected during its service. This default dataset shall be scaled to the spacecraft-specific PDGS based on the Mbps capacity and the km of distance between stations that are part of the PDGS used for the spacecraft (per Mbps * km).

Only a portion of the PDGS shall be used by the specific spacecraft, based on the number of connections (expressed in Mbps). The portion of the PDGS used for in-orbit related activities of the spacecraft shall be based on company-specific information on minimum Mbps required for the operation of the spacecraft.

The PDGS operates continuously. It might serve several spacecrafts simultaneously, which is implicitly taken into consideration by the volume of data linked to it. Therefore, the use of the PDGS shall be allocated to the specific spacecraft based on the portion of the PDGS that is dedicated to the spacecraft's mission, based on the minimum throughput capacity required (expressed in Mbps * time). This parameter is directly related to the Functional Unit (FU), as it quantifies the total data volume associated with the spacecraft mission operations. The allocation of the PDGS to the spacecraft shall be based on company-specific information. The different inputs shall be measured and allocated using the following steps:

1. The total annual consumption of electricity, gas, water and auxiliaries shall be measured.
2. The type and amount of cables, all IT equipment and building infrastructure (see modelling details in Section 5.13), divided by their lifetime.
3. At this point, the total service delivered by the PDGS over one year shall be calculated using the total data volume of the PDGS (in Mbps * times) over one year.
4. In case a default PDGS is used (and no company-specific data are available for the steps 1-3), this default PDGS shall be scaled to the spacecraft-specific PDGS based on the data volume and the km of distance (per Mbps * time * km)
5. In case company-specific data are available for the PDGS, the inputs identified in steps 1 and 2, related to step 3, are allocated to the spacecraft based on company-specific information on the minimum data volume required for the service of the spacecraft.

6.6.1.4.2 Equipment on the user side

User-side equipment (see section 6.4.1.12) during the use stage of the spacecraft is out of scope for Earth Observation Services and shall therefore be excluded from use stage modelling.

6.6.1.5 End of life stage

No deviations from horizontal rules.

6.6.2 Positioning, Navigation and Timing Services

6.6.2.1 Raw material acquisition and pre-processing stage

Activity data (amounts) for ‘Transport of subsystems’ shall be mandatory company specific data.

6.6.2.2 Manufacturing stage

No deviations from horizontal rules.

6.6.2.3 Distribution stage

No deviations from horizontal rules.

6.6.2.4 Use stage

Equipment on the user side (see section 6.4.1.12 of the horizontal rules) shall be excluded from the modelling. The rationale for exclusion of equipment on the user side is that it can be found in many different forms. There is a lack of knowledge about the receivers and the number of deployed receivers of the open service is unknown. Choosing one type of equipment over the other will influence the results, risking the inability to compare systems.

No additional deviations from horizontal rules.

6.6.2.5 End of life stage

No deviations from horizontal rules.

6.6.3 Video services

6.6.3.1 Raw material acquisition and pre-processing stage

No deviations from horizontal rules.

6.6.3.2 Manufacturing stage

No deviations from horizontal rules.

6.6.3.3 Distribution stage

No deviations from horizontal rules.

6.6.3.4 Use stage

The amounts of the following activities shall be included when modelling the equipment on the user side for video services:

- The energy consumed by the user terminal and the antenna,
- The size of the antenna.

All other activities and equipment shall be excluded from the calculations.

The amount of electricity consumed per user terminal and the antenna, and the size of the antenna shall be modelled with company-specific information. For the antennas equipment, the default datasets provided in Annex XX [under development] shall be used and scaled with the company-specific information on the size of the antennas.

In the following paragraphs, it is explained how the user of this PEFCR shall:
a. Choose which user terminal to model when a wide variety exists,
b. Model the user terminal (electricity calculation and antennas modelling),
c. Model the amount of user terminals to comply to the given user density of the functional unit within 100 km^2 (i.e. 210 UT/100 km^2),
d. Scale the user terminal (the antennas) to 1 Mbps of video services of the Functional Unit.

A. Choosing which user terminal(s) to model

To ensure both fairness and representativeness, users of this PEFCR shall model user terminal(s) that corresponds to the primary application of delivering video services to the user. This user terminal shall reflect the user terminal type(s) most commonly used (i.e., covering at least 70% of total user terminals of the service delivered, in absolute terms) across the customer base for the specific delivery of video services.

If there is not a single user terminal type adding up to at least 70% of most commonly used, the user shall model the different types adding up to at least 70% of total use cases, modelling the respective fraction of most relevant user terminals. The user shall follow the below instructions for each type of most relevant user terminal, and create a weighted-average based on the split.

B. Modelling the user terminal (i.e., Modelling energy consumption and antenna per user terminal)

To model one user terminal, the user shall model the energy consumption of the user terminal and the antenna per Mbps and per year, and the antenna(s) used. The rest of the user terminal shall be excluded from the modelling.

For the antenna(s), the user shall use company-specific information on the size of the antenna(s) and use the default datasets from Annex XX [under development] and scale those datasets to the respective size.

The user terminal and the antenna(s) can have a shared energy supply, or have separate energy supplies. The energy consumption for both the user terminal and the antenna(s) shall be modelled. The energy consumption is highly dependent on the usage. Therefor below we present default assumptions for the usage to be used by all users. The company-specific datapoints needed are:

- Max. Download capacity (Mbps)
- Max. Download Energy (Watts) (combined for both user terminal and antenna(s))
- Max. Standby Energy (Watts) (combined for both user terminal and antenna(s))

The default assumption of split of hourly distribution between download (on) and standby mode (off) for video services are:

12.5 % of data download per day (3 hours[46])
87.5 % of standby mode a day (21 hours)

[Inputs for the % distribution of hours download and standby per day for the video terminal are welcome.]

