Life Cycle Assessment (LCA)

1. What is the LCA?

Life Cycle Assessment is a method to assess the full environmental impacts of a system (BBB)[1] . Another definition Life cycle assessment (LCA) or life cycle analysis is an important method for assessing the environmental impacts of a product, process or service throughout its entire life cycle. This includes the extraction of raw materials, production, use and post-use stages. Each of these life cycle stages can affect the environment in various ways[2] . Each part of a product's life cycle is catalogued from the extraction of raw materials to production; its inputs, transport, use and what happens to a product after use[3]. Life cycle assessment (LCA) is a quantitative tool which aims to avoid emotive attitudes such as "fossil fuels are bad" or "organic is better". Instead it is a process of evaluating the effects that a system has on the environment; including extraction, processing, manufacture, transport, distribution, use, reuse, maintenance, recycling and final disposal. As such, an LCA is said to include the 'cradle-to-grave' impacts of the system in question, but may also be defined as 'cradle-to-gate' or 'gate-to-gate[1]

2. Who developed it?

Life Cycle Analysis or Life Cycle Assessment (LCA) dates back to the late 1960s/early 1970s, when the first (partial) LCAs were conducted: "The scope of these studies was initially limited to energy analyses, but later they examined resource requirements, emission loadings and waste produced." It has been expanded to include [4]. The Environmental Protection Agency (EPA) and the Society of Environmental Toxicologists and Chemists (SETAC) developed and formalised methods for conducting LCAs in the 1990s[5].

Historically, LCA practitioners employed various approaches to conduct their studies. However, with the method's growing popularity and the emergence of commercial claims based on LCA outcomes, the demand for a unified LCA framework became apparent. This led to the evolution of LCA methodologies, beginning with SETAC's influential work in 1990 and 1993, and culminating in the ISO standards of 1997 and 2006. Presently, the ISO 14040 series, including ISO 14040(2006) and ISO 14044(2006), stands as the most universally recognized and adopted methodology in the field[6].

3. What types of initiatives is it useful for?

Life Cycle Assessment (LCA) is a comprehensive and systematic approach that enables organisations to understand and improve the sustainability performance of their products or processes. Today, LCA is a methodology used by scientists, policymakers, and business leaders to set sustainability goals. Often used in conjunction with other well-known tools such as material flow analysis (MFA)[7]

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4. What are the main objectives of the LCA?

LCA is an ISO standardised analytical method for simultaneously measuring multiple environmental impacts occurring throughout the entire life cycle of a product or service. LCA is a unique tool for investigating the consequences of various decisions and what factors influence potential impacts. The life cycles of products or services can be complex, starting from sources, through production and distribution to users, and recycling and disposal at the end of life. At each stage there are different factors to consider, such as energy and water consumption, transportation and data networks. All of these are taken into account in LCA [8].
The aim of LCA is to compare all environmental impacts attributable to products and services by measuring all inputs and outputs of material flows and assessing how these material flows affect the environment [9].

5. How does it work?

Especially due to production-oriented human activities, the Earth's limited resources are rapidly depleting. LCA measures the impact of a product or service on available resources and pollution. It helps us understand its impact holistically. In this way, it can be evaluated whether products and services are truly sustainable.
Here's how the LCA method usually works:
-Defining the purpose and objectives and scope of the LCA study.
-Preparation of Life Cycle Inventory (LCI). For example, collecting data and making a detailed inventory of all inputs (raw materials, energy, water) and outputs (emissions to air, water and soil, solid waste) associated with each life cycle stage.
Conducting Life Cycle Impact Assessment (LCIA):
Evaluating the potential environmental impacts of inputs and outputs identified in the LCI phase. This step involves applying characterization factors to quantify impacts in different impact categories (e.g., global warming potential, acidification potential, eutrophication potential).
Drawing conclusions and making recommendations based on the findings of the LCA study and interpreting the results.
Considering uncertainties and limitations in the data and methodology used and investigating sensitivity analyzes or scenario modelling, if necessary.
Reporting and Communication phase: Presenting the findings of the LCA study in a transparent and understandable manner. Tailoring the communication to different stakeholders, such as policy makers, consumers or industry professionals, by highlighting the key findings and conclusions.
Review: Critical review of the LCA study to ensure that the methodology complies with standards (e.g. ISO 14040 series) and best practices.
Obtaining feedback from reviewers or stakeholders to increase the robustness and reliability of the evaluation.
Throughout these phases, LCA practitioners use specialised software tools (e.g. SimaPro, GaBi, OpenLCA) to manage data, calculate impacts, and generate reports. The method is iterative and opportunities for improvement should be provided based on new data, technological advances, or changes in the system being evaluated. because
Overall, LCA supports informed decision-making towards more sustainable practices by providing a systematic framework for understanding the environmental impacts of products and systems [10].

