Unrestricted

Life Cycle Assessment Guidance for Unit Load Devices

ULDR Appendix J

Use of this guidance

This guidance has been developed as an adaptation of the *IATA Life Cycle Assessment methodology for single-use plastic products in the airline sector* (2025)[1], a comprehensive methodological framework aligned with ISO 14040 and 14044 that is directly applicable to Unit Load Devices (ULD). The present guidance does not replace these requirements but highlights the specific issues most relevant to ULDs, including durability, repair and refurbishment, pooling and repositioning, and end-of-life pathways. Readers should apply the single-use plastic products methodology as the baseline and use this ULD LCA guidance to ensure that these specific factors are consistently captured.

1. Introduction

Unit Load Devices (ULD) are widely used in air cargo operations because of their ability to ensure safety, enable efficiency, and standardize handling across global supply chains. There is a proliferation of methods for measuring the environmental performance of products, including ULD. However, current approaches are often limited, with some assessments considering the tare weight of ULD as a proxy for sustainability. While mass is an important driver of fuel burn, it does not capture the full range of environmental impacts associated with ULD manufacture, use, repair, repositioning, and end-of-life. Therefore, a more comprehensive, life-cycle-based approach is required.

Life cycle assessment (LCA) is a standardized methodology defined by ISO 14040 and 14044 that quantifies the environmental impacts of a product or service across its entire life cycle. This includes the extraction and processing of raw materials, manufacturing and assembly, distribution and use, as well as end-of-life treatment and disposal. By considering all stages of a product system, LCA provides a comprehensive picture of environmental performance, allowing for robust, comparable, and decision-useful results.

As with other product categories in aviation, countries and regions apply disparate rules and expectations regarding environmental reporting and end-of-life treatment. This makes it challenging for airlines and suppliers to agree on consistent performance measures. A harmonized methodology based on LCA, aligned with ISO standards, enables robust, comparable, and decision-useful results across the sector, ensuring that ULD performance is assessed across all materially relevant impact categories.

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[1] **IATA. Life Cycle Assessment methodology for single-use plastic products in the airline sector (2025)**

1.1. Purpose

This document outlines a standardized methodology for measuring and comparing the environmental impacts of ULDs and their components, as well as accessories (e.g., pallets, containers, doors, nets, straps, thermal covers) throughout their entire life cycle. It is designed to:

- Bring consistency to the air cargo industry's efforts to measure the environmental performance of ULDs across materials (e.g., aluminum, composite, hybrid) and design types.
- Enable benchmarking of alternatives that consider all life cycle stages.
- Provide airlines, ground handlers, and manufacturers with a transparent basis for procurement, repair, and operational decisions.
- Ensure that communications about ULD sustainability are grounded in comprehensive and comparable evidence, rather than single-attribute claims.

1.2. Scope

This guidance focuses on ULDs and associated components as well as accessories. The methodology is neutral with respect to material choice and design and may be applied to all ULDs. The approach is cradle-to-grave, covering raw material acquisition, manufacturing and assembly, distribution and storage, in-service use (including marginal fuel burn attributable to mass), repair and refurbishment, repositioning, and end-of-life management.

While primarily designed for ULDs, the methodology can also be extended to other restraint and protective items used in cargo operations. Where relevant, it draws on the existing IATA guidance for cargo wrapping, as outlined in the *IATA Life Cycle Assessment methodology for single-use plastic products in the airline sector* (2025), as a precedent.

1.3. Methodology

This guidance builds on the principles and structure of the IATA *Life cycle assessment methodology for single-use plastic products in the airline sector* (2025, hereinafter referred to as *IATA SUPP LCA methodology*), aligned with ISO 14040 and 14044, and developed with input from stakeholders across the aviation sector.

This guidance recognizes the need to address the specific operational characteristics of ULDs, including:

- Long service lifetimes with multiple repair and refurbishment cycles.
- Variability in return, loss, and damage rates.
- Pooling and repositioning requirements across global networks.
- Diverse end-of-life pathways, including recycling metals, plastics, and composites.

The methodology provides standard definitions, functional units, and default assumptions to ensure the robustness and comparability of studies. It also outlines requirements for scope definition, system boundaries, life cycle stages, data sources, data quality, sensitivity analysis, impact categories, interpretation, and peer review.

2. Guidance

General methodological requirements for goal and scope, functional units, system boundaries, data quality, sensitivity analysis, and interpretation are set out in the IATA SUPP LCA methodology. This section highlights ULD-specific aspects.

2.1. Goal and context of the LCA study

Refer to Section 2.1 of the *IATA SUPP LCA methodology*.

It is essential that the LCA study for ULD clearly states its purpose, setting out the context of the work, the reasons for its conduct, its intended application, and its target audience.