The formula below presents the formula for calculating the energy consumption (in Whrs) per user terminal and antennas per Mbps year:

$$Energy\ Consumption\ per\ user\ terminal\ and\ antennas\ (video)\left(in\,\frac{Whr}{Mbps.year}\right)$$

$$= (\left(\frac{\text{(Max. Download energy cons. (in Watts)} * \text{3 hrs per day download)} + \text{(Max. standby energy cons. (in Watts)} * \text{21 hours per day standby}}{\text{max. Mbps downloaded}}\right)$$

$$* \, 365\ days$$

C. Amount of user terminals to model

The functional unit incorporates an area component of 100 km². It is essential to account for the average user density within the area to ensure comparability among assessments. In 2008, approximately 50% of the 243 million television households in Europe received broadcasts digitally[47]. Of these, 52% were served via satellite transmission, equating to 63.2 million satellite receivers across Europe. This results in

[46] https://uk.themedialeader.com/tv-viewing-time-in-europe-ahead-of-us/
[47] https://satellitemarkets.com/europe-middle-east-and-africa/market-trends/50-percent-european-homes-receive-digital-tv

an estimated average receiver density of 630 receivers per 100 km². To prevent double counting, considering that satellite video services in Europe are predominantly provided by three main operators, the receiver density is assumed to be evenly distributed among them. This results in an adjusted average receiver density of approximately 210 receivers per 100 km².

Users of this PEFCR shall consider 210 user terminals needed to fulfil the FU defined in this PEFCR. This means that the user terminal energy per year and the antenna(s) modelled as explained above shall be multiplied by 210 to fulfil the FU.

D. Scale to 1 Mbps Functional unit

The energy consumption of the user terminals and the antennas is already per Mbps year, so no further scaling is required to the FU is required.

The antennas itself shall be divided by the lifetime of 15 years, and subsequently divided by the maximum capacity (in Mbps) delivered by the terminal.

[We would appreciate inputs if the antenna itself should be divided by the total capacity of the satellite system to scale the impacts to the Functional Unit, or by the maximum data rate of the terminal, used above in the calculation for the energy consumption]

6.6.3.5 End of life stage

No deviations from horizontal rules.

6.6.4 Connectivity Services

6.6.4.1 Raw material acquisition and pre-processing stage

No deviations from horizontal rules.

6.6.4.2 Manufacturing stage

No deviations from horizontal rules.

6.6.4.3 Distribution stage

No deviations from horizontal rules.

6.6.4.4 Use stage

The amounts of the following activities shall be included when modelling the equipment on the user side for connectivity services:

- The energy consumed by the user terminal and the antenna,

- The size of the antenna.

All other activities and equipment shall be excluded from the calculations.

The amount of electricity consumed per user terminal and the antenna, and the size of the antenna shall be modelled with company-specific information. For the antennas equipment, the default datasets provided in Annex XX [under development] shall be used and scaled with the company-specific information on the size of the antennas.

In the following paragraphs, it is explained how the user shall:
a. choose which user terminal to model when a wide variety exists,
b. model the user terminal (electricity calculation and antennas modelling),
c. amount of user terminals to be modelled.
d. scale the user terminal (the antennas) to 1 Mbps of connectivity services of the Functional Unit.

A. Choosing which user terminal(s) to model

To ensure both fairness and representativeness, users of this PEFCR shall model the user terminal(s) that corresponds to the primary application of delivering connectivity services to the user. This user terminal shall reflect the user terminal type(s) most commonly used (i.e., covering at least 70% of total user terminals of the service delivered, in absolute terms) across the customer base for the specific delivery of connectivity services.

If there is not a single user terminal type adding up to at least 70% of most commonly used, the user shall model the different types adding up to at least 70% of total use cases, modelling the respective fraction of most relevant user terminals. The user shall follow the below instructions for each type of most relevant user terminal, and create a weighted-average based on the split.

B. Modelling the user terminal (i.e., Modelling energy consumption and antenna per user terminal)

To model one user terminal, the user shall model the energy consumption of the user terminal and the antenna per year, and the antenna(s) used. The rest of the user terminal shall be excluded from the modelling.

For the antenna(s), the user shall use company-specific information on the size of the antenna(s), and use the default datasets from Annex XX [under development] and scale those datasets to the respective size.

The user terminal and the antenna(s) can have a shared energy supply, or have separate energy supplies. The energy consumption for both the user terminal and the antenna(s) shall be modelled. The energy consumption is highly dependent on the usage. Therefore below we present default assumptions for the usage to be used by all users. The company-specific datapoints needed are:

- Max. Upload Capacity (Mbps)
- Max. Download Capacity (Mbps)
- Max. Upload Energy Consumption (Watts) (combined for both user terminal and antenna(s))
- Max. Download Energy Consumption (Watts) (combined for both user terminal and antenna(s))
- Max. Standby Energy (Watts) (combined for both user terminal and antenna(s))

The default assumption of split of hourly distribution between upload (on), download (on), and standby mode (off) for connectivity services are[48]:

1% of the time used for data uploaded per day (0.25 hours)
8% of the time used for data download per day (2 hours)
91% of standby mode a day (21.75 hours)

Simultaneous up- and download is not considered.

[Inputs for the % distribution of hours upload, download and standby per day for the connectivity terminal are welcome.]

The formula below presents the formula for calculating the energy consumption (in Whrs) per user terminal and antennas per Mbps year:

$$Energy\ consumption\ per\ user\ terminal\ and\ antennas\ (connectivity)\left(in\ \frac{Whrs}{Mbps.year}\right) =$$

$$\left(\left(\frac{\begin{matrix}(Max.\ uplaod\ energy\ consumption\ (in\ Watts)*0.25\ hours\ per\ day\ upload)+\\ (\ Max.\ download\ \ energy\ consumption\ (in\ Watts)*2\ hours\ per\ day\ download)+\\ (Max.Standby\ energy\ consumption\ (in\ Watts)*21.75\ hours\ per\ day\ standby)\end{matrix}}{max.\ Mbps\ uploaded\ max.+\ Mbps\ downloaded}\right)+\right)*$$

$$365$$

C. Amount of user terminals to be modelled

As per functional unit, the user of the PEFCR shall model one user terminal.

D. Scale to 1 Mbps Functional unit

The energy consumption of the user terminals and the antennas is already per Mbps year, so no further scaling is required to the FU is required.

[48] Based on Novaspace engineering judgement, 2025.

The antennas itself shall be divided by the lifetime of 15 years, and subsequently divided by the maximum useful capacity (in Mbps) delivered by the terminal.

[We would appreciate inputs if the antenna itself should be divided by the total capacity of the satellite system to scale the impacts to the Functional Unit, or by the maximum data rate (upload and download) of the terminal, used above in the calculation for the energy consumption]

6.6.4.5 End of life stage

No deviations from horizontal rules.

