Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 8 ~ Issue 11 (2022) pp: 35-39
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Life Cycle Assessment: Why and How?

Beyhan Kocadagistan
Ataturk University, Engineering Faculty, Environmental Engineering Department, 25240 Erzurum, Türkiye,

ABSTRACT: *The wild consumption caused by the rapidly increasing population and needs in recent years drags the world we live into a dead end. Countries have rapidly sought solutions and are trying to move on to new practices before reaching the point of no return. Life cycle assessment stands out as one of these applications and almost the most important one. This study focuses on what life cycle assessment is, how it is created, what it does and why it is important to human beings. The studies examined revealed that the life cycle assessment is very important in terms of both the profitability it provides to the manufacturer, reducing environmental impacts and applicability to similar processes. It is believed that this process, which can be applied to almost every stage of life, is essential because of the responsibility to future generations.*
KEY WORDS: *Life cycle, Sustainability, Environmental impact, resource efficiency*

R*eceived 02 Nov., 2022;* ***R****evised 010 Nov., 2022;* ***A****ccepted 12 Nov., 2022 © The author(s) 2022.*
P*ublished with open access at* ***www.questjournals.org***

I. INTRODUCTION

In today's world, the pursuit of sustainability has become a well-known term because of the depletion of natural resources and the damage to the environment. Sustainability consists of economic, environmental and social components. A sustainable product can be thought of as a product that has minimal impact on these ingredients throughout its life cycle [1].

Life Cycle Assessment (LCA) is an assessment method that measures the environmental impact, resource efficiency and amount of waste generation of products throughout their life cycles. Life cycle assessment is an applicable method for products and substances that we encounter at every stage of our ordinary life. In recent years, a large number of articles on sustainability and LCA stand out in the literature such as solar communities [2], anaerobic digestion of organic fraction municipal solid waste[3], geopolymer concrete [3], refrigerators [4], the whole city [5], buildings [6], Bitcoin mining[7], beverage packaging [8], electric vehicles [9], green roofs [10], food systems [11], pharmaceutical packaging [11], electronic waste products [12], asphalt pavements [13]. With LCA, industrial product suppliers can compare the environmental impact of products during the production process and easily make the necessary improvements. They can gain insights for potential innovations by identifying the significant environmental impacts of products at each stage of their lifecycle, and also identify potential risks and liabilities using LCA results for a sustainability strategy. Human beings, on the other hand, adopt a sustainable lifestyle in a way that will leave a more liveable world to future generations thanks to the awareness created.

In this article, it is aimed to contribute to creating awareness in the society by providing information about what LCA is and how it is evaluated.

II. RESULTS AND DISCUSSION

2.1 Definition and Necessity of LCA

The lifecycle is the sequential and interconnected phases of a product or service system, from the extraction of natural resources to their final disposal. LCA provides an assessment of the environmental impact of products, processes or services through production, use and disposal. In theory, it is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the operation of a product or service system throughout its lifecycle. LCA is a technique for assessing the potential environmental impacts associated with a product or service by creating an inventory of the relevant inputs and outputs, evaluating the potential environmental impacts associated with these inputs and outputs, and interpreting the results of the inventory and impact stages according to the objectives of the study [14]. LCAs include production-to-consumption analyses of production systems and provide comprehensive assessments of all energy inputs and environmental emissions. The cost and time consuming of LCAs somewhat limits their use in both the public and private sectors. In other words, LCA is the process of assessing the environmental loads associated with a product, process or activity by identifying and quantifying the energy and materials used, and the waste released into the environment. The aim is to evaluate the impact of these energy and materials used and released to the environment and to identify opportunities that will affect environmental improvements. Evaluation includes the entire life cycle of the activity, such as extraction of raw materials, product, process or production, transportation and distribution, use, reuse, maintenance, recycling and final disposal[15].A flow diagram of LCA is given in Figure 1[16].

