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Exploring the Research Frontier of Life Cycle Sustainability Assessment—A Systematic Literature Review of Applied Bibliometric Analysis

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All organizations are impacted by sustainability, both positively and negatively. It is therefore important to assess the sustainability of any human activity, product, or development. Life Cycle Sustainability Assessment (LCSA) is one of the most effective methods for assessing sustainability. The significance of this study is that it highlights significant and key ideas in the subject of LCSA, including research commonality, research trends, model shortcomings, existing appropriate methods, and research gaps using a systematic review of the literature and bibliometric analysis. The developing tendency of reviewing suggests that while sustainability issues are a severe problem for all countries, they will continue to rule social, economic, and environmental issues in the years to come. There are still a lot of uncharted territories. The study found that energy was the most popular topic among related areas of LCSA application. According to the research findings, it was also suggested that LCSA could be improved in future research in the following areas: the development of impact categories to enable study comparison, the definition of coherent system boundaries, the development of impact assessment methodologies, the development of trustworthy databases to enable the evaluation of economic and social perspectives, the development of tools for performing uncertainty analysis and communication strategies. To advance technique development and comprehend the interplay between environmental, economic, and social aspects, more case studies are required. It is envisaged that the development and application of LCSA will contribute to the accomplishment of Sustainable Development Goals across a range of international locations, businesses, and goods.

1. Introduction

The strategic decision-making process for goods has recently incorporated sustainability principles and evaluation methods that can be applied to analyze the sustainability of production (Kurka, 2013). It is crucial to perform early sustainability assessments of a variety of alternative products so that key decision-makers can base their decisions on the findings of the analysis. One of the most promising approaches to measuring sustainability is LCSA (Souza et al., 2015). The Brundtland notion of sustainability is the foundation of LCSA (World Commission on Environment and Development, 1987). Sustainability lays a heavy emphasis on simultaneously maximizing environmental performance, economic issues, and social concerns, which are the most prevalent justification for this definition (Pintarič and Kravanja, 2006). The three dimensions of sustainability (i.e., environment, economy, and social) are frequently assessed using the LCSA technique (Chang et al., 2012). A framework for the Life Cycle Sustainability Assessment (LCSA) incorporates the three aspects of sustainability from the triple bottom line (TBL) (Hoque et al., 2019). The three approaches that make up the LCSA methodology are life cycle assessment (LCA), life cycle costing (LCC), and social life cycle assessment (S-LCA). The formula of the LCSA framework is LCSA = LCA + LCC + S-LCA (Klöpffer and Renner, 2008). LCA is one such technique for evaluating the environmental impacts of products across their entire life

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cycle; from production to disposal (Buchert et al., 2015). The phrase "life cycle assessment" refers to the examination of possible environmental effects of a good process or service over the course of their whole lifespan; from the acquisition of raw materials to the final disposal of trash (Rajaeifar et al., 2017). It can provide information on possible environmental and safety impacts (Martínez-Blanco et al., 2015). It is also frequently employed as an important tool to compare competing products from the standpoint of environmental sustainability (Campanario and Gutiérrez Ortiz, 2017). S-LCA is a method for evaluating how the social impacts of products may influence employees, local communities, customers, (Sining et al., 2022), value chain participants, and society at large during the course of a product's life cycle (Baumann et al., 2002). Life Cycle Costing (LCC) focuses on the flows involved in the creation and consumption of products and services. The life cycle cost of a product, process, or activity is a measure of its total discounted costs during its lifespan (Roy et al., 2022). It relates to costs in general, not just environmental costs. The LCA technique can aid in decision-making by providing a more comprehensive picture of technologies (at various phases of development) and their environmental effects (Koch and Mihalyi, 2018), the LCA technique can aid in decision-making(Walmsley et al., 2018). A robust LCC framework can connect LCA research and the financial costing approach used by business decision-makers. LCC and LCA have been shown to constitute two of the three pillars of sustainability assessment, with social assessment serving as the third (Chang et al., 2012).
The purpose of this article is to systematically review the important LCSA concepts and ideas from around the globe. A thorough evaluation of the literature was conducted to identify pertinent studies, papers, and articles for studying the LCSA in its dimensions. The following questions are the focus of this review: What are the current LCSA bibliometric analysis-based research commonalities and hotspots? What are the research trends of LCSA? What are the shortcomings of the LCSA model and the existing appropriate methods? The review includes mapping research gaps, and the authors give their conclusions and recommendations based on this paper.