6.6.5 In-space Transport Services

6.6.5.1 Raw material acquisition and pre-processing stage

No deviations from horizontal rules.

6.6.5.2 Manufacturing stage

No deviations from horizontal rules.

6.6.5.3 Distribution stage

No deviations from horizontal rules.

6.6.5.4 Use stage

Equipment on the user side (see section 6.4.1.12 of the horizontal rules) shall be excluded since it is not relevant for the sub-category in-space transport.
No additional deviations from horizontal rules.

6.6.5.5 End of life stage

No deviations from horizontal rules.

6.6.6 Uncrewed launch services from Earth to space

When the modelling of the uncrewed launch services from Earth to space deviates from the horizontal rules, it is either specified in the text or sub-sections that are launch-specific were created.

6.6.6.1 Raw material acquisition and pre-processing stage

Materials consumed for the refurbishment of reusable launcher stages shall be included in LCS1.
No additional deviations from horizontal rules.

6.6.6.2 Manufacturing stage

MAIT processes and cleanroom/infrastructure use that are required for the refurbishment of reusable launcher stages shall be included in the manufacturing stage.
No additional deviations from horizontal rules.

6.6.6.3 Distribution stage

Launch-specific sub-section was created.

6.6.6.4 Use stage

Launch-specific sub-section was created.

6.6.6.5 End of life stage

Launch-specific sub-section was created.

7. PEF Results

7.1 Benchmark values

[Here the TS shall report the results of the benchmark for each representative product. The results shall be provided characterised, normalised, and weighted (as absolute values), each in a different table, according to the template provided below. Results shall also be provided as a single overall score, based on the weighting factors provided in Section 5.2.2 of Annex I and of Annex B.1]

As presented in the scope of this PEFCR, benchmark results will be provided for the sub-categories:

1. Positioning, navigation and timing services: Not available. Due to limited data no benchmark results are presented in this first iteration (Annex 4.2: Limited scope of the first PEF-RPs for more information).
2. Satellite video services: see Table 58[49].
3. Satellite connectivity services: Not available. Due to confidentiality issue arising from the partial modelling of the market, no benchmark results are presented in this first iteration (Annex 4.2: Limited scope of the first PEF-RPs for more information).
4. In-space transport services: see Table 59.
5. Uncrewed launch services: see Table 60 to Table 63:

[49] The difference in characterized results for the impact category Climate Change for the Video RP is +0.9 % if calculated including Climate Change Launch emissions, and hotspots don't change. Therefore we present the results only with Climate Change Launch Emissions (max.).

Table 58. Characterised, normalised and weighted benchmark values, incl. GWP from launch emissions, for Satellite Video Services (FU: to receive 1 Mbps broadcast services, over 100km^2, over one year). See Annex 4.2: Limited scope of the first PEF-RPs.

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Acidification	mol H+ eq	1,12E-01	9,49E-01	Person-eq.	2,02E-03	1,71E-02	Pt	1,25E-04	1,06E-03
Climate change[50]	kg CO2 eq	1,90E+01	1,05E+02	Person-eq.	2,52E-03	1,39E-02	Pt	5,30E-04	2,92E-03
Ecotoxicity, freshwater	CTUe	9,96E+01	1,55E+03	Person-eq.	1,76E-03	2,73E-02	Pt	3,37E-05	5,24E-04
Particulate matter	disease inc.	9,57E-07	5,10E-06	Person-eq.	1,61E-03	8,56E-03	Pt	1,44E-04	7,67E-04
Eutrophication, marine	kg N eq	2,04E-02	1,27E-01	Person-eq.	1,04E-03	6,47E-03	Pt	3,08E-05	1,92E-04
Eutrophication, freshwater	kg P eq	9,93E-03	1,10E-01	Person-eq.	6,18E-03	6,85E-02	Pt	1,73E-04	1,92E-03
Eutrophication, terrestrial	mol N eq	2,02E-01	1,26E+00	Person-eq.	1,14E-03	7,15E-03	Pt	4,25E-05	2,65E-04
Human toxicity, cancer	CTUh	9,03E-09	6,69E-08	Person-eq.	5,23E-04	3,88E-03	Pt	1,11E-05	8,26E-05
Human toxicity, non-cancer	CTUh	2,78E-07	3,61E-06	Person-eq.	2,16E-03	2,81E-02	Pt	3,98E-05	5,16E-04
Ionising radiation	kBq U-235 eq	1,17E+01	3,86E+01	Person-eq.	2,78E-03	9,14E-03	Pt	1,39E-04	4,58E-04
Land use	Pt	6,90E+01	4,92E+02	Person-eq.	8,42E-05	6,00E-04	Pt	6,69E-06	4,76E-05

[50] 99% of climate change impacts are caused by Climate change, fossil.

Ozone depletion	kg CFC11 eq	6,24E-06	1,16E-05	Person-eq.	1,19E-04	2,22E-04	Pt	7,52E-06	1,40E-05
Photochemical ozone formation	kg NMVOC eq	6,60E-02	3,98E-01	Person-eq.	1,62E-03	9,74E-03	Pt	7,72E-05	4,66E-04
Resource use, fossils	MJ	4,46E+02	1,88E+03	Person-eq.	6,86E-03	2,89E-02	Pt	5,71E-04	2,41E-03
Resource use, minerals and metals	kg Sb eq	4,49E-04	1,87E-02	Person-eq.	7,06E-03	2,94E-01	Pt	5,33E-04	2,22E-02
Water use	m3 depriv.	2,03E+01	4,66E+01	Person-eq.	1,77E-03	4,06E-03	Pt	1,51E-04	3,45E-04
Single overall score							**Pt**	**2,62E-03**	**3,42E-02**

Table 59. Characterised, normalised and weighted benchmark values, incl. GWP from launch emissions, for in-space transport services (FU: to transport 1 kg of cooperative object in space, 75% by single use OTV at 10 km/s and 25% by multi use OTV at 2 km/s). See Annex 4.2: Limited scope of the first PEF-RPs[22].

