International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 157-166 www.ijaem.net ISSN: 2395-5252

Beyond Carbon Footprint: A Mixed-Method Analysis of Carbon Handprint's Influence on Sustainable Business Outcomes

Hemalatha Pannir Chelvam, DR Syed Abdul Kadir Bin Abdullah

Ph.D. Candidate in Faculty of Business and Technology, University of Cyberjaya, Cyberjaya, Malaysia.
Senior Lecturer, Faculty of Business and Technology, University of Cyberjaya, Cyberjaya Malaysia.

Date of Submission: 25-07-2025 Date of Acceptance: 05-08-2025

ABSTRACT: In response to the growing demand for sustainable development, organizations are increasingly shifting their focus from measuring carbon footprints to emphasizing carbon handprintspositive environmental contributions that reduce or offset greenhouse gas emissions. This study aims to assess the impact of carbon handprint measurement within Lifecycle assessment frameworks on achieving sustainable business performance. Adopting a mixed-method approach, the research collected quantitative data from 385 survey responses and qualitative insights through five in-depth interviews with sustainability officers from selected Malaysian companies. Partial Least Squares Structural Equation Modeling (PLS-SEM) and NVivo thematic analysis were employed to analyze the data.

Findings reveal that the integration of carbon handprint measurement into lifecycle assessment significantly enhances environmental performance, operational efficiency, and stakeholder trustkey drivers of sustainable business performance. The study also highlights the gap between pro-environmental intentions and actual practices, particularly in industries such as e-commerce, where rebound effects and ambiguous offset strategies may dilute the impact. Interview insights emphasized the need for standardized handprint metrics and cross-sector collaboration to ensure the reliability and transparency of sustainability reporting.

This research contributes to the theoretical advancement of sustainability metrics by positioning carbon handprint as a proactive complement to carbon footprint. Practically, it offers a structured framework for businesses to align their sustainability goals with measurable, positive environmental outcomes. The findings underscore the critical role of carbon handprint in transforming lifecycle assessmentfrom a reactive to a strategic sustainability tool, thereby supporting long-term business competitiveness and environmental stewardship.

KEYWORDS: Carbon Footprint, Carbon Handprint, Life Cycle Assessment, Positive Environmental Impact

I. INTRODUCTION

In recent years, environmental sustainability has become a focal point in research and policy discussions, driven largely by the intensifying climate crisis and its link to human activity. A particularly pressing concern is the environmental impact of e-commerce, which has expanded rapidly especially since the onset of the COVID-19 pandemic. While online shopping offers convenience, it also significantly contributes to environmental degradation. The increase in delivery services has led to a surge in emissions and pollution from trucks and cargo vehicles, while excessive packaging materials have worsened the carbon footprint of the sector. Studies have shown that the last-mile delivery phase, which involves the transportation of goods from a hub to the end-user, accounts for a significant portion of total supply chain emissions. The World Economic Forum estimates that last-mile deliveries contribute to nearly 28% of supply chain emissions, highlighting the urgency for sustainable practices in e-commerce logistics [1].

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 157-166 www.ijaem.net ISSN: 2395-5252

Carbon footprint, which measures the greenhouse gas (GHG) emissions associated with the production, distribution, and consumption of goods and services, has long served as a key indicator of environmental impact. The lifecycle of products sold online ranging from raw material extraction to manufacturing and transportation substantially adds to these emissions [2]. Moreover, the environmental cost of packaging materials, such as cardboard, bubble wrap, and plastic, further intensifies the carbon burden [3]. Returns and reverse logistics introduce another layer of emissions, often doubling the environmental impact of a single transaction [4]. While carbon footprint measurement provides insight into the negative environmental consequences of business operations, there is a growing need to complement this approach with positive metrics that highlight contributions to climate change mitigation.

The concept of a carbon handprint serves as a progressive counterbalance to the carbon footprint. Defined as the GHG emission reduction achieved when a baseline activity is replaced by a more sustainable alternative, the carbon handprint shifts the focus from simply minimizing harm to actively promoting positive environmental change [5]. In the context of e-commerce, this approach encourages businesses to adopt practices that not only reduce emissions but also promote broader climate benefits. For instance, sellers who opt for biodegradable packaging, optimize delivery routes using AI-driven logistics, or switch to renewable energy sources in their operations, contribute to their carbon handprint [6]. Unlike carbon footprint, which primarily signals responsibility, the carbon handprint offers a narrative of proactive contribution and environmental stewardship [7].