Box 1. Examples of the goal and context of a ULD LCA study

Topic	Example
Reason for the study	To compare the life cycle impacts of different ULDs with the same ULD Type Code (e.g., aluminum AKE vs. composite AKE), considering manufacturing, use, repair, repositioning, and end-of-life.
Intended application	To inform airline procurement and renewal decisions. To provide evidence for freight forwarders and shippers to integrate ULD-related impacts into sustainability reporting and target setting.
Intended audience	Internal use for planning and purchasing. External use by freight forwarders and shippers. Other airlines, ground handlers, manufacturers, regulators, and researchers.
Other considerations	Whether the study is intended to be used to make comparative assertions that will be disclosed to the public.

2.1.1 Reason for study and decision context

This guidance supports the primary use case of informing environmental decision-making when considering different ULD materials, designs, and service models.

2.1.2 Intended application

The guidance focuses on assessing and comparing the life cycle impacts of ULDs in the context of air cargo transport. It is particularly suited for comparing:

- Aluminum versus composite ULDs
- Different aircraft temperature-controlled containers (TCC) with the same ULD Type Code (RKN vs. RKN)
- Lightweight versus heavy-duty ULDs
- Different restraint mechanisms (e.g., nets, straps, doors). The impact of design features on repairability, refurbishment cycles, and recyclability

2.1.3 Target audiences

The primary audience for this guidance is decision-makers in the aviation cargo sector and ULD manufacturers as well as ULD pooling/leasing service providers. However, it is also relevant to:

- Shippers and freight forwarders
- Regulators and policymakers
- Environmental NGOs and standard-setting bodies
- Scientists and researchers
- Members of the public

2.1.4 Comparative assertions

In addition to the several specific requirements for comparative LCAs detailed in ISO 14044 and the approaches that the *IATA SUPP LCA methodology* details in its section 2.1.4 to address them, users must take into account that when comparing ULD alternatives, equivalence of service must be demonstrated (e.g., safe transport of a defined cargo volume over a distance). Special attention should be given to repairability, lifetime turns, and repositioning requirements, which are often decisive factors in overall impact.

2.2. Scope definition

Refer to Section 2.2 of the *IATA SUPP LCA methodology*.

Following ISO 14044, the scope definition must clearly describe:

- the product system to be studied
- the functions of the product system or systems
- the functional unit and reference flow
- allocation procedures
- LCIA methodology and types of impacts
- interpretation to be used
- data requirements and data quality requirements
- assumptions
- value choices and optional elements
- limitations
- type of critical review, if any
- type and format of the report

Specific to ULDs, additional scope considerations include:

- Product system to be studied: Studies should clarify whether the scope covers only the ULD structure or also components regularly used with it
- Operational scope: Because ULDs are globally repositioned or pooled, LCA should capture average repositioning distances and modes (air, road, sea) as these can materially affect impacts. Company-specific data may replace averages where available.
- Lifetime performance: ULDs are durable assets with multiple lifetimes and repair cycles. The study must specify the assumed number of turns per ULD and include sensitivity analysis on this parameter. Loss and damage rates should also be taken into account.
- Shipper and forwarder relevance: To support Scope 3 reporting, ULD LCAs should provide impact results in forms that can be integrated into customer disclosures, for example, normalized to cargo-tonne-kilometer.
- Assumptions and limitations: Explicitly state assumptions around repairability, return logistics, and end-of-life pathways.

2.3. Functional units and reference flows

Refer to Section 2.3 of the *IATA SUPP LCA methodology*.

The functional unit (FU) must describe the **service provided**, ensure **comparability** between alternatives, and be clearly **linked to the reference flows** that quantify the amount of product system needed to deliver that service.

2.3.1 Functional unit

For ULD, the service provided is the safe consolidation, restraint, and protection of cargo during air transport and associated ground handling.

The recommended functional unit for ULD is "the consolidation, restraint, and protection of 1 tonne of cargo over 1,000 km of air transport, including standard ground handling". This mass–distance formulation is aligned with the cargo-tonne-kilometer (CTK) metric commonly used for Scope 3 emission disclosures by air cargo customers.

However, LCA practitioners may also consider additional functional units, such as for lanes or products constrained by volume rather than weight, where a volume-based FU may be used: 1 m^3 of cargo consolidated, restrained, and protected over 1,000 km.

2.3.2 Reference flows

Reference flows are determined by translating the FU into the number and type of ULDs, components, and operations required for the task. In the case of ULDs, they should capture:

- Material composition of the ULD (e.g., an aluminum AKE container weighing 70 kg versus a composite AKE container weighing 55 kg).
- ULD/accessories regularly used in service (nets, straps, thermal covers).
- Lifetime performance: number of turns achieved, including repair and refurbishment cycles; loss and damage rates.
- Utilization and repositioning: average load factors, share of empty repositioning, and transport modes (air, road, sea).
- Leasing/pooling models: airline-owned vs. leased/pooled fleets, which affect ULD logistics optimization.