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Acidification	mol H+ eq	2.81E+01	2.81E+01	Person-eq.	5.06E-01	5.06E-01	Pt	3.14E-02	3.14E-02
Climate change	kg CO2 eq	5.16E+03	5.16E+03	Person-eq.	6.83E-01	6.83E-01	Pt	1.44E-01	1.44E-01
Ecotoxicity, freshwater	CTUe	2.53E+04	2.53E+04	Person-eq.	4.47E-01	4.47E-01	Pt	8.58E-03	8.58E-03
Particulate matter	disease inc.	2.09E-04	2.09E-04	Person-eq.	3.52E-01	3.52E-01	Pt	3.15E-02	3.15E-02
Eutrophication, marine	kg N eq	5.05E+00	5.05E+00	Person-eq.	2.58E-01	2.58E-01	Pt	7.65E-03	7.65E-03
Eutrophication, freshwater	kg P eq	4.40E+00	4.40E+00	Person-eq.	2.74E+00	2.74E+00	Pt	7.66E-02	7.67E-02

Eutrophication, terrestrial	mol N eq	4.80E+01	4.80E+01	Person-eq.	2.71E-01	2.71E-01	Pt	1.01E-02	1.01E-02
Human toxicity, cancer	CTUh	2.32E-06	2.32E-06	Person-eq.	1.34E-01	1.34E-01	Pt	2.86E-03	2.86E-03
Human toxicity, non-cancer	CTUh	1.04E-04	1.38E-06	Person-eq.	8.05E-01	8.05E-01	Pt	1.48E-02	1.48E-02
Ionising radiation	kBq U-235 eq	1.30E+03	1.30E+03	Person-eq.	3.09E-01	3.09E-01	Pt	1.55E-02	1.55E-02
Land use	Pt	2.45E+04	2.45E+04	Person-eq.	2.99E-02	2.99E-02	Pt	2.37E-03	2.37E-03
Ozone depletion	kg CFC11 eq	1.97E-04	1.97E-04	Person-eq.	3.76E-03	3.76E-03	Pt	2.37E-04	2.37E-04
Photochemical ozone formation	kg NMVOC eq	1.51E+01	1.51E+01	Person-eq.	3.69E-01	3.69E-01	Pt	1.76E-02	1.76E-02
Resource use, fossils	MJ	8.08E+04	8.08E+04	Person-eq.	1.24E+00	1.24E+00	Pt	1.03E-01	1.03E-01
Resource use, minerals and metals	kg Sb eq	1.18E-01	1.18E-01	Person-eq.	1.85E+00	1.85E+00	Pt	1.40E-01	1.40E-01
Water use	m3 depriv.	3.07E+03	3.07E+03	Person-eq.	2.68E-01	2.68E-01	Pt	2.28E-02	2.28E-02
Single overall score							**Pt**	**6.29E-01**	**6.29E-01**

Table 60. Characterised, normalised and weighted benchmark values, incl. and excl. GWP100 (in CO_2 equivalents) for launch and re-entry emissions, for Uncrewed launch services from Earth to space , per transport and release of 1 kg of payload in orbit, at ΔV9, for 1 launch

		Characterised results			Normalised results			Weighted results		
Impact category		Units	Excluding use	Total impacts	Units	Excluding use	Total impacts	Units	Excluding use	Total impacts
Acidification		mol H+ eq	2,38E+00	5,77E+00	Person-eq	4,28E-02	1,04E-01	Pt	2,65E+00	6,43E+00
Climate change	**incl.** launch and re-entry emissions from propellant use	kg CO_2 eq	2,95E+02	9,80E+02	Person-eq	3,91E-02	1,30E-01	Pt	8,23E+00	2,73E+01
	excl. launch and re-entry emissions from propellant use	kg CO_2 eq	2,95E+02	9,07E+02	Person-eq	3,91E-02	1,20E-01	Pt	8,23E+00	2,53E+01
Ecotoxicity, freshwater		CTUe	2,52E+03	5,26E+03	Person-eq	4,45E-02	9,27E-02	Pt	8,54E-01	1,78E+00
Particulate matter		disease inc.	2,05E-05	4,99E-05	Person-eq	3,44E-02	8,39E-02	Pt	3,08E+00	7,52E+00
Eutrophication, marine		kg N eq	4,21E-01	1,03E+00	Person-eq	2,15E-02	5,25E-02	Pt	6,38E-01	1,55E+00
Eutrophication, freshwater		kg P eq	1,72E-01	3,87E-01	Person-eq	1,07E-01	2,41E-01	Pt	3,00E+00	6,75E+00
Eutrophication, terrestrial		mol N eq	3,94E+00	1,03E+01	Person-eq	2,23E-02	5,82E-02	Pt	8,28E-01	2,16E+00
Human toxicity, cancer		CTUh	1,78E-07	5,63E-07	Person-eq	1,03E-02	3,26E-02	Pt	2,20E-01	6,95E-01
Human toxicity, non-cancer		CTUh	5,96E-06	1,00E-05	Person-eq	4,63E-02	7,77E-02	Pt	8,51E-01	1,43E+00
Ionising radiation		kBq U-235 eq	1,84E+02	2,50E+02	Person-eq	4,36E-02	5,92E-02	Pt	2,18E+00	2,97E+00
Land use		Pt	1,25E+03	3,16E+03	Person-eq	1,53E-03	3,86E-03	Pt	1,21E-01	3,06E-01
Ozone depletion		kg CFC11 eq	7,29E-05	8,22E-05	Person-eq	1,39E-03	1,57E-03	Pt	8,78E-02	9,91E-02
Photochemical ozone formation		kg NMVOC eq	1,28E+00	3,51E+00	Person-eq	3,14E-02	8,59E-02	Pt	1,50E+00	4,10E+00
Resource use, fossils		MJ	7,29E+03	1,56E+04	Person-eq	1,12E-01	2,40E-01	Pt	9,33E+00	1,99E+01

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Resource use, minerals and metals	kg Sb eq	1,02E-02	1,26E-02	Person-eq	1,60E-01	1,99E-01	Pt	1,21E+01	1,50E+01
Water use	m3 depriv.	1,99E+02	1,10E+03	Person-eq	1,74E-02	9,58E-02	Pt	1,48E+00	8,15E+00
Single overall score	Pt	n/a	n/a	Pt	n/a	n/a	Pt	**4,71E+01**	**1,06E+02**