2. Research methodology

Web of Science and Scopus are generally recognized as the two finest options for bibliometrics and literature reviews (Dabić et al., 2020). The search string (“LCSA*” OR “life cycle sustainability assessment*”) was take into consideration when searching within the article title, abstract, and keywords. The search covered all types of papers published exclusively in English between February 2008 and January 11, 2023, or from the start of the first study to the date this study was conducted. These selection criteria were based on the PRISMA Declaration (Moher et al., 2009). The search was primarily concerned with mapping the body of literature on LCSA sustainability development in the social sciences, environmental sciences, economics, econometrics, and finance. The search covered the entire LCSA study, from the earliest to the most recent. The search focused on all countries/territories within specific document types, such as articles, reviews, and conference papers. At this stage, 490 records were extracted from Scopus and 373 records from WOS. Duplicates were removed and all abstracts of the articles were carefully scrutinized for analysis and pacification to ensure the relevance and accuracy of the academic literature subsequently included. The exclusion condition was the restriction on articles published in English only. After each item was assessed against the aforementioned inclusion and exclusion criteria, 278 articles were selected for this paper’s review.

3. Results and Discussion

3.1 Co-occurrence of keywords and evaluation of publications over time

By looking at keywords, research themes and hotspots could be found. This could be achieved by grouping the authors' keywords according to how often they appeared together and creating a network of keyword co-occurrences. Two keywords are considered to have co-occurred if they appeared in the same title or abstract (Chakraborty et al., 2021). On the co-occurrence map, the separation between two nodes is inversely related to how similar the terms are to one another. Words that occur together more frequently are therefore kept apart. The VOS viewer software used "all keywords" to visualize the analysis (Chakraborty et al., 2021). Figure 1 displays the co-occurrence map of words with a minimum of five occurrences. So, only 21 keywords were to be selected and divided into six clusters, with a total link strength of 486. These were those with at least five minimum occurrences. As shown in Figure 1, the most frequently used keywords in this network are "life cycle sustainability assessment", "life cycle assessment", "sustainability", "social life cycle assessment", and "life cycle costing." Given the strength and relevance of these four keywords, most researchers apply LCSA by taking into account the three pillars of sustainability: environment, social, and economics. The interlinking lines that connect these keywords demonstrate how strong and significant these nodes are. These terminologies are frequently used when discussing the LCSA; therefore, the outcome was expected. There are also other significant links, including “sustainable transportation interacting with electric vehicles, life cycle sustainability assessment, life cycle assessment, multi-criteria decision making"; "multi-criteria decision-making integrating with sustainable transportation, electric vehicles, life cycle sustainability assessment, life cycle thinking, and sustainability assessment"; and "multi-criteria decision analysis integrating with life cycle costing, sustainability, life cycle assessment, life cycle sustainability assessment, and sustainability assessment." The present industry fields and associated concept applications related to the LSCA can be displayed through the combination of these keyword links. LCSA's integration with the circular economy is another matter. In LCSA studies, sustainable transportation was generally a hot topic. In fact, multi-criteria decision-making (MCDA) and multi-criteria decision analysis (MCDM) are frequently used approaches to aid in decision-making. The likelihood that two or more keywords are connected to the same subject or theme increases when they are grouped together (Feng et al., 2020).