2.3.3 Ensuring comparability

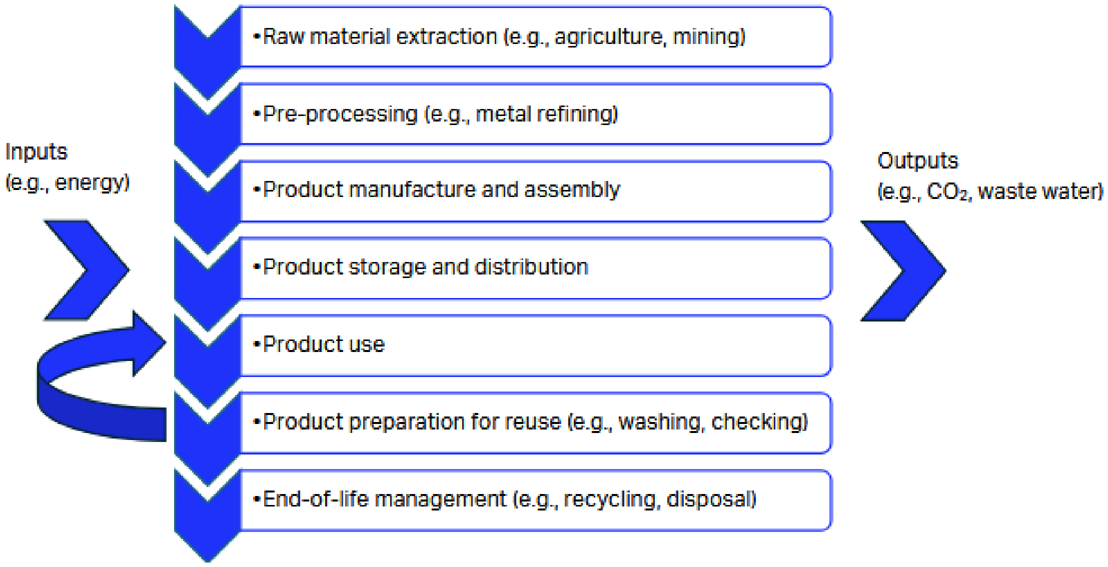
When comparing ULD alternatives, the equivalence of service must be ensured: all options must provide the same level of restraint, protection, and compliance with airworthiness requirements (e.g., applicable TSO-C90 requirement). Differences in lifetime, repair frequency, or loss rates must be reflected in the reference flows (e.g., "X composite ULDs are required to deliver the same number of turns as Y aluminum ULDs over the FU distance"). Finally, fuel burn differences due to tare weight should be modeled using the marginal fuel burn factors by distance band provided in the SUPP LCA methodology appendices, unless higher-quality company-specific data are available.

2.4. System boundary

Refer to Section 2.4 of the *IATA SUPP LCA methodology*. The same cradle-to-grave principle applies to this guidance

The system boundary for a ULD LCA shall include all life cycle stages, from raw material acquisition through to end-of-life treatment. Inputs (e.g., energy, materials) and outputs (e.g., CO_2, wastewater, solid waste) should be consistently included across all alternatives.

Figure 1: Scope and system boundary



Cut-offs should not be used except in cases where a prior scoping LCA is conducted or where published, peer-reviewed, and ISO 14040/44 compliant literature provides robust evidence. For published studies and those making environmental claims, the cumulative value of cut-off processes should not exceed 3% of the total material and energy flow. All processes subjected to a cut-off should be explicitly identified, along with justification for the decision. Determination of whether a process, material, or energy flow can be omitted under the cut-off rules should be based on a screening LCA or a published study conducted using data that are comparable based on product system, geography, and technological context.

Processes that are identical across both products being compared should not be excluded, unless they meet the criteria set out above. This is necessary to avoid overemphasizing differences between compared products relative to large(r) impact lifecycle stages, even if those stages have the same impact for both products.

2.5. Life cycle stages

Refer to Section 2.5 of the *IATA SUPP LCA methodology*.

2.5.1 Raw material acquisition (extraction and pre-processing)

This stage includes the extraction and processing of all raw materials used in ULDs and their accessories. Examples are bauxite mining and alumina refining for aluminum, polymer synthesis for composite resins, textile production for nets, and steel processing for fittings. Transport of semi-finished materials to component manufacturers is also part of this stage. These processes are often energy-intensive and should be modelled using supplier-specific data, where possible, or reputable life cycle inventory databases, where not.

2.5.2 Product manufacture and assembly

Manufacture encompasses the fabrication of ULD panels, doors, frames, pallets, nets, and straps, as well as their assembly into finished units. This stage accounts for process energy and emissions from forming, machining, curing, riveting, and welding, as well as scrap and yield losses. Manufacturer-specific LCAs provide the most accurate representation, but in their absence, bill-of-materials data combined with secondary datasets can be used.

2.5.3 Product storage and distribution

After manufacture, ULDs are transported to airlines or pooling depots and may be stored before entering service. This stage encompasses outbound logistics from factories, including crating and packaging, as well as any depot storage requirements. Balancing logistics before first use, where units are redistributed across the network, should also be included.