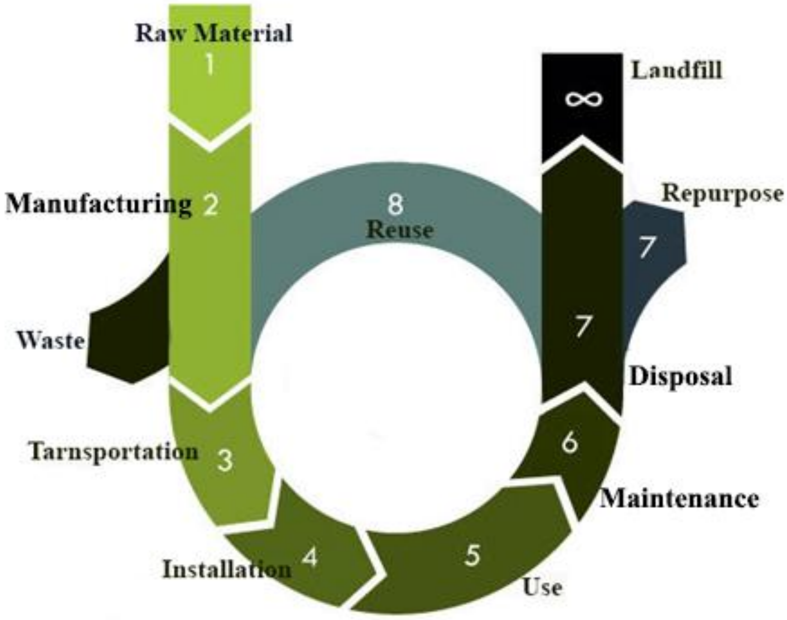

Figure 1. LCA flow diagram.

LCA has many benefits. Industrial product suppliers can compare the environmental impact of products during the production process and easily make the necessary improvements thanks to LCA. Additionally, they can gain insights for potential innovations by identifying the significant environmental impacts of products at each stage of their lifecycle, and also identify potential risks and liabilities using LCA results for a sustainability strategy. Country managers can make decisions by comparing all environmental impacts. In terms of sustainability, it can be seen what is needed to achieve carbon footprint targets. A purchasing department can find out if suppliers have sustainable products and methods [17]. Human beings, on the other hand, adopt a sustainable lifestyle in a way that will leave a more liveable world to future generations thanks to the awareness created.

When the results given in the studies on LCA in the literature were examined, it was seen that very useful results were obtained. In a study comparing the life cycle performance of two urban energy systems, raw material and energy supply, system manufacturing, systems usage phase, on-site energy generation and use, maintenance and replacement of components were examined and ozone depletion and land use were 79.7% and 27%, respectively. It has been seen that the remaining impact categories can also decrease by 39-56% [2].

2.2 Modelling the LCA

According to the International Organization for Standardization (ISO), LCA consists of four main steps defined as goal and scope definition, inventory analysis, impact assessment and interpretation.

The first step, the definition of the target and scope, is very important for the consistent creation of the LCA. Besides being the first, it is the most basic step. With a broad definition of system boundaries, it is easier and more accurate to determine which processes cause the greatest environmental loads.Sometimes, opportunities for waste, environmental impact and cost reduction can arise in unexpected areas of the supply chain. Thus, by evaluating these determined points, it is possible to reduce the environmental burdens further. This can mean an opportunity for businesses to increase their profitability. LCA is a model and often quite complex. The best way to ensure results are unaffected by this complexity is to carefully define the purpose and scope with a precise definition of the product and its lifecycle, and with well-defined system boundaries. System boundaries reveal what is considered and what is not, such as excluding a small amount of content that contributes little to the overall footprint [17].

The second stage, inventory analysis, consists of the foreground and background data processing procedure to quantify the inputs and outputs of the system. Inventory data usually consists of water, energy, land, or other materials or products consumed or produced within the system.These data are verified and associated with the process units. In the third stage, the evaluation of the effects of the digitized data on human health and the environment should be carried out in the second stage. Common impact categories include water consumption, land conversion and climate change. Category indicators are selected for the categories covered. According to the results of this evaluation, the fourth stage is started and the data is evaluated in order to minimize the harmful effects on people and the environment. This is the last step in LCA and requires a systematic approach. The flow chart of the LCA model is given in Figure 2 with the technical standards of ISO [18].

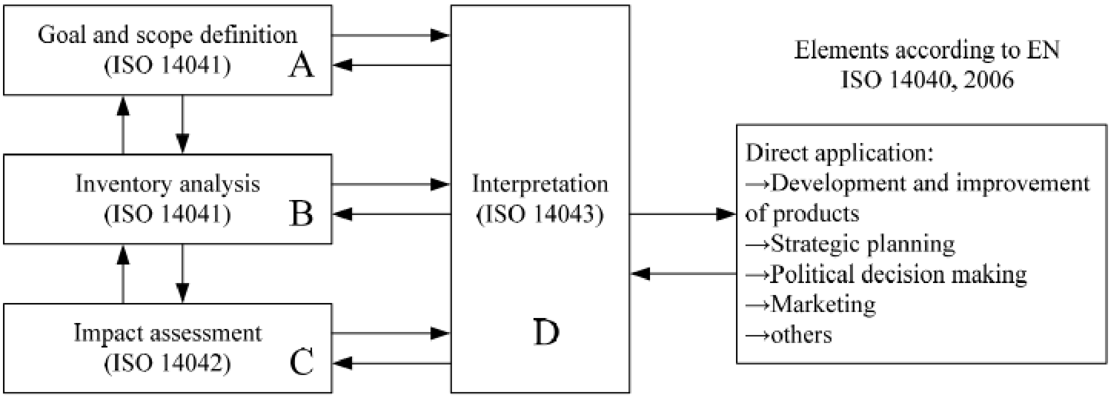

Figure 2. The diagram of LCA steps according to the ISO technical standard 14040.

