Chapter 17

Life cycle assessment (LCA) – application of the process

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17.1. INTRODUCTION

LCA (life cycle assessment) is defined as an assessment of the life cycle from "cradle-to-grave". It assesses the effect of product or technology on the environment at all stages of their lifes. LCA is a methodology that supports planning, organization, and management, whose main purpose is the assessment of potential threats concerning environmental aspects. In other words, LCA is aimed at estimating the environmental risk of the technological process for the final effectiveness of the of the applied solution (Güereca et al., 2019). This methodology, regarding its nature, analysis quality, and data completeness, can be used as a tool supporting the decision-making process in the whole life cycle of the product or technology.

The aim of the study is to present general information on the life cycle assessment technique. Historically, the first mention of LCA methodology could be found in the study of Harold Smith, presented at the World Conference on Energy in 1963 (Klöpffer and Grahl, 2014). Research conducted by Smith focused on various chemical methods of energy production. One of the first companies interested in using these analyses in practice was Coca-Cola Company. In the late 1960s, the concern commissioned the study on each kind of liquid packaging for raw materials, expenditure, and energy used in the production process with environmental impact.

The development of LCA was also influenced by issues related to the formation of acid rains and the greenhouse effect. In 1993 Society of Environmental Toxicology and Chemistry (SETAC) has published the first LCA procedure "A code of practice", which gained widespread acceptance (Hauschild and Huijbregts, 2015). Over the same period the International Organization for Standardization (ISO) also started working for a standardization of the LCA process. As a result, ISO 1404x standards were developed. International Standard ISO 14040 defined LCA as, (ISO, 2006): "A life cycle assessment (LCA, also known as life cycle analysis, eco-balance) is a technique for a product-related

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estimation of environmental aspects and impact. LCA assesses every impact associated with all stages of a process from cradle-to-grave (i.e., from raw materials through materials processing, manufacture, distribution, use, repair, maintenance, and disposal or recycling)."

The concept of the LCA process is presented in Figure 17.1.

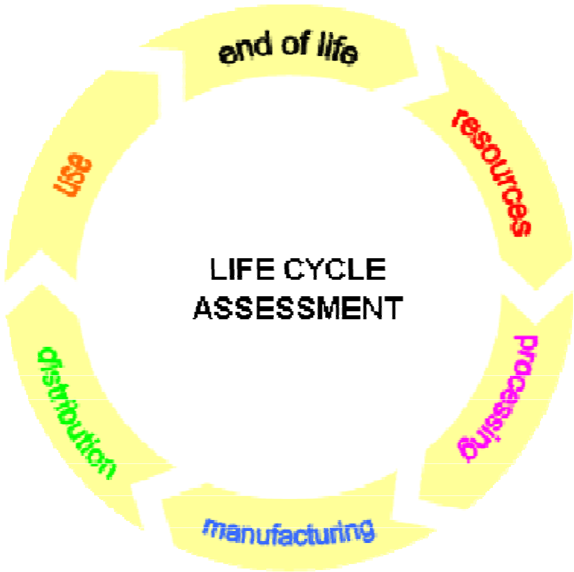

Fig. 17.1. Life cycle assessment (Brusseau, 2019)

17.2. STAGES OF THE LCA PROCESS

According to ISO 14040 LCA process consists of four stages (ISO, 2006):

17.2.1. PURPOSE AND SCOPE OF LCA ANALYSIS

This stage defines the context of the study, technical details, way to communicate the results, and the final addressee. It aims to demonstrate how great a part of the cycle of product/ technology will be estimated. Both the aim and scope should be clearly defined and coherent with the destiny as well as with end-use. The nature of the LCA process may cause that during the study redefinition of the aim and scope will be necessary.

17.2.2. LIFE CYCLE INVENTORY (LCI)

The second step is analysis of the data set of inputs and outputs. Collect and analyze data relating to inputs and outputs to/from the environment. These data are collected for each unit process specified in the product system. A statement is made of the number of materials and energy entering and leaving (by-products, emissions, waste) to/from a given process. Input data and output data are compiled for unit processes that are inside the product system boundary and contribute most to mass and energy flows and cause significant releases to the environment. This takes account of the flow balance of materials and energy in the product system in the context of interactions with the natural environment, used raw materials, and emission of harmful substances (including noise and odors). In this step, the data is assigned to individual unit processes (data allocation) and converted into a functional unit (e.g. per ton of product or product unit).