2.5.4 Product use

In service, ULDs perform their primary function of consolidating, restraining, and protecting cargo. Their tare mass contributes to marginal fuel burn, which should be modeled using distance-specific fuel-burn factors as outlined in the *IATA SUPP LCA methodology* appendices, unless higher-quality airline data is available. Ground handling activities such as loading, unloading, and transfers between facilities also form part of this stage. ULDs moved empty during backhaul or repositioning flights should be explicitly accounted for here.

2.5.5 Product preparation for reuse

Because ULDs are durable assets, preparation for reuse is a critical life cycle stage. It includes inspection, repair, refurbishment, and panel or door replacements, as well as cleaning and sanitation processes required for special cargo. These activities may involve transport to maintenance depots and should be modeled consistently over the expected service lifetime.

2.5.6 End-of-life management

At the end of service, ULDs are dismantled and their materials treated through recycling, recovery, or disposal. Aluminum typically achieves high recycling rates, while composites often end in disposal or low-value recovery. Textiles and metals from nets and straps may also be recycled. The selected end-of-life treatment mix should reflect regional practice and be clearly documented.

2.5.7 Recycling (allocation)

Recycling should be modeled following the cut-off approach, in line with the *IATA SUPP LCA methodology*. Under this approach, the upstream impacts of raw material extraction and processing are attributed fully to the first product life cycle. When the ULD, its components, or accessories reach end-of-life, only the burdens of collection, dismantling, and recycling are attributed to that product system. The benefits of using recycled materials are passed on to the next product system that utilizes the secondary material.

Box 2. Example of the cut-off method

	Process	Impacts from the following life stages
First product	Manufactured from virgin materials	Raw material extraction and processing Manufacture Distribution and use
	Sent to landfill	Landfill at end-of-life (including transport)
	Sent to recycling	Collection and transport to the recycling plant
Recycled product	Recycled aluminum is used to produce a new product	Recycling the aluminum to produce the secondary raw material Manufacturing Distribution and use End-of-life (as appropriate, depending on whether it is landfilled or recycled)

2.6. Data sources and quality

Refer to Section 2.6 of the *IATA SUPP LCA methodology*.

In the case of ULD, primary data are especially important for: tare weight and material composition; number of turns per year and expected lifetime; repair and refurbishment frequency and intensity; repositioning distances and mode splits; and end-of-life treatment routes. Airlines, pooling companies, and manufacturers should be the main sources for this data. Where not available, reputable life cycle inventory databases may be used; however, assumptions must be documented transparently and tested through sensitivity analysis to ensure their validity.

2.7. Sensitivity and uncertainty analysis

Refer to Section 2.7 of the *IATA SUPP LCA methodology*.

For ULD, sensitivity analysis should always test the effect of assumptions about lifetime turns, since durability and reuse intensity strongly determine comparative outcomes. The frequency and type of repair and refurbishment are also crucial, as they can extend service life but also require additional material and energy inputs. Repositioning rates and modes represent another critical factor, particularly for pooled fleets, where empty movements can substantially change overall results.

Loss and damage rates should be included in sensitivity tests, since premature retirement of ULD means that the environmental burdens are distributed across fewer turns. Similarly, end-of-life recycling percentages must be tested, especially when comparing aluminum and composite designs, given the vast differences in current recycling practices. Finally, marginal fuel burn factors should be varied, using airline-specific data where available, to capture their influence on weight-related use phase impacts.

Uncertainty analysis should be applied to reflect variability and data limitations. Where possible, quantitative techniques such as Monte Carlo simulation or analytical error propagation may be used; otherwise, qualitative assessment should be provided. Comparative assertions between ULDs should demonstrate robustness by reporting results across the tested ranges or through break-even analysis (e.g., the number of turns required for a composite ULD to outperform an aluminum equivalent).

2.8. Impact categories

Refer to Section 2.8 of the *IATA SUPP LCA methodology*.

The same minimum set of Product Environmental Footprint (PEF) midpoint indicators shall be applied to ULDs to ensure comparability across studies.

Box 3. PEF environmental impact categories with indicators and units.

Impact category	Impact category indicator	Unit
Climate change	Global warming potential, GWP100	kg CO_2 eq.
Ozone depletion	Ozone depletion potential, ODP	kg CFC-11 eq.
Human toxicity, cancer	Comparative toxic unit for humans (CTU_h)	CTU_h
Human toxicity, non-cancer	Comparative toxic unit for humans (CTU_h)	CTU_h
Particulate matter	Impact on human health	kg PM2.5 eq.
Ionizing radiation, health	Human exposure efficiency relative to U235	kBq U^235 eq.
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq.
Acidification	Accumulated exceedance (AE)	mol H+ eq.
Eutrophication	Accumulated exceedance (AE)	mol N eq.
Ecotoxicity	Comparative toxic unit for ecosystems (CTU_e)	CTU_e
Land use	Soil quality index	Dimensionless
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 water eq. deprived water
Resource use, minerals, and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq.
Resource use, fossil	Abiotic resource depletion, fossil fuels (ADP fossil)	MJ

For ULD, climate change remains the most visible impact category, primarily influenced by marginal fuel burn during the use phase and by the energy intensity of aluminum and composite material production. However, other categories are equally important in distinguishing between designs and materials. Resource use (minerals and metals) is particularly relevant, as ULDs contain large fractions of aluminum and increasingly composites, whose recyclability and recovery rates differ significantly. Resource use (fossil) is also important given the role of petroleum-based resins in composite ULDs.