As can be seen from Figure 2, all the steps are in a cycle and interact. An error to be made at any step in the LCA model may cause the whole model to collapse and the evaluation to be made may cause more harm than good to the system owner and the environment. Therefore, LCA can be considered as a complete cyclical model consisting of interconnected elements in a chain structure.

In a study comparing the life cycle performance of two urban energy systems, raw material and energy supply, system manufacturing, systems usage phase, on-site energy generation and use, maintenance and replacement of components were examined and ozone depletion and land use were 79.7% and 27%, respectively. It has been seen that the remaining impact categories can also decrease by 39-56%. In a discussion of methodologies applied to several important environmental aspects of biofuel lifecycles, emissions of climate-influencing substances, depletion of virtually non-renewable abiotic resources, primary energy demand, and water footprint were evaluated. With the LCA revealed in the study, it has been revealed that it will be useful in determining the life cycle stages and processes that contribute greatly to environmental loads, determining the energetic return of energy invested in biofuels, determining environmental trade-offs and comparing the life cycle environmental loads of products [19].

It was seen that alternative packages for the same drug have very different effects and this is up to 5 times more important for blisters than bottles and bags in a LCA of pharmaceutical packaging. It has been determined that material production provides the highest contribution and the use of aluminium has very high effects especially for acidification, while PVC has significant effects for fossil fuel consumption. Among the materials used, PVC was the forming film with the lowest environmental impact, followed by PVC/PVDC and OPA/Alu/PVC. The effects of trucking are more significant for larger sized packages due to the lighter material of the amount of packaging transported. Train and ship showed better environmental performance in the transport process [20].

The sustainability of six alternatives for the treatment of industrial wastewater from a gasifier was compared, considering both environmental and economic aspects. The processes were developed under a zero liquid discharge approach. The LCA noted that the six scenarios yield comparable results, as common chemical treatment causes the highest contribution. The optimization allowed a 25% reduction in gas emissions and a 15% reduction in stored goods. According to the results obtained in the study, the use of thermal waste as an auxiliary program for wastewater treatment processes has proven its effectiveness and it has been determined that the optimization of the crystallization unit is the most environmentally and economically appropriate alternative [20].

The results obtained in a study analysing a teaching building at a university in northern China showed that the environmental impacts and economic costs were greatest due to the use of electrical energy during the operation phase of the life cycle, while the environmental impacts and economic costs during the construction phase were found to originate from the building material production process. Thus, thanks to this LCA, a reference has been established for the design, construction and operation management of similar buildings [21].

An LCA was performed on a double-glazed triple-window technology with aluminium, wood and polyvinyl chloride frames used in an office building in Israel to examine the impact of natural gas or photovoltaic power generation on the selection of the best window technology for operational energy needs. It has been determined that aluminium and wood framed windows are the best choice when photovoltaic energy is used, and there is no difference for natural gas [22].

The amount of de-icer used in an LCA for road maintenance in winter has been identified as the main source of emissions contributing to all impact categories. In addition, it has been observed that energy use throughout the system is another important emission source. The environmental impacts of de-icer application have been demonstrated to be higher compared to mechanical cleaning of roads and strongly contribute to the generation of particulate matter and impact categories such as terrestrial, freshwater and human toxicity[23].

The environmental effects and economic costs of Compound Microbial Fertilizer (CMF) obtained from chemical fertilizers, organic wastes and microorganisms were evaluated and showed that the effects on fossil resource scarcity, water consumption and terrestrial acidification contribute significantly to the overall effects. The raw material stage played a critical role in the environmental performance of the CMF life cycle with a rate of 48%, followed by the transportation and production stages. Basic material analysis showed that the use of monoammonium phosphate in production is a hotspot and significantly increases the environmental burden of CMF production. In addition, economic analysis has shown that the life cycle cost of CMF is 675.75 CNY/t and raw material costs contribute the most to the total life cycle cost with over 70%[24].

