Introduction to Aerospace Life Cycle Assessment (LCA)

Basic concepts and tools

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Version ***01***

This document is released for purpose of providing an initial introduction to the concepts of Lifecycle Assessment (LCA) in an aerospace context

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Version History

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Acronyms

BoM – Bill of Materials

CBAM- Carbon Border Adjustment Mechanism

CORSIA – Carbon Offsetting and Reduction Scheme for International

Aviation CSRD- Corporate Sustainability Reporting directive

EF – Environmental Footprint

EoL – End of Life

EPD – Environmental Product

Declarations FU – Functional Unit

GHG – Greenhouse Gases

IAEG – International Aerospace Environmental Group

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

ISO – International Organization for

Standardization IP – Intellectual Property

KPI – Key Performance Indicators

LCA – Lifecycle assessment

LCIA –Lifecycle Impact Assessment

OEF – Organization Environmental

Footprint PCF – Product Carbon Footprint

PCR – Product Category Rule

PEF – Product Environmental Footprint

SAF – Sustainable Aviation Fuel

EXECUTIVE SUMMARY

IAEG seeks to develop voluntary leading-edge solutions across the value chain to promote a responsible and sustainable aerospace industry.   The purpose of this document is to offer an introduction document to explain key concepts of Lifecycle Assessments (LCA) to companies and associates that design and manufacture products for aerospace.

This document contains an overview of key concepts, a simple explanation of the process of an LCA and a section on common tools used to carry out LCAs in aerospace companies.

This document is intended as a quick reference guide and only covers basic principles if more detailed guidance is sought, please refer to the LCA framework document in the IAEG website[7].

1. LIFECYCLE ASSESSMENT Introduction

This introduction to LCA section has been created as a helpful broad overview for LCA newcomers to get up to speed with basic LCA nomenclature and concepts. Section 1 covers basic information about the LCA landscape, stakeholder groups and brief descriptions of LCA essentials are provided here as a starter pack. Some simplified explanations have been provided in this section as a way to start learning about LCA, in Section 2, there is a more detailed overview of the type of tools used in LCA and their intended use.

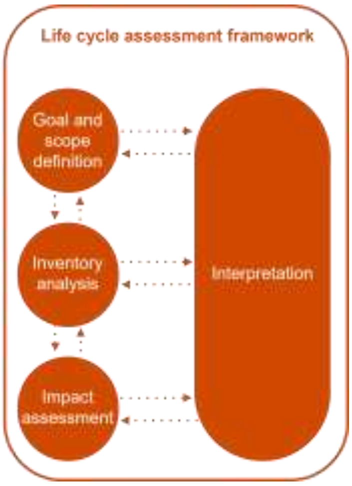

Figure 1. Lifecycle assessment flow (adapted from ISO 14040)

1.1 Welcome to Lifecycle Assessment

Lifecycle Analysis (LCA), also known as Life Cycle Assessment, is a systematic approach used to evaluate, quantify and assimilate environmental impact associated with all stages of a product's life, from raw material extraction (cradle) through production, use, and disposal (grave).

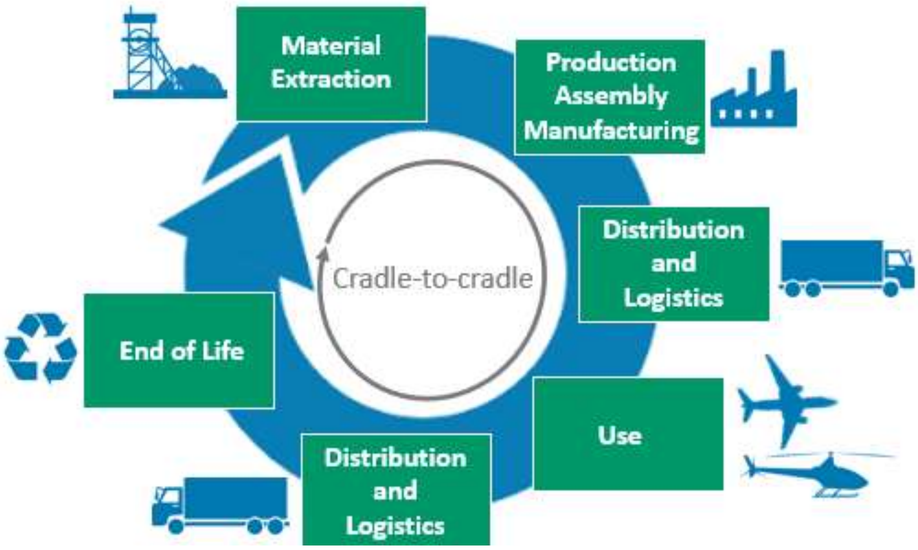

Figure 2. Circular lifecycle example picture (either, or, or similar)

1.2 Lifecycle Assessment Methodology

The LCA process is defined in the ISO14040[1] and ISO14044[2] standards and is divided into four key phases: Goal and Scope Definition, Inventory Analysis, Impact Assessment, and Interpretation. This document contains a brief introduction of these phases to facilitate an initial learning of LCA principle but is not intended to replace the details of the standards.

