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Life-Cycle Data for Carbon Disclosure: Aligning Assessment with Reporting Standards

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Abstract

Globally, increasing regulatory pressure, stakeholder expectations, and societal awareness of climate change have intensified demands on corporations to disclose their environmental impacts and demonstrate accountability for reducing greenhouse gas emissions. In this context, carbon disclosure has become a central component of corporate sustainability reporting. Life-Cycle Assessment (LCA), which evaluates environmental impacts across the entire product life cycle i.e. from raw material extraction and production to distribution, use, and end-of-life disposal which offers a comprehensive and systematic approach for measuring and managing corporate carbon footprints.

This research examines the extent to which LCA is integrated into corporate carbon disclosure practices by conducting a thorough secondary data analysis of sustainability and climate-related reports published by multinational corporations across diverse industries. The study evaluates the quality, consistency, and transparency of LCA-based carbon reporting, with particular attention to methodological choices, system boundaries, data sources, and alignment with established reporting frameworks and standards. In addition, it identifies prevailing trends in LCA adoption, explores sector-specific differences, and investigates the practical challenges companies face when implementing LCA within their disclosure strategies.

The findings indicate that while the use of LCA in corporate carbon reporting is steadily increasing, its potential to support strategic decision-making and effective stakeholder communication remains constrained. Key limitations include inconsistent application of LCA methodologies, limited disclosure of Scope 3 emissions, data availability and reliability issues, and a lack of standardisation across reporting practices. Based on these insights, the study offers practical recommendations for improving the robustness and comparability of LCA-based disclosures, enhancing transparency, and strengthening the role of LCA as a strategic tool for advancing corporate sustainability and climate mitigation efforts.

Keywords: Carbon Disclosure, Life-Cycle Assessment, Sustainability Reporting, Secondary Data Analysis, Environmental Transparency

Introduction

Life cycle assessment (LCA) is a framework for quantifying resource inputs, outputs, emissions, and environmental impacts throughout a product system's life cycle, or "from cradle to grave" (Klöpffer and Grahl 2014). It is a tool used to assess environmental aspects by measuring the resources used and potential impacts correlated to products or processes throughout the life cycle (Yeo, Chopra, Zhang, & An, 2019) (Bartolozzi, Rizzi, & Frey, 2013), based on ISO 14,040 and 14,044 standards (International Organization for Standardization [ISO], 2006). The key objective is to characterize and assess environmental inputs and outputs from all life cycle activities, conduct multi-criteria impact assessments, and support recommendations/decision making. LCA's holistic approach enables its use at regulatory, industry, and consumer levels (Bjørn et al. 2018a, Owsianiak et al. 2018, Jegen 2024).

This study investigates how multinational corporations integrate LCA into carbon disclosure, drawing exclusively on secondary data from sustainability reports, CDP submissions, and GRI reports. The research addresses three questions: 1. How do service market incorporate LCA into carbon disclosure practices across the globe? 2. What trends, gaps, and challenges exist in the adoption of LCA for corporate reporting? 3. How can LCA integration enhance transparency, decision-making, and sustainability outcomes?

By analyzing publicly available reports, the study highlights patterns of LCA use, assesses the quality and scope of disclosures, and provides insights for managers and policymakers to improve global reporting practices.

Objectives of the Study

The following objectives have been taken into consideration during the course of this study:

- To investigate how service market integrates LCA into their carbon disclosure practices across the globe.
- To identify the trends, gaps & challenges exist in the adoption of LCA for carbon reporting.
- To study how the integration between LCA & Carbon Disclosure enhances transparency, decision-making & sustainability outcomes.

Literature Review

Carbon Disclosure

Sari & Budiasih (2022), utilized the stakeholder theory as well as the legitimacy theory in their study, to examine the carbon disclosure practices taken up by the manufacturing companies listed on the Indonesia Stock Exchange & it was found at the end of the study that carbon emissions reporting practices positively influence the firm value of those listed companies. Bolton et al. (2022) in their study, advocated mandatory carbon disclosures for both publicly listed & privately held companies. The companies are required to report their annual direct greenhouse gases which are measured in Co_2 equivalents.