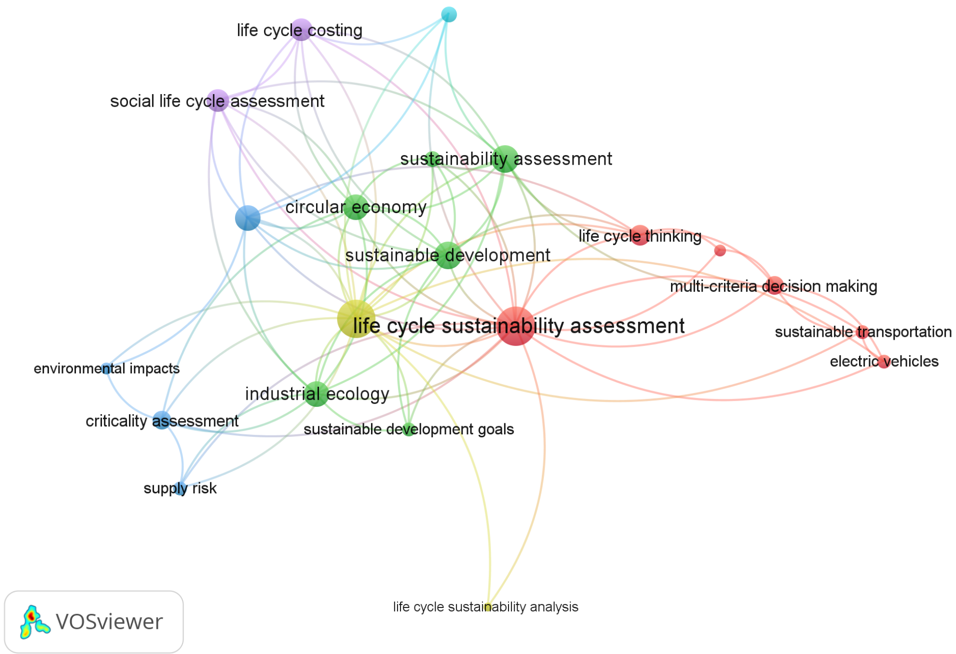

Figure 1: Author keywords co-occurrence life cycle sustainability assessment approach study

Figure 2 shows the findings that revealed an increase in academic attention to the life cycle sustainability evaluation between 2008 and 2023. The number of academic publications produced each year on LCSA's sustainable growth exhibited minor fluctuations, according to the analysis. The first article was published in 2008. By 2013, the volume of papers published had skyrocketed. Visentin et al. (2020) asserted that the rise in 2013 publications was due to the opening of a request for LCSA-related work by the Journal of Life Cycle Assessment in the same year. In 2013-2014, the number of publications decreased, from 16 papers to 9 papers, but from 2015-2021, the number was mostly growing, with minor oscillations. From 2015 to 2017, the number of publications increased from 17 to 26. However, from 2017 to 2018, the number of publications decreased from 26 to 24. The year 2019-2020 has the same publication number, which was 31 papers. The most linear growth in publications was in 2020-2021. In 2021-2022, the number of publications increased from 42 to 45. They were papers published before January 11, 2023. The characteristic exponential expansion of the field signaled a growing dispute. More and more authors recognize the importance of sustainable development and and employ the LCSA method for their studies.

Figure 2 points out that LCA is evolving into LCSA, and the development of the LCSA framework represents a substantial challenge to both global political organizations and the scientific community. Such strong international collaboration is essential to avoid a multiplicity of diverse approaches and methodologies (Guinée et al., 2011). This subject is gaining a positive impact despite its youth and what appears to be a concentration of influence in a small number of publications. The works on the LCSA have been cited numerous times as a result of the topic's intense political interest. Citations serve as a tool for gauging reader interest and awareness in a piece of writing. More citations indicate that the research is worthy of continuing in the future; hence, it is a crucial indicator for authors and researchers (Menegaki et al., 2021). Overall, the expanding pattern demonstrated that this issue will continue to dominate social, economic, and environmental discussions in the years to come as it is a major concern for all countries.

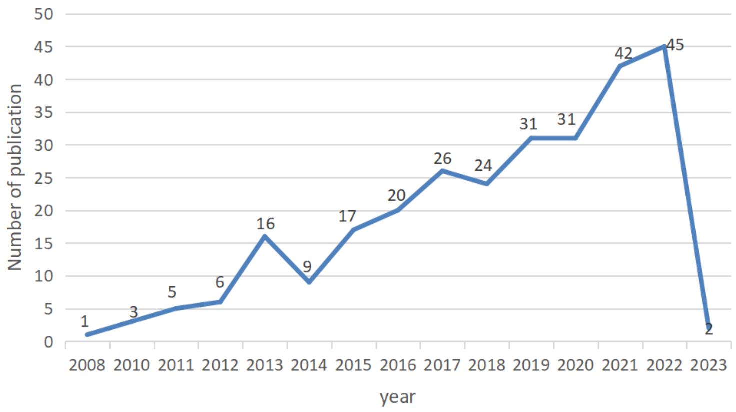

Figure 2: Number of publications per year on the LCSA approach study for the period of 2008-2023