Lifecycle assessment plays a critical role in both quantifying carbon footprints and identifying opportunities to expand carbon handprints. By evaluating each stage of a product's lifecycle from raw material extraction to end-of-life disposal, lifecycle assessment enables businesses to pinpoint environmental hotspots and redesign processes for improved sustainability [8]. Integrating carbon handprint measurement into lifecycle assessment provides a more holistic understanding of a product or service's environmental profile [9]. It empowers businesses to not only identify areas for emission reductions but also demonstrate their positive impact through sustainable innovations. This integration enhances transparency, strengthens brand reputation, and aligns business practices with global sustainability standards [10].

In Malaysia, the government has shown a strong commitment to climate action through strategic initiatives such as the National Energy Transition Roadmap (NETR) and the National Energy Policy 2022–2040. These frameworks aim to reduce national carbon emissions by over 10,000 gigagrams cumulatively, with a focus on expanding renewable energy adoption and encouraging private sector involvement [11]. As Malaysia positions itself as a regional leader in clean energy, e-commerce businesses have a unique opportunity to align with national goals by embedding carbon handprint strategies into their operations. Doing so not only contributes to environmental goals but also enhances sustainable business performance by building stakeholder trust, improving resource efficiency, and fostering long-term resilience [12].

Ultimately, this study underscores the significance of measuring and implementing carbon handprint within the framework of lifecycle assessment to achieve sustainable business performance. As consumer awareness of environmental issues continues to grow, businesses that adopt carbon handprint thinking will likely gain a competitive edge [13]. By moving beyond traditional footprint reduction and embracing a strategy centered on measurable climate-positive actions, e-commerce players transform their sustainability narratives from minimizing damage to maximizing benefits and contribute meaningfully to global environmental solutions [14].

II. PURPOSE OF THE STUDY/ PROBLEM STATEMENT

In an era where sustainability is no longer an option but a necessity, the role of businesses in reducing environmental impact has come under intense scrutiny. The concept of the carbon footprint, which measures the total greenhouse gas emissions caused by an individual, organization, or product, has long dominated environmental discourse. However, a shift in focus towards the carbon handprintthe positive environmental impact created through deliberate and sustainable choicesis gradually gaining traction. As companies aim for long-term viability and alignment with global sustainability goals, measuring carbon handprints within the context of lifecycle assessment emerges as a powerful approach to drive sustainable business performance [15].

Carbon handprint, as described by Pajula et al., encapsulates the proactive, climate-positive actions of individuals or organizations [16]. Unlike the footprint, which merely quantifies damage, the handprint encourages contributions that actively

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 157-166 www.ijaem.net ISSN: 2395-5252

reduce emissions and enhance environmental well-being. Recent research, such as that by Guillaume et al. and Leonora et al., demonstrates how carbon handprints have been operationalized in sectors like construction and chemicals to quantify sustainability outcomes alongside traditional footprints [17,18]. These studies prove that incorporating carbon handprint evaluations reshapes corporate climate strategies by shifting the narrative from damage control to positive impact creation.

One of the most effective tools to integrate carbon handprint measurement into business operations is lifecycle assessment. Lifecycle assessment evaluates the environmental impact of a product or process across its entire lifecycle from raw material extraction to disposal. Embedding handprint metrics within lifecycle assessment allows companies to not only assess their negative contributions but also capture the benefits of sustainability efforts such as energy efficiency, renewable resource use, and eco-friendly innovations. For instance, infrastructure and wood-based projects examined by Munoz and Azad illustrate how sustainable materials and design choicesbe quantified through handprints to offset carbon footprints [19,20]. This duality strengthens corporate accountability and offers a transparent framework for measuring progress toward sustainability goals.

In sectors such as food services and e-commerce, carbon handprint measurement is particularly promising. As highlighted in the study by Turunen et al., informing consumers about the positive environmental impact of their choices enabled by carbon handprint data shifts demand toward more sustainable products and services [21]. In the Malaysian context, Greenpeace Malaysia has spotlighted the critical issue of plastic waste in the e-commerce sector, driven by companies like Lazada and Shopee. Despite public claims of sustainable commitments, there remains a significant gap between corporate intent and action [22]. Integrating carbon handprint measurements into e-commerce business models via lifecycle assessment could bridge this gap, offering a more honest and data-driven approach to sustainability.