17.2.3. LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The third stage is the most important part of the analysis. It allows for a detailed description of the impact of product/technology on the selected elements of the natural environment. It also allows for the numerical interpretation of this impact, including calculations of category indicator. In this way it is possible to estimate the volume of natural gas used for the production of the product or application of the unit process, and also estimate its effect on global warming as the result of this gas burning.

17.2.4. INTERPRETATION OF THE LIFE CYCLE

The last stage includes critical analysis, identifying the boundaries of the technology and its working conditions, decision criteria taking into account the costs and yield, presentation of optional solutions, as well as a presentation of the results and conclusions including graphical interpretation of the data. This stage fits completely with the aim and scope of the analysis. The relationship between various LCA stages is presented in Figure 17.2.

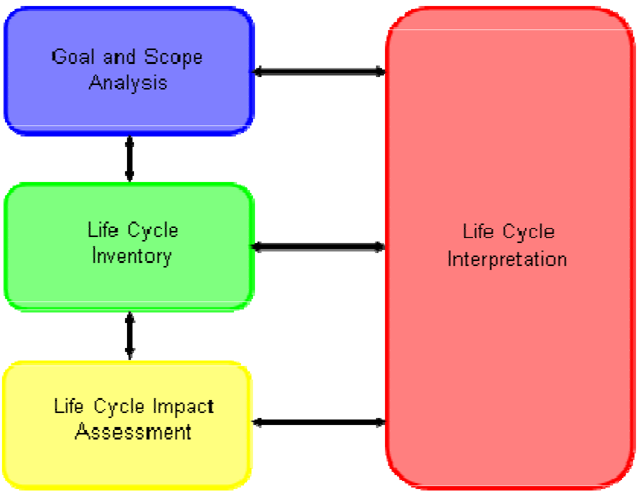

Fig. 17.2. Phases of LCA (ISO, 2006)

17.3. WHAT IS THE PURPOSE OF THE APPLICATION OF LCA?

The range of LCA is wide, and this method is used mainly for the determination of the real impact of various solutions on the natural environment, and consequently choosing the least harmful technology or product. And that applies to (Goermer et al., 2020):

- designing of products/ processes and/ or technologies;
- improvement of products and/ or technologies;
- comparative analyses of applied solutions;
- system of eco-labeling (process, product environmentally friendly);
- establishing rigorous pro-ecological standards;
- eco-product policy development;
- designing sustainable development strategies;
- waste management;
- marketing activities.

The use of LCA makes the decision-making process easier for companies and also leads to improving designed product/ technology concerning environmental protection. More and more economic players implement the technologies based on LCA within sustainable development, because this is a precondition to obtaining the ISO 14001 certificate (ISO, 2015). This leads to a revised life cycle of product/technology. The production process involving concept, production, packaging, and distribution finally includes application of the product concerning the effect on human health, use of natural resources as well as potential ecological threats, taking into consideration the quantity of water and energy used, generation of waste, and the CO_2 footprint.

The LCA method, especially extended with the functions of assessing individual scenarios and their optimization, can be used in the implementation of the idea of the circular economy (Lausselet et al., 2017). The concept of a circular economy assumes waste minimization at the product design level, and then covers the successive phases of the life cycle, up to the reuse or recycling phase. Such possibilities are offered by the LCA technique because it enables (Zarębska and Joachimiak-Lechman, 2016):

- determination of environmental loads on products and selection of the least resource-consuming and energy-consuming products from among them,
- assessment of the environmental impact of alternative ways of performing the same function by different product systems,
- comparison of production processes in terms of the production factors used,
- identification of potential environmental impacts of selected streams or unit processes and their comparison, presentation of the ratio of burdens to environmental benefits,
- reducing the amount of waste generated.