Repair and refurbishment activities, such as welding, panel replacement, and cleaning, may impact human toxicity, particulate matter, and photochemical ozone formation. Meanwhile, ecotoxicity and water use can be affected by cleaning and end-of-life disposal practices. Land use and eutrophication are generally less influential but should be reported consistently to maintain alignment with the PEF indicator set.

As in the IATA SUPP LCA methodology , results should not be reduced to a single aggregated score. Instead, impact categories must be reported separately, allowing decision-makers to identify trade-offs (e.g., a lighter composite ULDs may minimize climate change impacts but increase fossil resource use or limit recycling benefits).

Box 4. Additional considerations for aircraft temperature-controlled containers (TCC)

Aircraft TCC (both active and passive) offer additional functions, specifically maintaining a defined temperature range during transport. As such, their life cycle requires special attention to stages and parameters beyond those of conventional aircraft containers.	
Functional Unit	In addition to consolidation, restraint, and protection, the service provided includes temperature control within specified ranges, which should be reflected in functional unit definitions where relevant.
System boundary and life cycle stages	Active TCC requires modeling of electricity consumption for battery charging, dry ice replenishment, or alternative cooling media. Passive TCC involves insulation materials and phase-change materials, which must be included in material and manufacturing inventories. Preparation for reuse should capture activities such as battery replacement, calibration, and recharging.
Data sources and quality	Primary data should be sought from providers of aircraft TCC for energy consumption per trip, phase-change material usage rates, maintenance cycles, and replacement rates of insulation or battery systems.
Sensitivity and uncertainty	Key parameters to test include energy use per trip, the lifetime and replacement frequency of batteries or insulation materials, phase-change material consumption, and the potential benefits of spoilage reduction.
Impact categories	Climate change, fossil resource use, and toxicity may carry greater weight due to additional energy use, refrigerant losses, or chemical composition of insulation. Interpretation should also consider

	trade-offs between higher container impacts and avoided cargo spoilage, especially for pharmaceuticals and perishables.

2.9. Interpretation

Refer to Section 2.9 of the *IATA SUPP LCA methodology*.

For ULD, interpretation must place results in the context of the broader air cargo system. The share of ULD-related impacts compared to total aircraft operations is typically small; however, the choices between materials, designs, and asset management models can still be significant when scaled to a global fleet and considered in relation to Scope 3 reporting requirements. Results should therefore be expressed both in absolute terms and normalized to the functional unit, with additional reporting per cargo-tonne-kilometer to enable integration into value-chain accounting.

Trade-offs between impact categories should be made explicit. For example, a lighter composite ULD may reduce fuel burn and, therefore, climate change impacts, but may also increase fossil resource use and face limitations in end-of-life recycling. An aluminum ULD may carry a higher production footprint but achieve lower impacts per turn due to greater durability and recyclability. Such trade-offs must be clearly presented to avoid misleading single-attribute conclusions.

For aircraft TCC, interpretation must also consider the additional material and operational burdens associated with insulation, type of refrigeration systems, batteries, or expendable refrigerant such as phase-change materials. These features can increase production impacts, tare weight, and energy use during operation, while offering benefits in terms of reduced spoilage and compliance with pharmaceutical logistics requirements. Results for aircraft TCC should therefore be reported separately from those for standard units, and the trade-offs explained transparently. For example, an active aircraft TCC may have higher climate change impacts due to electricity or refrigerant use, but could reduce overall value-chain impacts by preventing cargo loss and waste.

Where comparative assertions are made, practitioners should demonstrate that results are robust under the sensitivity and uncertainty analyses described in Section 2.7. Break-even analyses, such as the minimum number of lifetime turns required for one design to outperform another, are recommended to support decision-making.

Finally, results should be communicated with transparency about assumptions, data sources, and limitations. For shippers and freight forwarders, interpretation must clarify how ULD-related results can be incorporated into Scope 3 inventories, including any boundaries applied to fuel burn, repositioning, and end-of-life assumptions. This ensures that results are not only scientifically robust but also decision-useful for industry stakeholders.

2.10. Peer review

Refer to Section 2.10 of the *IATA SUPP LCA methodology*.

Peer review is essential when results are intended to be disclosed publicly, used in comparative assertions, or form the basis for external communications. Reviews should ensure that the study complies with ISO 14040 and 14044, that methodological choices are transparent and consistent, and that the underlying data and analyses support the conclusions.