3.2 Mapping existing literature

Among the literature reviewed in this paper are case study articles that used the LCSA approach. I categorized the 67 case study articles by case product or case focus and found ten categories in total: 5 papers study animal products, 4 papers study transportation, 15 papers study energy, 2 papers study plants, 12 papers study waste, 7 papers study building, 6 papers study chemical or biological products, 5 papers study minerals, 11 papers study industry. The most common case study is related to energy. From this part, it is easy to see that LCSA has already been applied in a variety of areas or products; in this study, the most popular area was discovered, but there is still room for further research. Other authors should be made aware of this analysis. LCSA has been applied to illustrate which products or fields have gaps, which ones are currently being researched on more or less, and to help researchers quickly identify research gaps.

Troullaki et al. (2021) highlighted that LCSA, as it is currently utilized, cannot serve as a comprehensive and cross-disciplinary framework for sustainability. To assess the relative relevance of each impact indicator and the accompanying views of decision-makers or stakeholders, a decision-making model should be utilized in conjunction with the LCSA methodology's interpretation phases (Furness et al., 2021). The top two approaches used in/with LCSA in the sustainability study are displayed, which are Multi-Criteria Decision-Making (MCDM) and Multi-Criteria Decision Analysis (MCDA). MCDA is increasingly being used to combine data and accelerate decision-making and policy-making processes (Dantas and Soares, 2022). Meanwhile, MCDA techniques can help life cycle practitioners address subjective assumptions, consider participant values, and address trade-offs among various sustainability dimensions in an objective manner. Life cycle tools can inform MCDA research locally and globally, as well as mitigate adverse impacts and prevent burden shifting. Additional consideration of Life Cycle Sustainability Assessments will also be taken into account in the future (De Luca et al., 2017). Berticelli et al. (2020) said that decision-making processes needed to be backed by systematic methods and supported by alternatives based on environmental effectiveness, social acceptability, and financial accessibility. The amount of environmental, social, and economic indicators that were gathered from the sample as a whole demonstrates that LCSA practitioners have experienced varying degrees of methodological and practical challenges depending on the sustainability element (Lassio et al., 2021). The present study found that there was little discussion of social factors and even less of economic issues. Despite practical challenges with data and indicators, social issues receive less attention, and conceptual understanding of both S-LCA and LCSA remains lacking (Zamagni et al., 2013). Dynamic criteria, particularly environmental impact analysis taking into account social and economic issues, should be adopted to compare the findings of future LCSA studies. Future research should concentrate on a range of industries in developing countries (Salim et al., 2022). Method developers are requested to help by developing or enhancing currently lacking or unknown causal chains and mechanisms of LCSA. For increased rigor and repeatability of outcomes, further technological and policy recommendations for conducting LCSA are made. To support the SDGs and sustainability evaluations, it is hoped that LCSA will be developed and implemented in numerous global locations, industries, and goods (Valdivia et al., 2021).

4. Conclusion and Recommendations

This paper reviews articles related to LCSA in recent years, summarizing development trends and relevant hot topics. It identifies methods to supplement the decision-making of the LCSA model and identifies shortcomings. The LCSA technique is expected to dominate social, economic, and environmental discussions in the future, with energy being the most frequently discussed topic. The study highlights the importance of utilizing a decision-making model with the LCSA technique to determine the relevance of definite effect indicators and the perspectives of participants or decision-makers. MCDM and MCDA are widely used methodologies for supporting decision-making in multi-criteria decisions, but they fail to consider the relationships and interactions between criteria.LCSA still requires improvement in a number of areas, including the creation of trustworthy databases for the evaluation of economic and social perspectives, the definition of coherent system boundaries, the creation of impact categories to enable the comparison of studies, as well as the development of impact assessment tools for uncertainty analysis and communication tactics. To advance technological development and our understanding of how environmental, economic, and social issues interact, more case studies are needed. The development and use of the LCSA are anticipated to aid in the assessment of the SDGs and sustainability across a variety of worldwide locations, businesses, and products.