Table 61. Characterised, normalised and weighted benchmark values, incl. and excl. GWP100 (in CO_2 equivalents) for launch and re-entry emissions, for Uncrewed launch services from Earth to space , per transport and release of 1 kg of payload in orbit, at ΔV10, for 1 launch

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Acidification	mol H+ eq	3,43E+00	7,95E+00	Person-eq	6,17E-02	1,43E-01	Pt	3,82E+00	8,87E+00
Climate change – **incl.** launch and re-entry emissions from propellant use	kg CO_2 eq	4,26E+02	1,34E+03	Person-eq	5,64E-02	1,78E-01	Pt	1,19E+01	3,75E+01
Climate change – **excl.** launch and re-entry emissions from propellant use	kg CO_2 eq	4,26E+02	1,25E+03	Person-eq	5,64E-02	1,66E-01	Pt	1,19E+01	3,49E+01
Ecotoxicity, freshwater	CTUe	3,63E+03	7,26E+03	Person-eq	6,41E-02	1,28E-01	Pt	1,23E+00	2,46E+00
Particulate matter	disease inc.	2,95E-05	6,92E-05	Person-eq	4,96E-02	1,16E-01	Pt	4,45E+00	1,04E+01
Eutrophication, marine	kg N eq	6,06E-01	1,41E+00	Person-eq	3,10E-02	7,22E-02	Pt	9,19E-01	2,14E+00
Eutrophication, freshwater	kg P eq	2,47E-01	5,32E-01	Person-eq	1,54E-01	3,31E-01	Pt	4,31E+00	9,27E+00
Eutrophication, terrestrial	mol N eq	5,68E+00	1,41E+01	Person-eq	3,21E-02	8,00E-02	Pt	1,19E+00	2,97E+00
Human toxicity, cancer	CTUh	2,58E-07	7,69E-07	Person-eq	1,49E-02	4,46E-02	Pt	3,18E-01	9,49E-01

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Human toxicity, non-cancer	CTUh	8,64E-06	1,41E-05	Person-eq	6,71E-02	1,09E-01	Pt	1,23E+00	2,01E+00
Ionising radiation	kBq U-235 eq	2,64E+02	3,51E+02	Person-eq	6,26E-02	8,31E-02	Pt	3,13E+00	4,16E+00
Land use	Pt	1,81E+03	4,42E+03	Person-eq	2,20E-03	5,39E-03	Pt	1,75E-01	4,28E-01
Ozone depletion	kg CFC11 eq	1,07E-04	1,20E-04	Person-eq	2,05E-03	2,29E-03	Pt	1,29E-01	1,44E-01
Photochemical ozone formation	kg NMVOC eq	1,86E+00	4,84E+00	Person-eq	4,54E-02	1,18E-01	Pt	2,17E+00	5,66E+00
Resource use, fossils	MJ	1,06E+04	2,17E+04	Person-eq	1,62E-01	3,34E-01	Pt	1,35E+01	2,78E+01
Resource use, minerals and metals	kg Sb eq	1,47E-02	1,80E-02	Person-eq	2,31E-01	2,83E-01	Pt	1,75E+01	2,14E+01
Water use	m3 depriv.	2,87E+02	1,53E+03	Person-eq	2,50E-02	1,34E-01	Pt	2,13E+00	1,14E+01
Single overall score	Pt	n/a	n/a	Pt	n/a	n/a	Pt	**6,81E+01**	**1,47E+02**

Table 62. Characterised, normalised and weighted benchmark values, incl. and excl. GWP100 (in CO2 equivalents) for launch and re-entry emissions, for Uncrewed launch services from Earth to space , per transport and release of 1 kg of payload in orbit, at ΔV10.6, for 1 launch

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Acidification	mol H+ eq	3,81E+00	9,05E+00	Person-eq	6,85E-02	1,63E-01	Pt	4,25E+00	1,01E+01
Climate change – **incl.** launch and re-entry emissions from propellant use	kg CO_2 eq	4,72E+02	1,53E+03	Person-eq	6,25E-02	2,03E-01	Pt	1,32E+01	4,28E+01
Climate change – **excl.** launch and re-entry emissions from propellant use	kg CO_2 eq	4,72E+02	1,42E+03	Person-eq	6,25E-02	1,88E-01	Pt	1,32E+01	3,97E+01
Ecotoxicity, freshwater	CTUe	4,04E+03	8,24E+03	Person-eq	7,13E-02	1,45E-01	Pt	1,37E+00	2,79E+00

	Characterised results			Normalised results			Weighted results		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Particulate matter	disease inc.	3,27E-05	7,86E-05	Person-eq	5,50E-02	1,32E-01	Pt	4,93E+00	1,18E+01
Eutrophication, marine	kg N eq	6,75E-01	1,61E+00	Person-eq	3,45E-02	8,24E-02	Pt	1,02E+00	2,44E+00
Eutrophication, freshwater	kg P eq	2,77E-01	6,07E-01	Person-eq	1,72E-01	3,78E-01	Pt	4,82E+00	1,06E+01
Eutrophication, terrestrial	mol N eq	6,31E+00	1,61E+01	Person-eq	3,57E-02	9,13E-02	Pt	1,33E+00	3,39E+00
Human toxicity, cancer	CTUh	2,85E-07	8,77E-07	Person-eq	1,65E-02	5,08E-02	Pt	3,51E-01	1,08E+00
Human toxicity, non-cancer	CTUh	9,51E-06	1,58E-05	Person-eq	7,38E-02	1,22E-01	Pt	1,36E+00	2,25E+00
Ionising radiation	kBq U-235 eq	2,95E+02	3,96E+02	Person-eq	7,00E-02	9,39E-02	Pt	3,51E+00	4,70E+00
Land use	Pt	2,00E+03	5,01E+03	Person-eq	2,44E-03	6,11E-03	Pt	1,94E-01	4,85E-01
Ozone depletion	kg CFC11 eq	1,15E-04	1,29E-04	Person-eq	2,19E-03	2,47E-03	Pt	1,38E-01	1,56E-01
Photochemical ozone formation	kg NMVOC eq	2,04E+00	5,50E+00	Person-eq	5,00E-02	1,35E-01	Pt	2,39E+00	6,44E+00
Resource use, fossils	MJ	1,16E+04	2,45E+04	Person-eq	1,79E-01	3,77E-01	Pt	1,49E+01	3,13E+01
Resource use, minerals and metals	kg Sb eq	1,63E-02	2,01E-02	Person-eq	2,56E-01	3,16E-01	Pt	1,93E+01	2,38E+01
Water use	m3 depriv.	3,19E+02	1,75E+03	Person-eq	2,78E-02	1,53E-01	Pt	2,37E+00	1,30E+01
Single overall score	Pt	n/a	n/a	Pt	n/a	n/a	Pt	**7,53E+01**	**1,67E+02**