The first phase, Goal and Scope Definition, sets the boundaries and objectives of the study. This stage defines what will be included in the analysis, such as specific environmental impacts (e.g., carbon footprint, water usage) and the lifecycle stages to be evaluated. In the second phase, Inventory Analysis, data is collected on energy use, raw materials, emissions, and waste for each stage of the product's lifecycle. The third phase, Impact Assessment, involves translating the data collected into environmental impacts using established methodologies.

In LCA, the LCIA phase aims to understand and evaluate the magnitude of the potential environmental impacts of a system based on the information provided in the previous inventory analysis stage. For example, emissions of carbon dioxide can be quantified in terms of their contributions to climate change, acidification and ozone depletion; or Lithium batteries have significant impacts on global warming but also human toxicity, acidification, depletion of natural resources, ozone formation and depletion and freshwater toxicity and eutrophication.

Finally, in the Interpretation phase, the results are analyzed, and recommendations are made to reduce the overall environmental impact of the product or process. This process can be iterative as the inventory analysis, impact assessment or the interpretation of results phases might determine that the goal and scope of the study should be changed to match the study objectives once some data has been gathered.

1.2.1 Goal and scope definition

Many stakeholder groups might be interested in an LCA study depending on what the objective of LCA study is.

Determining ‘contributors’ and ‘recipients’ early is essential so that requirements can be clearly identified to support the definition and goal statements of the LCA study. Drawing and sharing a stakeholder map can help align contributors to recognize recipient needs and related rules from day.

For further detail of potential stakeholders and LCA uses – refer to the LCA framework document[7], Section 2: USE CASES.

1.2.1.1 LCA SCOPE

In conjunction with mapping the LCA goals to indicate intended recipients and involved organizations, diagrams indicating LCA scope and coverage are helpful. Understanding what parts of the product lifecycle will be included and who will participate in the data inventory for an LCA is key to having the right team ready to contribute to the LCA study

Some LCA boundary templates are available to support clear communication. At the initial stages of an LCA study creating and sharing a clear diagram with the LCA study contributors may help minimize unwanted variation and duplicated or conflicting work. These diagrams can represent a linear lifecycle (*Figure 3*) capturing a products end of life or move towards a circular lifecycle (*Figure 2*). However, the boundary of whether the LCA study includes the second-life product or not needs to be clearly defined. More details of the possible system boundaries and their implications are detailed in the System boundaries sub-section of the framework document. [7]

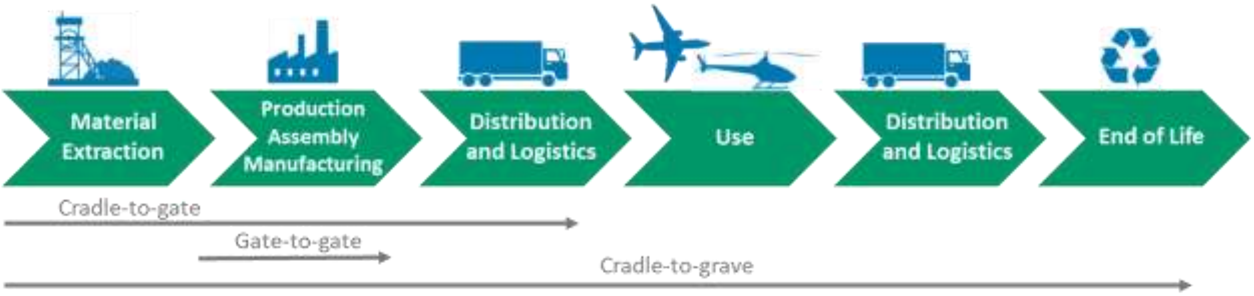

Figure 3. Figure explaining scopes

1.2.1.2 LCA contributors

Once the scope of the study is defined, key data collection contributors can be transparently planned further by tabulating relevant roles in any contributing organization. Some examples of the roles of an LCA are detailed in the table below:

Table 1. Examples of data collection roles involved in LCAs

Product Manager or owner	Supply chain and procurement	Operations or process personnel	Environmental health and safety	Designers and researchers
Provide data about the product lifecycle such as the BoM, installation instructions, expected use, maintenance data and manuals	Provide data about the product upstream suppliers, logistics, packaging	Provide data on production and assembly processes such as production and scrap rates, energy usage, water and chemical usage	Provide data on emissions and waste streams	Provide data on possible scenarios for scenario analysis and design alternatives

1.2.2 Leveraging LCA Results for Decision-Making

LCA results are not only intended for reporting purposes, an LCA study can have many purposes as outlined in Appendix B. The different use cases, mean that the results of an LCA study can be actively applied to support sustainability strategies within aerospace companies. Potential applications include:

a) Design & Engineering

- Results to be integrated into design reviews and trade-off studies (e.g., material selection, lightweighting, modularity, design-for-disassembly).
- LCA-derived KPIs should be linked to design milestones and technology readiness levels.

b) Supplier Engagement

- Suppliers could provide product carbon footprint (PCF)/LCA data at the component level to enable better supplier choice.
- LCA results may be included in sourcing criteria and RFQs (Request for Quotation) to encourage sustainable supply chains.

c) Operations & Fleet Management

- Results can highlight operational hotspots (an energy hungry process, an opportunity to change cleaning fluid).

- Results may inform fleet-level optimization strategies, eco-routing, and retrofit programs.

d) Corporate Reporting & Strategy

- Aggregated LCA results can be aligned with industry-level frameworks such as ICAO CORSIA, and EU CSRD.
- LCA outcomes could be incorporated into annual sustainability reports and internal scorecards.

e) Regulatory & Certification Alignment

- Standardized LCA outputs can be used to demonstrate compliance with regulatory requirements (e.g., EPDs, PCF)
- Results may be leveraged to support harmonization across global regulatory regions.

1.2.2.1 LCA results for KPI development

To support comparability and transparency across organizations, LCA results could be incorporated as KPIS into a company's decision making process. A set of examples of such KPIs is included in Table 11.

Table 2. Example KPIs derived from LCA results or activities

Category	Example KPIs	Application
Climate & Energy	Carbon footprint per functional unit (e.g., kg CO_2-eq/seat-km) Energy intensity per part or subsystem (MJ/kg)	Fleet strategy, product benchmarking
Circularity & Materials	% recycled content Recyclability rate Design-for-disassembly index	Eco-design reviews, supplier engagement
Air Quality	NOx, SOx emissions per flight hour PM emissions at airports	Local community impacts, regulatory reporting
Resource Use	Critical raw materials intensity (kg/part) Fossil resource depletion (MJ) Water footprint (m^3)	Supply chain resilience, substitution analysis
Improvement Tracking	% reduction vs baseline product % of suppliers providing LCA/PCF data	Progress monitoring, target alignment

1.2.2.2 Results Interpretation & Visualization

Proper interpretation of results is critical to avoid misrepresentation and ensure informed decision-making:

- Results shall be evaluated in the context of the study goal, scope, and system boundaries.
- Limitations and assumptions (e.g., data gaps, cut-off rules, allocation choices) shall be clearly communicated alongside results.
- Comparative results (e.g., between products or technologies) shall be presented only if the study complies with ISO 14044 requirements for comparative assertions.
- Results should be supplemented with sensitivity or uncertainty analyses to demonstrate

robustness.

- When communicated externally, results shall not be reduced to a single score or oversimplified metric, as this can obscure trade-offs and lead to misinterpretation.
- Clear messaging should be provided on how results inform next steps (e.g., material substitution, supplier dialogue, design iteration).

Results can be communicated through clear visualization formats tailored for different stakeholder audiences such as:

- Engineering dashboards (trade-off curves, material hotspot analysis)
- Circularity diagrams (material recovery and reuse potential)
- Executive scorecards (product-level LCAs rolled up to corporate net-zero targets)
- Supply chain heatmaps (emissions or raw material hotspots by tier)

1.2.3 Growing interest in LCA in aviation and potential overlaps

Understanding and quantifying the environmental impact of aerospace products and process and how they affect the environment allows the aviation industry to leverage the ongoing technological advances such as modernization of materials, fuels, flight profile management, aerodynamic efficiency and propulsion to minimize potential impacts. LCA is an important tool for quantification and can serve to prioritize and strategize on technological advancements while limiting unwanted consequences from focusing only on single impact reduction.