3. Compliance with this guidance

Refer to Section 3 of the *IATA SUPP LCA methodology.*

LCAs of ULDs must follow the rules and minimum requirements outlined in this guidance to be considered compliant.

Box 5: Summary of key requirements for LCA studies.

Criteria	Report not published – internal use only	No Comparative Assertions - Published	Comparative Assertions - Published
Reason for the Study	Clearly state the purpose, intended audience, and decision context.		
Scope and System Boundaries	Clearly delineate system boundaries, including functional units and processes.	Align with ISO 14000/14040 requirements for third-party reports (Section 5.2). Include boundaries, assumptions, and exclusions.	Align with ISO 14040/14044 requirements for third-party reports (Section 5.2) and comparative assertions (Section 5.3) to ensure equivalent system boundaries for compared systems.
Life Cycle Impact Assessment (LCIA)	Provide characterization of life cycle impacts using relevant methods.	Include LCIA results in line with recognized methodologies.	Ensure inclusion of all material impact categories.
Data Quality Assessment	Assess data quality using a data quality matrix (ISO 14044 Annex D).	Include detailed data quality assessment, documented in the report.	Include data quality assessment and uncertainty analysis, as per ISO 14044 Section 4.2.3.6.
Uncertainty and Sensitivity Analysis	Optional but recommended where data limitations exist.	Mandatory: conduct sensitivity analysis to assess key assumptions.	Mandatory: conduct uncertainty sensitivity analysis of key parameters.
Interpretation of Results	Provide discussion of LCIA results, relevance, and materiality. Highlight limitations.	Provide interpretation of results, including completeness, consistency, and relevance.	Critical discussion of relevance, materiality, limitations, and significance of differences found.
Peer Review	Strongly recommended (internal review acceptable).	Independent critical review by a named external reviewer. Publish peer review statement.	Critical review by an expert panel to avoid bias. Dissenting views must be documented and published.
Transparency and Justification	Document limitations and decisions made during the study.	Explicitly document changes to scope, assumptions, and methods, along with justification.	Fully document changes to scope, assumptions, methods, and justification for critical decisions.
ISO Compliance	Not required but should aim to align with ISO 14040/14044 best practices.	Must comply with ISO 14040 Section 5.2 for third-party reporting.	Must comply with ISO 14040 Sections 5.2 and 5.3 for comparative assertions disclosed to the public.

4. Glossary

Cradle-to-Grave - A full life cycle approach in LCA that includes all stages from raw material extraction (cradle) to disposal or recycling (grave).

Cut-Off Rules - Guidelines used to exclude inputs or outputs from an LCA study if they are below a specified threshold, such as 3% of total material or energy flows.

End-of-Life - The final stage in a product's life cycle, which involves waste treatment options such as disposal, incineration, or recycling.

End-point indicator - In LCIA, an indicator that maps from one or several mid-point indicators to a final impact defined in terms of damage in a specific area. Examples might include human health or environmental quality.

Equivalent Still Air Distance (ESAD) - The horizontal distance an aircraft would travel in still air (i.e., with no wind effect) under actual conditions of flight. ESAD accounts for real-world atmospheric factors such as wind, making it a standardized measure for comparative flight distance.

Functional Unit - A quantified description of the primary function or service provided by a product system, used as the basis for comparison in an LCA study. For example, "the provision of cutlery services for one passenger on a flight."

Impact Categories - Environmental impacts assessed in the LCIA phase of LCA, such as climate change or resource depletion, using characterization models to quantify impacts. These are often divided into mid-point indicators and end-point indicators.

Life Cycle Assessment (LCA) - A systematic method to evaluate the environmental impacts of a product, process, or service throughout its life cycle, from raw material extraction (cradle) to end-of-life disposal (grave).

Life Cycle Impact Assessment (LCIA) - The phase of LCA that evaluates potential environmental impacts using indicators such as global warming potential, water use, or human toxicity. LCIA translates emissions and resource use into impacts.

Life Cycle Impact Assessment Method - A methodology used within the Life Cycle Impact Assessment (LCIA) phase of an LCA. It provides the characterization models and impact categories used to assess environmental burdens. Examples include TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) and ReCiPe.

Life Cycle Inventory (LCI) - The phase of LCA where inputs (e.g., materials, energy) and outputs (e.g., emissions, waste) are quantified for each stage of the product life cycle.

Marginal Fuel Burn - The incremental increase in aircraft fuel consumption caused by additional weight, often expressed as kilograms of fuel per kilometer per kilogram of added load.

Mid-point indicator - A measure used in LCIA that quantifies environmental impacts at an intermediate stage in the cause-effect chain, such as global warming potential (GWP) or acidification, without linking to final damage.

Normalization - A technique in LCIA where impact results are scaled against a reference value, such as the average annual environmental impact per capita, to provide a relative comparison across impact categories.

Person year equivalent - An approach to normalization that expresses each environmental impact indicator as a proportion of the emission of an average human being's impact across one year.

Product Environmental Footprint (PEF) - A standardized method for assessing the environmental performance of products and services across their life cycle, developed under the European Commission framework.