Table 63. Characterised, normalised and weighted benchmark values, incl. and excl. GWP100 (in CO2 equivalents) for launch and re-entry emissions, for Uncrewed launch services from Earth to space, per transport and release of 1 kg of payload in orbit, at ΔV12, for 1 launch

	Characterised results			Normalised results			Weighted results		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
Acidification	mol H+ eq	5,70E+00	1,22E+01	Person-eq	1,03E-01	2,20E-01	Pt	6,36E+00	1,36E+01
Climate change – **incl.** launch and re-entry emissions from	kg CO_2 eq	7,11E+02	2,10E+03	Person-eq	9,41E-02	2,77E-01	Pt	1,98E+01	5,84E+01

	Characterised results			*Normalised results*			*Weighted results*		
Impact category	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*	*Units*	*Excluding use*	*Total impacts*
propellant use									
excl. launch and re-entry emissions from propellant use	kg CO_2 eq	7,11E+02	1,93E+03	Person-eq	9,41E-02	2,55E-01	Pt	1,98E+01	5,38E+01
Ecotoxicity, freshwater	CTUe	6,11E+03	1,08E+04	Person-eq	1,08E-01	1,90E-01	Pt	2,07E+00	3,64E+00
Particulate matter	disease inc.	4,98E-05	1,10E-04	Person-eq	8,36E-02	1,84E-01	Pt	7,49E+00	1,65E+01
Eutrophication, marine	kg N eq	1,00E+00	2,23E+00	Person-eq	5,13E-02	1,14E-01	Pt	1,52E+00	3,38E+00
Eutrophication, freshwater	kg P eq	4,15E-01	7,69E-01	Person-eq	2,58E-01	4,79E-01	Pt	7,23E+00	1,34E+01
Eutrophication, terrestrial	mol N eq	9,40E+00	2,24E+01	Person-eq	5,32E-02	1,27E-01	Pt	1,97E+00	4,69E+00
Human toxicity, cancer	CTUh	4,54E-07	1,13E-06	Person-eq	2,63E-02	6,54E-02	Pt	5,60E-01	1,39E+00
Human toxicity, non-cancer	CTUh	1,53E-05	2,31E-05	Person-eq	1,19E-01	1,79E-01	Pt	2,19E+00	3,30E+00
Ionising radiation	kBq U-235 eq	4,28E+02	5,30E+02	Person-eq	1,02E-01	1,26E-01	Pt	5,09E+00	6,30E+00
Land use	Pt	3,06E+03	7,63E+03	Person-eq	3,74E-03	9,31E-03	Pt	2,97E-01	7,39E-01
Ozone depletion	kg CFC11 eq	1,86E-04	2,08E-04	Person-eq	3,54E-03	3,97E-03	Pt	2,24E-01	2,51E-01
Photochemical ozone formation	kg NMVOC eq	3,11E+00	7,87E+00	Person-eq	7,61E-02	1,93E-01	Pt	3,64E+00	9,21E+00
Resource use, fossils	MJ	1,76E+04	3,49E+04	Person-eq	2,71E-01	5,37E-01	Pt	2,25E+01	4,47E+01
Resource use, minerals and metals	kg Sb eq	2,48E-02	2,95E-02	Person-eq	3,90E-01	4,63E-01	Pt	2,95E+01	3,50E+01
Water use	m3 depriv.	4,77E+02	3,02E+03	Person-eq	4,16E-02	2,63E-01	Pt	3,54E+00	2,24E+01
Single overall score	Pt	n/a	n/a	Pt	n/a	n/a	Pt	**1,14E+02**	**2,37E+02**

7.2 PEF profile

The user of the PEFCR shall calculate the PEF profile of its product in compliance with all requirements included in this PEFCR. The following information shall be included in the PEF report:

- full life cycle inventory;
- characterised results in absolute values, for all impact categories (as a table);
- normalised results in absolute values, for all impact categories (as a table);
- weighted result in absolute values, for all impact categories (as a table);
- the aggregated single overall score in absolute values.

Together with the PEF report, the user of the PEFCR shall develop an aggregated EF compliant dataset of its product in scope. This dataset shall be made available to the European Commission and may be made public. The disaggregated version may remain confidential.

7.3 Classes of performance

[The identification of classes of performance is not obligatory. Each Technical Secretariat is free to define a method to identify the classes of performance, in case they deem it appropriate and relevant. In case classes of performance are identified, they shall be described and provided in this section. Please refer to A.5.2 for further guidance.]

8. Verification

The verification of a PEF study/ report carried out in compliance with this PEFCR shall be done according to all the general requirements included in section 9 of the Annex I, including part A of this Annex, and the requirements listed below.

The verifier(s) shall verify that the PEF study is conducted in compliance with this PEFCR.

In case policies implementing the PEF method define specific requirements regarding verification and validation of PEF studies, reports and communication vehicles, the requirements in said policies shall prevail.

The verifier(s) shall validate the accuracy and reliability of the quantitative information used in the calculation of the study. As this can be highly resource intensive, the following requirements shall be followed:

- *the verifier(s) shall check if the correct version of all impact assessment methods was used. For each of the most relevant EF impact categories (ICs), at least 50% of the characterisation factors shall be verified, while all normalisation and weighting factors of all ICs shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with[140]. This may also be done indirectly, for example:*
    - *Export the EF-compliant datasets from the LCA software used to do the PEF study and run them in Look@LCI[141] to obtain LCIA results. If Look@LCI results are within a deviation of 1% from the results in the LCA software, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.*
    - *Compare the LCIA results of the most relevant processes calculated with the software used to do the PEF study with the ones available in the metadata of the original dataset. If the compared results*

      Available at: http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml

      https://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml

      are within a deviation of 1%, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct
- *cut-off applied (if any) fulfils the requirements at section 4.6.4 of Annex I.*
- *all datasets used shall be checked against the data requirements (sections 4.6.3 and 4.6.5. of Annex I).*