Life-Cycle Assessment

Kaynak et al. (2025) in their study, advocated on the use of standardized tools as outlined in ISO 14040 to evaluate environmental impacts. Carbon Footprint Analysis was also needed to be used so as to quantify the greenhouse gases emissions. The study in the end, addressed the importance of Life Cycle Assessment (LCA) as well as the Carbon Footprint Analysis (CFA) in the analysis of the impact which a product or process has on the environment in their entire life cycle. Raghav et al. (2025), utilized in their study, the Life Cycle Assessment (LCA) methodology to promote sustainability by assessing the environmental impact which a product or process has when it passes throughout their entire life cycle, i.e., from the extraction of the raw materials to its conversion into first, finished goods and then end of life disposal. The study also recognized the use of various technologies based on Artificial Intelligence, Internet of Things (IOT) to enhance sustainable manufacturing practices which later on leads to the development of circular economy models.

Integration of LCA and Carbon Disclosure

Truant et al. (2024), studied the integration of Life Cycle Assessment Strategies into Carbon Accounting and sustainability disclosures by conducting a systematic literature review of 78 scholarly articles. This research revealed that LCA can be effectively integrated into carbon accounting & also there has been differences in the carbon emissions & policies across various nations & industries. Asif et al. (2022), identified & evaluated the critical hotspots in the supply chains of Walmart regarding Scope 3 emissions & its reduction using the life cycle assessment approach. Findings revealed that with the continuous use of these assessment techniques, Walmart has reduced their emissions by 10%.

Research Methodology

Research Design

This study employs a qualitative secondary data analysis approach in which sustainability reports from the official websites of various MNCs as well as the ones made available by international finance institutions. The green finance taxonomies were also studied from different regions (Europe, North America, Asia, and Latin America) were also analyzed.

Data Collection & Analysis

Sustainability reports were sourced from various corporate websites. Reports, published within the last two years, i.e., 2023-24 & 2024-25, which explicitly mentioned carbon disclosure practices as well as LCA methodologies were also used for the purpose of the study. Overall, a total of 25-30 reports were collected to fulfill the objectives of the study. These reports were assessed & discussed in a significant manner on the basis of themes involving LCA adoption & the different facets of carbon disclosure practices, i.e., the Scope 1, 2 & 3.

Findings

As per the Life Cycle Assessment (LCA) insights provided by the various sustainability reports, the market size is expected to reach USD 2.5 Billion by 2033 at a CAGR of 9.1% from 2026 to 2033. This service market has experienced robust growth in recent years. These market insights have helped businesses in the identification & optimization of resources which in turn, helps in the formulation & execution of effective carbon footprint management strategies.

Life Cycle Assessment Service Market Segmentation

The service type involving LCA focuses completely on comprehensive & material environmental & economic evaluations related to eco-friendly products & processes. This complete assessment enables the stakeholders to optimize their sustainability initiatives, reduce carbon emissions & enhances cost management strategies. **This service type involves various types of assessment, which have been explained below:**

1. **Cradle to Grave Assessment:** The type of assessment which evaluates environmental impacts on every stage in the product life-cycle, i.e., from raw material extraction to its disposal. Such initiatives are made which reduces carbon emissions on every stage up to 30%.
2. **Cradle to Gate Assessment:** It focuses on the environmental effects which a particular product has, from raw material extraction to factory gate. This assessment doesn't give space to the disposal phase. This service segment accounts for near about 40-50% of total product life-cycle.
3. **Life-Cycle Inventory Analysis:** It helps in the quantification of inputs & outputs that are involved in the production process.
4. **Life-Cycle Impact Assessment:** It translates inventory data into various impact categories that have been provided by various sustainability related frameworks.
5. **Life-Cycle Costing:** It evaluates the total economic cost related to a product's life-cycle which helps in the reduction of end-of-life management costs.