Recycling - The process of collecting, processing, and converting used materials into new products, thereby reducing the need for virgin raw materials and minimizing waste disposal.

Reference Flow - The measurable quantity of goods or services necessary to deliver the defined functional unit. **Reuse** - The practice of using a product more than once, for the purpose for which it was originally intended. Reuse often involves ancillary processes such as inspection, cleaning, refurbishment, or repair.

Sensitivity Analysis - A method to determine how variations in key assumptions or parameters (e.g., weight, return rate) affect the outcomes of an LCA study.

Single-Use Plastic Product (SUPP) - An item made primarily from fossil fuel-based chemicals (petrochemicals) and designed for one-time use, after which it is disposed of or recycled. Examples include single-use plastic cutlery, bottles, and cargo wrapping.

System Boundary - The set of criteria defining which life cycle stages, processes, and flows are included or excluded in an LCA study. For aviation, this typically includes cradle-to-grave analysis, covering raw materials to disposal.

Teardown - The process of systematically disassembling and analyzing all the components of a product to establish its material composition and manufacturing processes.

Temperature Controlled Container (TCC) - Thermal container incorporating, in addition to insulation, an automatic temperature control system, which may operate either only on the ground phases of the transport cycle, or also during flight. It can be active or passive, and it can contain an expendable refrigerant such as dry ice, etc. or not.

Unit Load Device (ULD) - A device for grouping and restraining cargo, mail, and baggage for air transport. It is either an aircraft container or a combination of an aircraft pallet and an aircraft pallet net. ULD is designed to be restrained by the aircraft Cargo Loading System (CLS).

ULD Turn (also called ULD utilization cycle) - One complete cycle from ULD build-up to break-down, after which the ULD is ready for reuse.

Weighting - The process of assigning importance to impact categories in LCIA, often based on policy or stakeholder priorities, to produce a single aggregated score.

5. Appendices

5.1. Appendix 1: Default flight assumptions

This appendix aims to provide valid default assumptions on standardized flight distances, aircraft types, and marginal fuel burn to improve comparability across different LCAs. The information presented in these tables is intended solely for the purpose of providing a set of general-purpose values that will facilitate easier comparison of LCAs. Note that company-specific or region-specific data may be more appropriate for any given study, and there is no requirement to use these defaults if more appropriate data are available.

Table 1: Default flight distances per flight duration.

Flight duration	Range (km)	Mid-point for modeling (km)
Very short haul	< 500	250
Short haul	500 – 1,500	750
Medium haul	1,500 – 4,000	2,800
Long haul	> 4,000	7,400
Ultra long haul	**N/A**	**12,000**

Source: Eurocontrol and Wilkerson et al. (2010).[2]

Table 2: Assumptions around flight distance.

Distance	Aircraft †	ESAD (km)	Passenger loading ‡	Cargo loading ††	Flight time (hours) ‡‡	Taxi time in (min) ‡	Taxi time out (min) †††
Short haul	B737	750	82%	47.3%	1.5	5	10
	A320	750	82%	47.3%	1.5	5	10
Medium haul	B737-900ER	2,800	82%	47.3%	4	5	10
	A321neo	2,800	82%	47.3%	4	5	10
Long haul	B777	7,400	82%	47.3%	9.5	5	10
	A350	7,400	82%	47.3%	9.5	5	10
Ultra long haul	B777	12,000	82%	47.3%	15.5	5	10
	A350	**12,000**	**82%**	**47.3%**	**15.5**	**5**	**10**

† Aviation for aviators (2021). Which Planes Are Used for Short, Medium, and Long Haul Flights?
‡ Aircraft Commerce (2020). The effect of varying payloads & AUW on aircraft fuel burn.
†† IATA (2024). Air Cargo Demand up 9.8% in October 2024 - 15th Month of Consecutive Growth.
‡‡ Provisional figure based on WRAP review of flight times at: Flightmath.com - Flight time and distance between airports.
††† Eurocontrol (2020). Taxi times - Winter 2019-2020

The table below shows the impact of 1 kilogram of additional (or reduced) weight on marginal fuel burn (kg fuel/kg payload) for a range of flight scenarios. It is intended to be used when considering the impact of differing product weights on the use-phase impacts of products.

Table 3: Assumptions on marginal fuel burn.

Aircraft	2,000km	4,000km	5,000km	7,000km	12,000km
A320-200	0.07	0.12	0.16		
A330-300	0.05	0.08	0.11	0.18	
A380-800	**0.10**	**0.17**	**0.18**	**0.26**	**0.45**

Source: Steinegger, R (2017).[3]

[2] **Wilkerson et al. (2010).** **Analysis of emission data from global commercial aviation: 2004 and 2006.**
[3] **Steinegger, R. (2017)** **Fuel Economy as Function of Weight and Distance.**

5.2. Appendix 2: Default parameters for ULD LCA reference flows

To support harmonization, the table below provides default values for the parameters needed for the LCA comparison. Company-specific data should override these where available, and sensitivity analysis must continuously test the impact of the assumptions.