- *For at least 80% (in number) of the most relevant processes (as defined in section 6.3.3 of Annex I), the verifier(s) shall validate all related activity data and the datasets used to model these processes. If relevant, CFF parameters and datasets used to model them shall also be validated in the same way. The verifier(s) shall check that the most relevant processes are identified as specified in section 6.3.3 of Annex I;*
- *For at least 30% (in number) of all other processes (corresponding to 20% of the processes as defined in section 6.3.3 of Annex I) the verifier(s) shall validate all related activity data and the datasets used to model these processes. If relevant, CFF parameters and datasets used to model them shall also be validated in the same way;*
- *The verifier(s) shall check that the datasets are correctly implemented in the software (i.e. LCIA results of the dataset in the software are within a deviation of 1% to the ones in the metadata). At least 50% (in number) of the datasets used to model most relevant processes and 10% of those used to model other processes shall be checked.*

In particular, verifier(s) shall verify if the DQR of the process satisfies the minimum DQR as specified in the DNM for the selected processes.

These data checks shall include, but should not be limited to, the activity data used, the selection of secondary sub-processes, the selection of the direct elementary flows and the CFF parameters. For example, if there are 5 processes and each one of them includes 5 activity data, 5 secondary datasets and 10 CFF parameters, then the verifier(s) has to check at least 4 out of 5 processes (70%) and, for each process, (s)he shall check at least 4 activity data (70% of the total amount of activity data), 4 secondary datasets (70% of the total amount of secondary datasets), and 7 CFF parameters (70% of the total amount of CFF parameters), i.e. the 70% of each of data that could be subject to a check.

The verification of the PEF report shall be carried out by randomly checking enough information to provide reasonable assurance that the PEF report fulfils all the conditions listed in section 8 of Annex I, including part A of this Annex.

[The PEFCR may specify additional requirements for the verification that should be added to the minimum requirements stated in this document].

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Annexes

ANNEX 1 – List of EF normalisation and weighting factors

Global normalisation factors are applied within the EF. The normalisation factors as the global impact per person are used in the EF calculations.

[The TS shall provide the list of normalisation and weighting factors that the user of the PEFCR shall apply. Normalisation and weighting factors are available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml142]

ANNEX 2 – PEF study template

[The PEFCR shall provide as an annex a checklist listing all the items that shall be included in PEF studies, using the PEF study template available as part E of this Annex of this document. The items already included are mandatory for every PEFCR. In addition, each technical secretariat may decide to add additional points to the template.]

ANNEX 3 – Review reports of the PEFCR and PEF-RP(s)

[Insert here the critical review panel reports of the PEFCR and PEF-RP(s), including all findings of the review process and the actions taken by the technical secretariat to answer the comments of the reviewers.]

ANNEX 4 – Other annexes

[The TS may decide to add other Annexes that are considered important. Such as, an example on the application of the DNM or DQR calculations, and explanations on decisions taking during the PEFCR development.].

Annex 4.1: List of missing launch and re-entry emissions (cut-off 0.01%)

Launch emissions:

Launch Species > 0.01%	Considered in this PEFCR
Al2O3	X
BC	X
CL	X
CL2	X
CO	X
CO2	X
H	
H2	
H2O	X
HCL	X
N2	
NO	X
NO2	X
O	
OH	

Re-entry emissions:

Re-Entrie Species > 0.01%	Considered in this PEFCR
Ag	
Ag2O	
AlO	
Al2O3	X
ALN	
BC	X
CH4	
Cl	X
Cl2	X
CO	

CO2	X
Cr	
Cr2O3	
CrN	
Cu	
Cu(OH)2	
CuO	
Fe	
Fe(OH)2	
Fe(OH)3	
Fe2O3	X
Fe3O4	
H2	
H2O	X
HCL	
LiALO2	
LiH	
Mg(OH)2	
MgAL2O4	
MgCL2	
MgH2	
MgO	X
Mn	
MnO2	
N2	
NH3	
Ni	
NiO	
NO	
NO2	
Si	
Si2N2O	
Si3N4	
SiO2	
Sn	
SnO2	
TiN	
TiO2	
Zn	

ZnO	

Annex 4.2: Limited scope of the first PEF-RPs

Earth Observation Services

As there is no representative product defined for Earth Observation Services, the results comprise a hotspot analysis only and no benchmark.

For the case study of the CO2M mission, LCS 1, LCS 2 and part of LCS 4 are modelled based on primary data. The launch campaign (LCS 3) has been modelled with a default market-representative dataset for GTO launches from the launching WG. For LCS5, no primary data has been received to date. Only the total amount of spacecraft fuel is modelled in LCS5.

For the case study of the Altius mission, LCS 1, LCS 2 and part of LCS 4 are modelled based on primary data. The launch campaign (LCS 3) has been modelled with a default market-representative dataset for GTO launches from the launching WG. LCS5 is not modelled as no data has been received. Only the total amount of spacecraft fuel is modelled in LCS5.

Positioning, Navigation and Timing Services

Due to data collection issues related to Global Navigation Satellite Systems (GNSS), it was not possible to model a PEF-RP for PNT in the first iteration. GNSS are estimated to have 96% of the market share and are therefore a key component of the RP. Moreover, they form the basis for the operation of SBAS, another component of the RP.

Satellite Video Services

For the Satellite Video Services PEF-RP, in this first iteration, only LCS 1, 2 and part of 3 have been modelled based on primary data. The BoM of the equipment in LCS1 is largely based on proxy datasets. The launch campaign (LCS 3) has been modelled with a default market-representative dataset for GTO launches from the launch WG. For LCS 4 and 5, no primary data has been received to date. Therefore, LCS 4 only contains the user equipment (based on secondary data), which has been modelled as the electricity consumption for the modem and antenna, and the antenna itself, as prescribed in the PEFCR Chapter 6.6.3.4. In the absence of primary data, the user equipment antenna has been modelled with a proxy for the antenna of the Kiruna Earth Station, and scaled to the relevan size of the RP. LCS 4 also contains the impacts of the production of spacecraft propellant used for in-orbit manouvers (split based on primary data), and LCS 5 only contains the production of spacecraft propellant used for deorbiting to end-of-life (split is based on primary data). In the second PEF-RPs, LCS 4 and 5 will be complemented and modelled based on primary data.