Reusable Plastic Crates (RPCs) LCA results showed that the life cycle effects were dominated by the manufacturing phase if the RPCs were used for fewer than 20 deliveries. According to the results, the contribution of the renewal process will increase as the number of deliveries increases, thus reaching 30-70% of the total impacts for 125 uses. Thanks to the modeling approach in this study, the environmental sustainability of other returnable package types will also be evaluated [25].

Another LCA study evaluated the environmental performance of a chicken meat chain, which included 119 different farms, abattoirs, meat processors and retailers, as well as 500 households. The focus of the research was on global warming potential, ozone depletion and cumulative energy demand. According to the results, the biggest contribution to the environmental profile of the entire poultry meat chain is feed production and energy use. It has been shown that it is possible to reduce environmental impacts by using grain legumes as a source of protein in feed, processing chicken litter in a biogas digester, applying energy efficient equipment along the entire chain, and recycling household waste [26].

A cradle-to-grave LCA was used for restoration mortars and binders to measure potential environmental impacts on the categories of global warming potential, depletion potential of abiotic resources, fossil fuels, acidification potential, and photochemical oxidant generation potential of restoration mortars. It has been revealed that hydraulic lime binders perform more positively in environmental effects, and the global warming potential of the mortars is in the range of 472-737 kg CO_2-eq/t. The critical hotspots in the study were the transport model assumptions and the fuel used for binder production. An important finding is that the use of natural gas instead of mineral coke can reduce the global warming potential by 14-22%, depending on the binder type [27].

III. CONCLUSIONS

As can be seen from the information presented in the study and the cases examined, the decrease in natural resources due to the increasing population and wild consumption has made LCA very important in terms of reintroducing and evaluating the consumed materials. As can be seen, thanks to LCA, manufacturers not only increase their profits and minimize their environmental impact, but also show an important way for similar applications. In addition, as can be seen from the cases examined, LCA is an important evaluation method that can be applied to procedures and processes in almost every area of life. For this reason, it is thought that it will be a very positive approach for future generations to request or encourage LCA for all industrial processes, just like environmental impact assessment by governments.

REFERENCES

[1] Zhang X, Zhang L, Fung KY, Bakshi BR, Ng KM. Sustainable product design: A life-cycle approach. Chemical Engineering Science. 2020;217:115508. https://doi.org/10.1016/j.ces.2020.115508. doi:10.1016/j.ces.2020.115508

[2] Guarino F, Longo S, Hachem Vermette C, Cellura M, La Rocca V. Life cycle assessment of solar communities. Solar Energy. 2020;207(June):209–217. https://doi.org/10.1016/j.solener.2020.06.089. doi:10.1016/j.solener.2020.06.089

[3] Demichelis F, Tommasi T, Deorsola FA, Marchisio D, Mancini G, Fino D. Life cycle assessment and life cycle costing of advanced anaerobic digestion of organic fraction municipal solid waste. Chemosphere. 2022;289(November 2021):133058. https://doi.org/10.1016/j.chemosphere.2021.133058. doi:10.1016/j.chemosphere.2021.133058

[4] Choi S, Jung Y, Kim Y, Lee H, Hwang Y. Environmental effect evaluation of refrigerator cycle with life cycle climate performance.

International Journal of Refrigeration. 2021;122:134–146. https://doi.org/10.1016/j.ijrefrig.2020.10.032. doi:10.1016/j.ijrefrig.2020.10.032

[5] Czamanski D, Broitman D. The life cycle of cities. Habitat International. 2018;72:100–108. https://doi.org/10.1016/j.habitatint.2016.09.002. doi:10.1016/j.habitatint.2016.09.002

[6] Asdrubali F, Grazieschi G. Life cycle assessment of energy efficient buildings. Energy Reports. 2020;6:270–285. https://doi.org/10.1016/j.egyr.2020.11.144. doi:10.1016/j.egyr.2020.11.144

[7] Köhler S, Pizzol M. Life Cycle Assessment of Bitcoin Mining. Environmental Science and Technology. 2019;53(23):13598–13606. doi:10.1021/acs.est.9b05687

[8] Brock A, Williams I. Life cycle assessment of beverage packaging. Detritus. 2020;13:47–61. doi:10.31025/2611-4135/2020.14025

[9] Rapa M, Gobbi L, Ruggieri R. Environmental and economic sustainability of electric vehicles: life cycle assessment and life cycle costing evaluation of electricity sources †. Energies. 2020;13(23). doi:10.3390/en13236292

[10] Giama E, Papageorgiou C, Theodoridou I, Papadopoulos AM. Life Cycle Analysis and Life Cycle Cost Analysis of green roofs in the Mediterranean climatic conditions. Energy Sources, Part A: Recovery, Utilization and Environmental Effects. 2021;00(00):1–14. https://doi.org/10.1080/15567036.2021.1914782. doi:10.1080/15567036.2021.1914782