Table 1: Default reference flow parameters for ULD LCA

Parameter	Typical range/default value	Notes
ULD tare weight (AKE container)	Aluminium: 65–75 kg (default 70 kg) Composite: 50–60 kg (default 55 kg)	Based on manufacturer data. Weight directly affects marginal fuel burn.
ULD tare weight (PMC pallet)	Aluminium: 100–110 kg (default 105 kg)	Excludes net/straps; ancillary items modeled separately.
ULD/accessories	Net: ~12–15 kg Strap: ~1.5 kg each (12 straps for a typical pallet load)	Included where used systematically.
Service lifetime (years)	Aluminium containers: 10–15 years (default 12) Composite containers: 6–10 years (default 8)	Depends on handling practices and ownership models (owned/leased).
Turns per year (utilization)	100–150 turns/year (default 120)	Varies by airline and fleet management efficiency.
Total turns per lifetime	Aluminium: ~1200–1800 turns (default 1440) Composite: ~600–1000 turns (default 800)	Combination of lifetime and turns/year.
Repair/refurbishment cycles	1–2 major repairs per year	Includes panel replacement, welding, door repairs.
% of ULD Loss/scrapped per year	8–12% per year (default 10%)	Includes lost, unaccountable, and scrapped ULDs
Mode used for repositioning	Mode split: air 60%, truck 40% (default).	Varies by ownership model, may include ocean shipping
End-of-life treatment	Aluminium: 85–95% recycling (default 90%) Composite: 0–30% recycling (default 10%)	Reflects current market practice in developed countries, needs to reflect relevant regional practice

5.3. Appendix 3: Resources[4]

ISO 14040: Life cycle assessment: principles and framework[5]: This standard provides the principles and framework for conducting LCA, including goal definition, scope, inventory analysis, impact assessment, and interpretation. It ensures consistency, transparency, and scientific validity in environmental assessments. ISO14040 is an essential basis for any LCA, and the guidance in this document does not substitute for fulfilling all the standard's core requirements.

ISO14044: Life cycle assessment: requirements and guidelines[6]: ISO14044 specifies the detailed requirements and guidelines for LCA, including methodological choices, data quality, reporting, and critical review processes. It aims to ensure a robust and comparable assessment of environmental impacts across product life cycles. ISO14044 is an essential basis for any LCA and the guidance in this document does not substitute for fulfilling all the core requirements of the standard.

UNEP (2024) A Policymakers' guide to Life Cycle Assessment[7]: This document provides useful advice on reviewing studies to ensure adherence to recognized standards, goal and scope alignment, comprehensiveness, critical review, and transparency. It is recommended that any LCA intended for communication to regulators or policymakers follow this guidance, but the guidance has further application and should be considered best practice for any study intended for communication to third parties.

Life Cycle Thinking e-learning courses[8]: The Life Cycle Initiative have developed three introductory level courses aimed at addressing life cycle assessment and life cycle thinking from the perspective of businesses and governments. These courses cover:

- An introduction of life cycle thinking.
- Life cycle thinking in business decision making.
- Life cycle thinking in policy making.

Product Environmental Footprint (PEF)[9]: Developed by the European Commission, PEF is an LCA methodology for measuring the environmental performance of products throughout their life cycle. It aims to standardize and improve comparability of environmental assessments across industries.

Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)[10]: Developed by the U.S. EPA, TRACI is an LCIA methodology for characterizing environmental impacts, including global warming, acidification, and ecotoxicity. It is widely used in LCA and sustainability assessments in the U.S.

Global Guidance on Environmental Life Cycle Impact Assessment Indicators (GLAM)[11]: Currently being developed by the Life Cycle Initiative under UNEP, the GLAM project aims to provide a globally harmonized framework for LCIA. It integrates regionalized and sector-specific data to improve environmental impact modeling. The method aims to enhance decision-making by offering science-based end-point indicators for climate change, biodiversity, human health, and resource depletion. It supports global sustainability goals by improving the consistency and accuracy of LCA results.

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[4] These resources make no attempt to be comprehensive. Many jurisdictions have their own required LCA methodologies, LCIA methodologies, or region-specific LCI datasets. It is advisable to consult with the regulatory authorities in the region where the LCA is to be conducted.
[5] ISO 14040:2026. Environmental management — Life cycle assessment — Principles and framework.
[6] ISO 14044:2006. Environmental management — Life cycle assessment — Requirements and guidelines.
[7] UNEP (2024) A Policymakers' guide to Life Cycle Assessment.
[8] LCI. Life Cycle Thinking e-learning courses.
[9] European Commission. European Platform on LCA | EPLCA. Environmental Footprint.
[10] United States Environmental Protection Agency. Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI).
[11] European Commission. European Platform on LCA | EPLCA. Global Guidance on Environmental Life Cycle Impact Assessment Indicators (GLAM).