Life Cycle Assessment Service Market Integration on Regional Level

The Life Cycle Assessment Service Market is projected to witness significant growth from certain years, which are 2026 to 2033, in which the North American region holds the largest market share. The reasons behind this trend are that there have been advanced environmental regulations & the sustainable practices have been adopted on a widespread level. Asia-Pacific emerges as the fastest-growing region, driven by rapid industrialization, increased environmental awareness, and government initiatives promoting green technologies. Meanwhile, Latin America stood out in this dimension as an emerging market, backed by growing investments in sustainable development & related practices. There has also been rise in demand for Life Cycle Assessment (LCA) services in agriculture and manufacturing sectors. Revenue and volume growth across these regions highlight the increasing global emphasis on comprehensive environmental impact assessments throughout product life cycles (www.verifiedmarketreports.com).

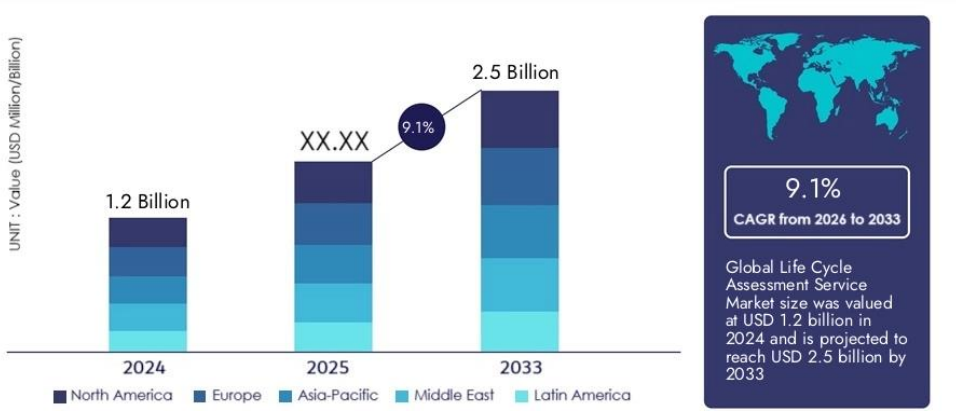

Fig. 1 *Source: www.verifiedmarketreports.com*

Europe Life Cycle Assessment Service Market Integration

The overall LCA market in Europe is expected to reach a projected revenue of US$ 428.7 million by 2030 & CAGR is expected to be 14.5% from 2025 to 2030. The fastest growing segment during the said duration is said to be of services (www.grandviewresearch.com).

Asia-Pacific Life Cycle Assessment Service Market Integration

The Asia-Pacific LCA market is supposed to achieve a significant growth of 14.8% CAGR during the tentative duration of 2025-2032. The Chinese market will continue to be a dominant market & achieve a market value of $187.3 million by 2032. In terms of CAGR, Japan will register a growth rate of 14.1% during the said duration whereas the Indian Market will register a growth rate of 15.6% (www.giiresearch.com).

Middle East & Africa Life Cycle Assessment Service Market Integration

The Latin American, Middle Eastern & African LCA Market, also known as the LAMEA LCA Market, is expected to witness a growth rate of 15.7% CAGR during the considered timeline of 2025-2032. In this market, Brazil emerged as a dominant market & will continue to do so until 2032 with a market value of $43.7 million. In terms of the CAGR, Argentina will witness a growth rate of 17.4% during the expected duration whereas the UAE market will register a CAGR of 14.5% (LAMEA Life Cycle Assessment Market Size & Competitors).
This was the overall Life Cycle Assessment Service Market Integration on Regional Level.