[11] Cucurachi S, Scherer L, Guinée J, Tukker A. Life Cycle Assessment of Food Systems. One Earth. 2019;1(3):292–297. doi:10.1016/j.oneear.2019.10.014

[12] Mangmeechai A. The life-cycle assessment of greenhouse gas emissions and life-cycle costs of e-waste management in Thailand. Sustainable Environment Research. 2022;32(1). doi:10.1186/s42834-022-00126-x

[13] Swarna ST, Hossain K, Bernier A. Climate change adaptation strategies for Canadian asphalt pavements; Part 2: Life cycle assessment and life cycle cost analysis. Journal of Cleaner Production. 2022;370(November 2021):133355. https://doi.org/10.1016/j.jclepro.2022.133355. doi:10.1016/j.jclepro.2022.133355

[14] ISO. 14040.2 Draft: Life Cycle Assessment - Principles and Guidelines. Switzerland; 2006.

[15] Consoli F, Allen D, Ian Boustead, Fava J. Guidelines for Life-Cycle Assessment: A "Code of Practice." In: SETAC Workshop. Portugal; 1993. p. 1–73.

[16] Shaik Mohiddin A, Wong MLD, Choo CM. Environmental Life Cycle Assessment of a Standalone Hybrid Energy Storage System for Rural Electrification Environmental Life Cycle Assessment of a Standalone Hybrid Energy Storage System for Rural Electrification. 2018;(January).

[17] Golsteijn L. Life Cycle Assessment (LCA) explained. 2022.

[18] Eugster M, Hischier R, Duan H. Key environmental impacts of the Chinese EEE industry - a life cycle assessment study. 2007.

[19] Reijnders L. Life Cycle AssessmentLife cycle assessment (LCA) of BiofuelsBiofuels. In: Basu C, editor. Biofuels and Biodiesel. New York, NY: Springer US; 2021. p. 53–67. https://doi.org/10.1007/978-1-0716-1323-8_4. doi:10.1007/978-1-0716-1323-8_4

[20] Bassani F, Rodrigues C, Marques P, Freire F. Life cycle assessment of pharmaceutical packaging. International Journal of Life Cycle Assessment. 2022;27(7):978–992. https://doi.org/10.1007/s11367-022-02062-9. doi:10.1007/s11367-022-02062-9

[21] Xue Z, Liu H, Zhang Q, Wang J, Fan J, Zhou X. The Impact Assessment of Campus Buildings Based on a Life Cycle Assessment–Life Cycle Cost Integrated Model. Sustainability. 2020;12(1). https://www.mdpi.com/2071-1050/12/1/294. doi:10.3390/su12010294

[22] Pushkar S. Life-cycle assessment of windows in Israel. Proceedings of the Institution of Civil Engineers - Engineering Sustainability. 2018;171(6):296–303. https://doi.org/10.1680/jensu.16.00031. doi:10.1680/jensu.16.00031

[23] Vignisdottir HR, Ebrahimi B, Booto GK, O'Born R, Brattebø H, Wallbaum H, Bohne RA. Life cycle assessment of winter road maintenance. The International Journal of Life Cycle Assessment. 2020;25(3):646–661. https://doi.org/10.1007/s11367-019-01682-y. doi:10.1007/s11367-019-01682-y

[24] Zhou Y, Xiao C, Yang S, Yin H, Yang Z, Chi R. Life cycle assessment and life cycle cost analysis of compound microbial fertilizer production in China. Sustainable Production and Consumption. 2021;28:1622–1634. https://www.sciencedirect.com/science/article/pii/S2352550921002608. doi:https://doi.org/10.1016/j.spc.2021.09.003

[25] Tua C, Biganzoli L, Grosso M, Rigamonti L. Life Cycle Assessment of Reusable Plastic Crates (RPCs). Resources. 2019;8(2). https://www.mdpi.com/2079-9276/8/2/110. doi:10.3390/resources8020110

[26] Skunca D, Tomasevic I, Nastasijevic I, Tomovic V, Djekic I. Life cycle assessment of the chicken meat chain. Journal of Cleaner Production. 2018;184:440–450. https://www.sciencedirect.com/science/article/pii/S0959652618306061. doi:https://doi.org/10.1016/j.jclepro.2018.02.274

[27] Diaz-Basteris J, Sacramento Rivero JC, Menéndez B. Life cycle assessment of restoration mortars and binders. Construction and Building Materials. 2022;326:126863. https://www.sciencedirect.com/science/article/pii/S0950061822005499. doi:https://doi.org/10.1016/j.conbuildmat.2022.126863