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References

Baumann, H., Boons, F., Bragd, A., 2002, Mapping the green product development field: Engineering, policy and business perspectives, Journal of Cleaner Production, 10(5), 409–425.

Berticelli, R., Pandolfo, A., Reichert, G.A., Salazar, R.F. Salazar, R.F.S., Kalil, R.M., 2020, Support system for decision-making processes related to municipal solid waste management by taking into consideration a sustainable life cycle assessment: Review on environmental, economic and social aspects, International Journal of Environment and Waste Management, 26(2), 147–167.

Buchert, T., Neugebauer, S., Schenker, S., Lindow, K., Stark, R., 2015, Multi-criteria decision making as a tool for sustainable product development – Benefits and obstacles, Procedia CIRP, 26, 70–75.

Campanario, F.J., Gutiérrez Ortiz, F.J., 2017, Fischer-Tropsch biofuels production from syngas obtained by supercritical water reforming of the bio-oil aqueous phase, Energy Conversion and Management, 150, 599–613.

Chakraborty, K., Mukherjee, K., Mondal, S., Mitra, S., 2021, A systematic literature review and bibliometric analysis based on pricing related decisions in remanufacturing, Journal of Cleaner Production, 310, 127265.

Chang, Y.-J., Schau, E.M., Finkbeiner, M., 2012, Application of life cycle sustainability assessment to the bamboo and aluminum bicycles in surveying social risks of developing countries, In Proceedings of the 2nd World Sustainability Forum, 1–30 November 2012, MDPI, Basel, Switzerland.

Dabić, M., Maley, J., Dana, L.P., Novak, I., Pellegrini, M.M., Caputo, A., 2020, Pathways of SME internationalization: A bibliometric and systematic review, Small Business Economics, 55(3), 705–725.

Dantas, T.E.T., Soares, S.R., 2022, Systematic literature review on the application of life cycle sustainability assessment in the energy sector, Environment, Development and Sustainability, 24(2), 1583–1615.

De Luca, A.I., Iofrida, N., Leskinen, P., Stillitano, T., Falcone, G., Strano, A., Gulisano, G., 2017, Life cycle tools combined with multi-criteria and participatory methods for agricultural sustainability: Insights from a systematic and critical review, Science of The Total Environment, 595, 352–370.

Feng, X., Huang, B., Li, Y., 2020, R&D investment in new energy vehicles with purchase subsidy based on technology adoption life cycle and customers' choice behaviour, IET Intelligent Transport Systems, 14(11), 1371–1377.

Furness, M., Bello-Mendoza, R., Dassonvalle, J., Chamy-Maggi, R., 2021, Building the 'Bio-factory': A bibliometric analysis of circular economies and life cycle sustainability assessment in wastewater treatment, Journal of Cleaner Production, 323, 129127.

Guinée, J.B., Heijungs, R., Huppes, G., Zamagni, A., Masoni, P., Buonamici, R., Ekvall, T., Rydberg, T., 2011, Life cycle assessment: Past, present, and future, Environmental Science and Technology, 45(1), 90–96.

Hoque, N., Biswas, W., Mazhar, I., Howard, I., 2019, LCSA framework for assessing sustainability of alternative fuels for transport sector, Chemical Engineering Transactions, 72, 103–108.

Klöpffer, W., Renner, I., 2008, Life-Cycle Based Sustainability Assessment of Products, Chapter In: S. Schaltegger, M. Bennett, R.L. Burritt, C. Jasch, (Eds.), Environmental Management Accounting for Cleaner Production. Eco-Efficiency in Industry and Science, Vol 24, Springer, Dordrecht, Netherlands,91–102.