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6. What skills and knowledge are useful for using the LCA?

Most LCAs require outside experts. Consultants with a specialised skill set that understands areas such as industrial processes, transportation modelling, human and ecological toxicity, and knowledge of available data sources. Usually, a team is formed to rely on external experts to conduct the LCA; however, experts need to be given access to personnel across the organisation who deal with different aspects of the product or service. The quality of LCA depends largely on how well this broader network of individuals can work together. Stakeholders outside the organisation, such as customers, competitors, NGOs and academics, may also be involved. If the decision has been made to consult stakeholders, it is a good idea to consult with these stakeholders during the design phase, in the early stages of the study. This gives you the opportunity to ensure all the right questions are asked and the right data is collected [11].

Using the Life Cycle Assessment (LCA) method effectively requires a combination of technical skills and knowledge across various disciplines. Here are some key skills and knowledge areas that are useful for conducting LCA:

1. **Environmental Science and Engineering**: Understanding of environmental processes, impacts, and regulations is crucial. Knowledge of environmental chemistry, biology, and physics helps in interpreting environmental impacts of different life cycle stages.
2. **Systems Thinking**: Ability to analyse complex systems and understand interrelationships between different stages of a product's life cycle (from raw material extraction to disposal).
3. **Data Analysis and Interpretation**: Proficiency in statistical analysis, data visualisation, and interpreting results from environmental databases and life cycle inventory data.
4. **Life Cycle Inventory (LCI) Analysis**: Knowledge of methodologies for compiling LCI data including unit processes, allocation procedures, and data quality assessment.
5. **Impact Assessment**: Understanding of impact categories (e.g., global warming potential, resource depletion) and methodologies (e.g., ReCiPe, IMPACT 2002) used to quantify and assess environmental impacts.
6. **Life Cycle Costing**: Ability to integrate cost data across different life cycle stages to understand economic implications of environmental impacts.
7. **Software Proficiency**: Familiarity with LCA software tools (e.g., SimaPro, GaBi, OpenLCA) and databases (e.g., Ecoinvent) used to conduct LCAs efficiently and accurately.
8. **Knowledge of Standards and Guidelines**: Understanding of international standards and guidelines (e.g., ISO 14040 series, PAS 2050, Product Environmental Footprint) that govern LCA methodologies and reporting.
9. **Communication Skills**: Ability to effectively communicate LCA findings to stakeholders with varying levels of technical expertise, including policymakers, industry professionals, and the public.
10. **Industry-specific Knowledge**: Familiarity with industry-specific processes and supply chains to accurately model the life cycle stages and identify relevant environmental impacts.

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11. **Critical Thinking and Problem Solving**: Capacity to identify key issues, uncertainties, and limitations within an LCA study and propose solutions or improvements.

12. **Sustainability Principles**: Understanding of sustainability concepts and principles to guide decision-making and recommendations based on LCA results.

These skills and knowledge areas collectively enable practitioners to conduct robust LCA studies, assess environmental impacts comprehensively, and contribute towards sustainable decision-making across various sectors and industries [10,12,13]

7. USEFUL LINKS AND RESOURCES

1-(Harding,2011). An Introduction to Life Cycle Assessment (LCA).
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12- **Ralph E. Horne**, **Karli Verghese**. (2009): Life Cycle Assessment: Principles, Practice and Prospects.

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