In addition, various forms of environmental regulation have been implemented and are anticipated to be implemented across different geographical regions. The global nature of the aerospace industry means a high degree of exposure to many of these regulations and therefore the industry needs to be prepared to comply with the most stringent of these regulations. LCA constitutes one of the tools available to comply with regulations requiring a quantified understanding of the environmental impacts of a particular product or process.

For example, an increasing number of regulations require or will require an accounting of the carbon footprint of a product. While LCAs generally provide a wider set of impact metrics, carbon footprint studies can be a subset of an LCA study focusing only on carbon dioxide emissions, or perhaps all GHG emissions.

It is not unusual for individuals working on emissions reporting at organizational level (GHG Protocol Corporate accounting and reporting standard), or on compliance with carbon disclosure regulations (CBAM, CSRD), or on material transparency compliance to also work on product lifecycle assessments.

Early understanding of areas where there are overlaps and differences helps minimize unwanted variation.

For example, in corporate emissions accounting it is common to define company activities with the Scope 1,2,3 division presented in *Figure 4*, whereas in LCA product level studies they are generally referred as foreground and background systems with upstream and downstream activities

Figure 4. GHG Scope emissions illustratio[5]

2. Introduction to LCA tools

This sub-section provides an introduction to LCA tools. The section was written as of 2025 and has information relevant to that date. The primary objective is to inform IAEG members and provide data for their decision-making efforts by examining the capabilities and features of various LCA tools available in the market. Here, we define and explore streamlined and advanced LCA tools while providing compelling comparisons of key features among the most widely used tools.

Disclaimer! This section is not intended to endorse a particular LCA tool for use by aerospace companies, rather it intends to guide industry in finding the best solution for their organization. Final choice on tools is a voluntary and unilateral decision of each company.

2.2 Considerations for LCA Tool Selection

2.2.1 Basic considerations

When choosing an LCA tool, you need to be clear about your specific needs, resources, and the level of expertise of team members. To assist in this selection process, you may consider the following questions:

- **What do you intend to use LCA for?** You first need to be clear about what you intend to use LCA for. Will you use LCA to make product claims, support R&D efforts, or simply identify the most problematic areas? For organizations aiming for a quick, high-level overview, a straightforward tool may be appropriate. However, if your goal is to conduct in-depth and detailed analyses, investing in a more sophisticated tool will provide the extensive functionality needed to obtain meaningful insights.
- **Are there any specific data needs?** Many LCA tools include databases as part of the subscription cost with more sophisticated tools being compatible with a number of datasets

that can be purchased separately. For example, some tools include databases with wide coverage (e.g., Ecoinvent) while others include databases for specific industries or products, such as chemical inventories or electronics. It is essential to understand whether these databases align with your specific needs.

- **Who will use the tool and how familiar with LCA are they?** Some tools are more user friendly than others. Those with limited LCA expertise will face a steep learning curve for more advanced tools when compared to other simplified solutions with guided workflows.
- **What is the budget?** Budget constraints can significantly impact tool selection. You need to consider subscription, database, and training costs when determining the overall investment costs.

There is no such thing as the 'right' tool for all LCAs as your choice will depend on your needs, preferences, and the depth of analysis required to achieve your study goals

2.2.2 Advanced vs. Streamlined LCA Solutions

Table 1 provides a comparison of Streamlined versus Advanced LCA tools. This classification captures the main differences in capability, complexity, and intended user base, providing clarity for organizations seeking tools aligned with their assessment needs.

Table 3. Comparison of streamlined and Advanced LCA tools

Criteria	Streamlined Tools	Advanced Tools
Typical cost of purchase	Lower	Higher
Typical software format	Web-based application	Desktop application
Ease of use	User friendly	Complex
Modelling flexibility	Limited	Highly customisable
Choice of LCIA methods	Limited	Comprehensive
Database coverage	Limited	Comprehensive
Access to training and support	Tool dependent	Tool dependent

Key aspects to consider when choosing an LCA tool

- **Cost of purchase:** how affordable is the tool, does it provide good value for money?
- **Ease of use/User friendliness:** has the tool got a user-friendly interface? Is it designed for LCA experts or is it accessible to all?
- **Database coverage:** does the tool include or support a variety of secondary databases? Are these databases aligned with your product's needs?
- **Lifecycle impact assessment (LCIA) compatibility:** which LCIA methods are supported by the tool? Is the tool focused on a carbon footprint, or does it allow for multi-impact assessments? Can you choose the LCIA characterization model (e.g., ReCiPe, IPCC, PEF)? Do you need to have access to multiple models?
- **Modelling flexibility:** does the tool allow for customization or include advanced modelling features, allowing users to build scenarios, adjust assumptions, or conduct sensitivity analysis? Do you need these advanced tools to support your LCA or wider sustainability goals?
- **Access to training and support:** what training and support does the software owner provide to users? Is there adequate documentation, tutorials, or direct technical support? How much support will your organization need to effectively adopt and use a tool?