Koch, D., Mihalyi, B., 2018, Assessing the change in environmental impact categories when replacing conventional plastic with bioplastic in chosen application fields, Chemical Engineering Transactions, 70, 853–858.
Kurka, T., 2013, Application of the analytic hierarchy process to evaluate the regional sustainability of bioenergy developments, Energy, 62, 393–402.
Lassio, J.G., Magrini, A., Branco, D.C., 2021, Life cycle-based sustainability indicators for electricity generation: A systematic review and a proposal for assessments in Brazil, Journal of Cleaner Production, 311, 127568.
Li, Y., Sharaai, A.H., Ma, S., Wafa, W., He, Z., Ghani, L.A., 2022, Quantification of carbon emission and solid waste from pottery production by using Life-Cycle Assessment (LCA) method in Yunnan, China, Processes, 10(5), 926.
Martínez-Blanco, J., Inaba, A., Finkbeiner, M., 2015, Scoping organizational LCA—challenges and solutions, International Journal of Life Cycle Assessment, 20(6), 829–841.
Menegaki, A.N., Ahmad, N., Aghdam, R.F.Z., Naz, A., 2021, The convergence in various dimensions of energy-economy-environment linkages: A comprehensive citation-based systematic literature review. Energy Economics, 104, 105653.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009, Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement, BMJ, 339(7716), 332–336.
Muhammad, K.I., Sharaai, A.H., Ismail, M.M., Harun, R., Yien, W.S. 2019, Social implications of palm oil production through social life cycle perspectives in Johor, Malaysia, International Journal of Life Cycle Assessment, 24(5), 935–944.
Omran, N., Sharaai, A.H., Hashim, A.H., 2021, Visualization of the sustainability level of crude palm oil production: A life cycle approach, Sustainability, 13(4), 1607.
Pintarič, Z.N., Kravanja, Z., 2006, Selection of the economic objective function for the optimization of process flow sheets, Industrial and Engineering Chemistry Research, 45(12), 4222–4232.
Rajaeifar, M.A., Tabatabaei, M., Abdi, R., Latifi, A.M., Saberi, F., Askari, M., Zenouzi, A., Ghorbani, M., 2017, Attributional and consequential environmental assessment of using waste cooking oil-and poultry fat-based biodiesel blends in urban buses: A real-world operation condition study, Biofuel Research Journal, 15, 638–653.
Roy, S.M., Machavaram, R., Moulick, S., Mukherjee, C.K., 2022, Economic feasibility study of aerators in aquaculture using life cycle costing (LCC) approach, Journal of Environmental Management, 302, 114037.
Salim, K.M.A., Maelah, R., Hishamuddin, H., Amir, A.M., Ab Rahman, M.N., 2022, Two decades of life cycle sustainability assessment of Solid Oxide Fuel Cells (SOFCs): A review, Sustainability, 14(19), 12380.
Sining, M., Sharaai, A.H., Wafa, W., 2022, A study of social well-being among university students, International Journal of Life Cycle Assessment, 27(3), 492–504.
Souza, R.G., Rosenhead, J., Salhofer, S.P., Valle, R.A.B., Lins, M.P.E., 2015, Definition of sustainability impact categories based on stakeholder perspectives, Journal of Cleaner Production, 105, 41–51.
Troullaki, K., Rozakis, S., Kostakis, V., 2021, Bridging barriers in sustainability research: A review from sustainability science to life cycle sustainability assessment, Ecological Economics, 184, 107007.
Valdivia, S., Backes, J.G., Traverso, M., Sonnemann, G., Cucurachi, S., Guinée, J. B., Schaubroeck, T., Finkbeiner, M., Leroy-Parmentier, N., Ugaya, C., Peña, C., Zamagni, A., Inaba, A., Amaral, M., Berger, M., Dvarioniene, J., Vakhitova, T., Benoit-Norris, C., Prox, M., … Goedkoop, M., 2021, Principles for the application of life cycle sustainability assessment, International Journal of Life Cycle Assessment, 26(9), 1900–1905.
Visentin, C., da Silva Trentin, A.W., Braun, A.B., Thomé, A., 2020, Life cycle sustainability assessment: A systematic literature review through the application perspective, indicators, and methodologies, Journal of Cleaner Production, 270, 122509.
Walmsley, T. G., Varbanov, P. S., Su, R., Klemeš, J. J., Koch, D., Mihalyi, B., 2018, Assessing the Change in Environmental Impact Categories when Replacing Conventional Plastic with Bioplastic in Chosen Application Fields. Chemical Engineering Transactions, 70, 853–858.
World Commission on Environment and Development, 1987, Our Common Future, Oxford University Press, Oxford.
Zamagni, A., Pesonen, H.L., Swarr, T., 2013, From LCA to life cycle sustainability assessment: Concept, practice and future directions, International Journal of Life Cycle Assessment, 18(9), 1637–1641.