Discussion

Trends in LCA Adoption across global standards

Standard/ Guidance	Use in Carbon Reporting	Publisher
GHG Protocol- Product Life-Cycle Accounting & Reporting Standard	It guides how integrating LCA/product life-cycle approaches with corporate carbon disclosure practices, specifically targeting products & supply chain.	**GHG Protocol**
ISO 14040/ ISO 14044 (LCA principles & requirements)	It provides foundational standards for all life-cycle assessment models & provides basis for allocation as well as calculation.	**ISO standards**
ISO 14067	The ISO 14067 is an international standard that defines the requirements necessary for companies to qualify the carbon footprint of their products (Greenly, 2024).	**ISO 14067**
IPCC 2019 Refinement to 2006 IPCC Guidelines	It provides National Inventory Guidance, which is used for enabling consistency in national GHG inventories.	**IPCC 2019 Refinement**
UNEP Life Cycle Initiative	For providing harmonization & consistency in LCA data, it provides LCI datasets & fosters initiative.	**UNEP Life Cycle Initiative**
SBTi/ Science-based guidance	It increasingly expects inclusion of Scope 3 emissions while setting targets.	**SBTi standards & guidance**

Table 1: Trends in LCA Adoption

Patterns of LCA Adoption & Usage

LCA Adoption has been increasing as evident by the trends discussed above, particularly in those companies which follow consistent carbon disclosure practices. In such companies, complete assessment & disclosure of carbon emissions is still hanging somewhere in its initial phase due to data, time & resource constraints. Meanwhile, the LCA is still stuck in product-level assessments rather than full value chain analyses. This pattern of LCA adoption & usage suggests a gap in formulation as well as their successful execution of such policies.

Gaps & Challenges

The key challenges that hamper the growth & adoption of LCA are:

i. **Data Unavailability:** It has been found in several sustainability reports that Scope 3 emissions haven't been recorded with regularity due to its inherent nature.
ii. **Resource Constraints:** Smaller firms lack the required funding as well as the expertise to perform the different life-cycle boundaries involved in LCA adoption.
iii. **Inconsistent Methodologies:** The standards which have been mandated for LCA adoption are quite different from each other in terms of their usage patterns leading towards inconsistencies in findings & also, the lack of generalizations.
iv. **Verification gaps:** It becomes difficult for the firms to verify their LCA data which ultimately leads to the engagement of third-party auditors.

Implications for stakeholders

The stakeholders like the investors, regulators & the non-profit organizations can benefit from this integration as it will provide them with an opportunity to make informed decisions, enhance performance & encourage sustainable activities in their concerned institution. It will also boost their goodwill or credibility in the market.

Recommendations

i. **Quality of Data:** The quality of data should be enhanced as it is observed that only Scope 1 & 2 is being reported by companies properly with consistency & the companies are still lacking data on Scope 3 emissions which can be due to its complexity.

ii. **Standardization of frameworks:** There have been several frameworks which have been mandated by institutions for LCA adoption as well carbon reporting but these frameworks do not provide a unified stand which makes it less generalizable in nature.
iii. **Proper training & guidance:** For the purpose of ensuring effective LCA adoption, the corporates need to hire professionals that hold expertise as well as experience in the concerned department & it can easily execute adoption strategies.
iv. **Verification:** The LCA data needs to be verified by auditors & third-party professionals consistently.
v. **Strategic Intent & Integration:** The LCA data needs to be properly aligned with carbon emissions data to ensure the formation & execution of effective management strategies.

Conclusion

The integration of life-cycle assessment strategies into corporate carbon disclosure practices has been a very crucial element in enhancing sustainable initiatives within a company, which in turn, increases transparency. While LCA adoption is growing in a significant manner, corporations still lack data on Scope 3 emissions, so it becomes difficult for them to report it & utilize standard methodologies & proper verification strategies. After conducting secondary data analysis of the sustainability reports of companies, it was observed that larger corporations have been leading in fuller life-cycle integration, while smaller firms have been facing resource & time constraints. Enhanced LCA adoption & its integration with carbon disclosure practices, improves the accuracy in emissions reporting & decision-making. It also builds the trust of several stakeholders which ultimately leads to contribution towards global climate mitigation efforts.

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