2.2.3 Streamlined LCA Tools

Streamlined LCA tools are designed for rapid analysis and typically focus on specific indicators (such as carbon footprint), industries (e.g., construction), or LCA impact assessment models (e.g., IPCC AR6). These tools are often web-based, utilizing secondary databases and user-friendly interfaces to help users quickly evaluate products, making it easier for organizations to produce LCAs efficiently. Owing to their cost-effectiveness and ease of use, these tools are particularly suited for individuals (or organizations) with limited LCA expertise, those only seeking a high-level understanding of their products' environmental impacts, or those with limited budgets (e.g., SMEs). There are hundreds of streamlined LCA tools on the market, examples include: AllocNow, Earthster, Ecochain Mobius, Greenly, and LCA Calculator.

While streamlined tools are suitable for initial assessments, they often lack the features required for comprehensive or highly specific analyses and thus may not be suitable for companies wanting to incorporate LCA results into research and development activities or make environmental claims.

2.2.4 Advanced LCA Tools

Advanced LCA tools are designed with comprehensive and complex analyses in mind. These tools allow users to create customized models and employ various Lifecycle Impact Assessment (LCIA) methods. However, the demands of manual data entry and the plethora of options available can be overwhelming, with subscription costs and time commitments often presenting significant barriers to entry for smaller organizations. Owing to the significant financial and time commitments, these tools are most suitable for organizations with experienced teams looking to invest long-term in their use as part of their ongoing sustainability efforts.

There are four Advanced LCA software options available on the market and considered in this study, each with unique strengths and limitations, as illustrated in the matrix in *Table 2*. SimaPro and LCA for Experts (LfE) are recognized as market leaders, widely used in both industry and academia. Furthermore, Sphera, the owners of the LfE software have a 'data on demand' service where users can request the development of new process datasets. OpenLCA serves as an open-source alternative that offers advanced modelling capabilities with no subscription fees. Lastly, Umberto has advanced modelling capabilities and good technical support, offering a balanced combination of features and usability for detailed analyses.

Table 4. Comparing the features of SimaPro, OpenLCA, LfE, and Umberto

Aspect	LfE (GaBi)	SimaPro	OpenLCA	Umberto
Software free to use	X	X	√*	X
Software free trial period	30 days	30 days	(Not applicable)	14 days
Included database	Professional Core	Ecoinvent	(Not applicable)	Ecoinvent
Ecoinvent compatible database	√	√	√	√
LfE compatible databases	√	X	X	X
BOM import capabilities	√ **	√ (**)	X	√
Integration with CAD software	√	X	X	√
Generate EPDs from LCIA results	√	√	√	√ (*)
Has a "data on demand" service	√ (*)	X	X	X
Scenario analysis	√	√	√	√
Sensitivity and Monte Carlo analysis	√	√	√ (**)	√ (**)
Ability to create customised reports	√	√	√	√
Inventory and result export to Excel	√ ***	√	√	√

*** Many databases will need to be purchased separately: https://nexus.openlca.org/databases (*) Depends on the selected plan/business model**
**** An add-on tool for purchase separately to the LfE licence: https://sphera.com/solutions/product-stewardship/life-cycle-assessment-software-and-data/lca-bom-import/**
(**) Indirectly, via external tools
***** Limited compatibility with Excel compared to the other options**

2.2.5 Use of LCA Databases

The use of these LCA tools often imply the use of commercial databases, it should be noted that special attention may be paid to the associated End-User License Agreements that may include specific use restrictions, such as:

- Licensee not entitled to publish licensed environmental data,
- Licensee must not publish any data allowing reverse-engineering of back-calculation of environmental data.

These conditions must be considered when elaborating reports and communicating during the analysis.
More discussion on the applicability and data present in aerospace databases is included in the complete Framework document.

2.2.6 Conclusion

Automatic screening tools have undoubtedly improved the accessibility of LCA to non-experts and the features of advanced software packages have proven invaluable for decision-makers. Screening tools provide users efficiency and advanced software solutions offer sophistication.

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