17.4. LCA FROM A STANDARISTION PERSPECTIVE

ISO 14040:2006 (ISO, 2006), ISO 14044:2006 (ISO, 2006), ISO 14045:2012 (ISO, 2012), ISO 14046:2014 (ISO, 2014), ISO/TR 14047:2012 (ISO, 2012), ISO/TS 14048:2002 (ISO, 2002), ISO/TR 14049:2012 (ISO, 2012), ISO/TS 14071:2014 (ISO, 2014), ISO/TS 14072:2014 (ISO, 2014), ISO/TR 14073:2017

(ISO, 2017), ISO/AWI TS 14074 standards have been assessed as guidelines in the European Union by the European Committee for Standardization (CEN). Additionally, Polish standards are based on these standards. They are:

- PN-EN ISO 14040:2009 – basic rules and instructions concerning LCA without detailed description of the LCA methodology (PKN, 2009);
- PN-EN ISO 14044:2009 – presents requirements and guidelines (old standards ISO 14041, ISO 14042, ISO 14043) (PKN, 2009);
- PN-EN ISO 14045:2012 – presents principles, requirements, and guidelines (PKN, 2012);
- PN-EN ISO 14046:2016-04 – water footprint – principles, requirements, and guidelines (PKN, 2016);
- PKN-ISO/TR 14047:2006 – presents examples of application of ISO 14042 (PKN, 2006).

17.5. ECO-LABELING

LCA as a tool of sustainable development is the basis for obtaining eco-labeling and environmental certificates. Eco-labeling impacts the perception of the trademark, value, and image of the company and also plays a role in increasing the competitiveness of the products compared to other companies' products. Eco-labeling is a recognizable logo that help facilities make more sustainable shopping decisions. It directly contributes to an increase in turnover and as a result increases the portability of the company. Labeling of ecological products and processes carries out the following functions: offers protection of the natural environment, provides information about ecological characteristics, encourage the companies to change the technologies they use to more environmentally friendly ones. It also carries out an educational function by expanding the knowledge on ecologically focused characteristics of the products (Thøgersen, 2010; Laso, 2017).

17.6. SOFTWARE FOR LCA ANALYSIS

For LCA analysis, more and more frequently specialized software is used. Often the software is developed by university specialists, societies, and organizations active in the field of environmental protection and provides support for acts in the area of environmental engineering and protection. The software is used for modeling and reporting life cycle (LCA) concerning environmental footprint. It includes databases that allow for the assessment of each of raw materials used and each process applied in production, at every stage, from the extraction of the resource to the end of the life cycle, taking into consideration the entire supply chain. The most popular tools (software) are: SimaPro, LCA Manager, OpenLCA, Umberto or GaBi Software (Iwaniuk, 2013; Lesiuk, 2012; Silva, 2019; Szamosi et al., 2020; Vervaeke, 2012).

Use of specialized software by companies contributes noticeably to not only protection of the environment and reducing the risk of its pollution, but also to (Iwaniuk, 2013; Lesiuk, 2012; Silva, 2019; Szamosi et al., 2020; Vervaeke, 2012):

- replacement of harmful components into the harmless ones,
- design changes of the products,
- develop environmentally friendly technologies,
- reorganization of production and distribution processes,
- improvement of business profits while maintaining the advantages of the products or technologies,
- establishing of new production standards,
- environmentally oriented management,
- change in branch perception (eco-labeling).

17.7. CONCLUSION

LCA is a life cycle assessment methodology, which allows for evaluation of the impact of the product or technology to the environment. It is an integrated approach to the environmental interactions and it includes a range of activities, from raw material extraction, through production, energy distribution, up to final utilization of the product.

In the company, LCA is simultaneously used both in accounting and environmental management. By implementation of the 14040 ISO standard, the following advantages are possible: sustainable development of enterprises, certification enabling the use of eco-labeling of products, as well as critical analysis of the projects. Use of specialized software assists in modeling and interpretation of the LCA analysis as well as in taking up sustainable actions favoring environmental management. LCA unambiguously contributes to broadening the awareness about the effect of product/technology in the perspective of the whole life cycle of a product. LCA standards are valuable guidance and standards that can help reduce your Product Carbon and Environmental Footprint.

The most important advantages of research using the LCA technique include: flexibility, interdisciplinarity, comprehensiveness, compatibility, and the result as a number. The main disadvantages of the LCA technique include: subjectivity, the fact that it's time-consuming and expensive, no spatial and temporal differentiation, incomplete data, and complexity of analyzes.

Despite the disadvantages presented, this method is becoming more and more important as a tool supporting environmental management all over the world. It is being constantly developed and improved, mainly in the direction of using it as a tool in the aspect of circular economy by extending its possibilities (e.g. adaptation with risk assessment) or combining it with other methods of environmental assessment (e.g. LCC – Life Cycle Costing).

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