[For the RP Modelling, we received limited primary data on the Bill of Materials of equipment and relied on data from other WGs. Please provide inputs how we can increase equipment-specific BoM for video sat.com satellites.]

Satellite Connectivity Services

For the Satellite Connectivity Services RP, only part of the market could be modelled (see Figure 4 for overview of total market to be modelled for the RP). The part of the market that could be modelled, similarly to video, is only based on primary data for LCS 1, 2, and part of 3. The BoM of the equipment in LCS1 is largely based on proxy datasets. The launch campaign (LCS 3) has been modelled with a default market-representative dataset for GTO launches from the launching WG. For LCS 4 and 5, no primary data has been received to date. Therefore, LCS 4 only contains the user equipment (based on secondary data), which has been modelled based on electricity consumption for the modem and antenna, and the antenna itself, as prescribed in the PEFCR Chapter 6.6.4.4. In the absence of primary data, the user equipment antenna has been modelled with a proxy of the antenna of the Kiruna Earth Station, and scaled to the relevant size of the RP. LCS 4 also contains the impacts of the production of spacecraft propellant used for in-orbit manouvers (split based on primary data), and LCS 5 only contains the production of spacecraft propellant used for deorbiting to end-of-life (split is based on primary data). In the second PEF-RPs, LCS 4 and 5 will be complemented for the part of the market that has partially been modelled, and the market representation will be completed.

Due to the open questions for the functional unit and reference flow for connectivity, the results for part of the market are calculated for the entire space mission. This means, that the entire spacecraft and the entire reached user terminals of that system over their lifetime are included in the assessment. Due to confidentiality of the partial market and the lack of applied reference flow, no benchmark results are provided for connectivity. Only the hotspot analysis is presented.

[For the RP Modelling, we received limited primary data on the Bill of Materials of equipment and relied on data from other WGs. Please provide inputs how we can increase equipment-specific BoM for connectivity sat.com satellites.]

In-space Transport Services

For the in-space transport services RP, data was available for only a part of the technologies available on the EU market as shown in Figure 5. The technologies included for the first PEF RP study are single use OTVs using chemical propulsion (75% of the RP) and multi use OTVs using chemical propulsion (25% of the RP). The single use OTV is represented by the Colibri of MaiaSpace – note that the IST function begins after Colibri has performed its kickstage function during launch – and is modelled based on primary data for LCS 1 and 2. Note that the model only considers one flight model, since no data is available on test models and prototypes. The multi use OTV is modelled based on primary data received from Dawn Aerospace for LCS 1 and 2, while the BoM of the equipment in LCS1 is largely based on proxy datasets. No data was available for OTVs using electrical propulsion, or for single use OTVs that perform in-space transport without performing kickstage first. For both technologies that are included in the current RP, the launch campaign (LCS 3) has been modelled with a default market-representative dataset for launches from the launch WG, a SSO launch for the multi use OTV and a mix of 95% SSO and 5% GTO launch for the single use OTV. LCS4 only considers an estimation of the propellant use. For LCS 5, no primary data has been received and is therefore not included in the PEF RP study. The propellant use is considered only in LCS4, although in practice a part of it will be consumed during LCS5, but no data was available.

[For the RP Modelling, we received no primary data for several relevant technologies, including OTVs using chemical propulsion, and single use OTVs that perform in-space transport without performing kickstage first. Please provide inputs how we can improve the representativeness of the RP.]

Uncrewed launch services from Earth to space

For the Uncrewed launch services from Earth to Space, only part of the market could be modelled. The modelled portion is based on primary data for the majority of LCS1, LCS2, and partially for LCS3 and LCS4, while LCS5 was not modelled. For LCS1, the BoM and amounts of equipment and subsystems were used, with several proxies applied for MAIT and production losses treatment. For LCS2, the core stage, upper stage, payload section, and strap-on boosters of Ariane 6 (configuration with two boosters), as well as all launcher stages of various Maiaspace micro-launcher configurations were modelled. In LCS2, partial data were received for the cleanroom and MAIT activities for Ariane 6 and micro-launcher, as well as for the refurbishment of the reusable first stage of a micro-launcher reusable configuration. For the micro-launcher, an average launcher configuration, with and without the kick stage, and in reusable and expendable forms, was modelled based on the expected launches for each setup. The different launcher configurations affect the payload mass that can be sent to orbit. For LCS3, the transport to the launch site was modelled using a proxy Ecoinvent container ship for the special Ariane 6 transport mode Canopée, and primary transport fuel consumption data for the micro-launcher. LCS4 mainly includes the propellant use, including production and fuelling, and the launch and re-entry emissions from propellant use for all the launchers serving the European market (Ariane 6, Vega C, Falcon 9, Falcon Heavy, Small/Micro launchers), as defined in section 3.2.6. Overall, data gaps are noted for LCS1 and LCS2, including the packaging of the launcher and subsystems. The Canopée BoM was not modelled in LCS3, while in LCS4 the data are incomplete for the launch site, launch pad, ground activities, flight safety centre, infrastructure and operations, antennas and RF infrastructure. LCS5 was not modelled due to the unavailability of data on re-entry emissions and all ground related activities.

Annex 4.3: Launch emissions and re-entry emissions from propellant use

An excel tool to calculate the launch emissions and re-entry emissions from propellant use is provided. The tool was developed by Jan-Steffen Fischer, University of Stuttgart, Institute of Space Systems (Fischer, 2025).

Annex 4.4: Re-entry emissions from burn-up

An excel tool to calculate the re-entry emissions from burn-up material is provided. The tool was developed by Jan-Steffen Fischer, University of Stuttgart, Institute of Space Systems (Fischer, 2025).

The tool to be filled in requires the material mass emitted per km of altitude. To calculate the material mass emitted the burn-up rate shall be calculated. [How to calculate the burn-up rate, and thus the amount of material to be emitted, is still under discussion. The recommended tool shall be freely accessible by all stakeholders using the PEFCR. Is it acceptable that users of the PEFCR use their own tool or specific calculation requirements are needed? Input during the open consultation is welcome.]

[IMPORTANT NOTE: Demise emissions are currently excluded in the first PEF-RP. Therefore, the re-entry emissions only cover propellant use from reusable launchers].