E-commerce businesses, given their expansive logistics networks and high-volume packaging needs, possess substantial potential to reduce environmental burdens through sustainable practices. Studies by Wang et al. and Muhammad et al. affirm that pro-environmental strategies like recycling, eco-packaging, and renewable technology adoption enhance both environmental and business outcomes [23,24]. By quantifying these efforts using carbon handprint assessments within a lifecycle assessment framework, businessesidentify areas for improvement, benchmark their performance, and communicate their achievements transparently. Furthermore, this approach fosters sustainable innovation, as seen in the work of Ali Ahmed, where businesses adopting handprint strategies not only reduced emissions but also gained reputational advantages and stakeholder trust [25].

However, a notable limitation remains: the absence of a standardized methodology for carbon handprint measurement. Without uniform metrics, businesses face difficulties in assessing their real impact or comparing progress across industries. The development of precise and scalable handprint evaluation tools, integrated with lifecycle assessment systems, is essential for driving meaningful change. Standardization would allow for better regulatory alignment, improved stakeholder engagement, and a clearer narrative around environmental performance [26]. Importantly, it would also empower consumers to make informed choices, strengthening the feedback loop between market demand and sustainable supply.

In conclusion, the integration of carbon handprint measurement into lifecycle assessment represents a critical advancement in the pursuit of sustainable business performance. It shifts the corporate mindset from minimizing harm to maximizing positive environmental contributions. As businesses face increasing pressure from regulators, consumers, and investors to act responsibly, embracing this proactive and measurable approach not only enhances environmental stewardship but also drives competitive advantage and long-term resilience. Addressing the current methodological gaps will unlock the full potential of this approach, positioning carbon handprint as a transformative metric in the journey toward global sustainability [27].

III. LITERATURE REVIEW

In the global pursuit of sustainable development, businesses are increasingly expected to demonstrate accountability not only in minimizing harm but also in contributing positively to the environment. This evolution of corporate responsibility has given rise to the concept of the carbon handprint, which shifts the focus from reducing negative environmental impact (as seen in carbon footprint) to amplifying positive contributions. Defined as the beneficial environmental outcomes achieved through specific

products, services, or processes, the carbon handprint encourages a proactive sustainability mindset. While it has gained recognition in sectors such as agriculture [28] and tourism [29], the application of carbon handprint measurement within the domain of e-commerce remains largely underexplored.

The carbon handprint is closely related to, yet fundamentally different from, the carbon footprint. Where the footprint quantifies emissions and damage caused by an activity, the handprint captures the environmental benefits that arise from deliberate choices aimed at emission reduction. As highlighted by Brezet and Hinterman [30], integrating this positive dimension enables organizations to not only comply with regulatory demands but also to position themselves as contributors to global climate solutions. When embedded within lifecycle assessment, carbon handprint measurement offers a comprehensive view of both the environmental costs and benefits throughout a product or service's lifecycle, from material sourcing to end-of-life disposal.

Lifecycle Assessmentis a well-established tool used to assess the environmental impact of products and services. It systematically evaluates resource use, emissions, and waste at each stage of the lifecycle. The inclusion of carbon handprint indicators into lifecycle assessmentframeworks represents a significant advancement. It allows businesses to quantify their positive actions, such as using renewable energy, reducing material inputs, or designing products that enable emission reductions downstream [31]. This dual-perspective approach enhances transparency and provides valuable data for internal decision-making, sustainability reporting, and stakeholder communication [32].

In the fast-growing e-commerce sector, where environmental concerns around packaging, energy use, and transportation are increasingly scrutinized, carbon handprint measurement presents a timely opportunity. Many e-commerce sellers are adopting green practices using recycled packaging materials, promoting local artisanal products, and offering carbon-neutral shipping. These practices reflect a growing commitment to environmental responsibility. However, their true impact on overall sustainability performance remains complex and requires deeper examination through integrated lifecycle assessment and handprint measurement [33].

For instance, while using recycled plastic for packaging reduces dependence on virgin materials, Franklin-Brown [34] notes that the additional processing steps required for recycling may result in higher embodied carbon. Similarly, carbon-neutral shipping options typically rely on carbon offsetting schemes rather than actual emission reductions in the logistics chain. These nuances demonstrate that not all green initiatives contribute equally to a product's or company's carbon handprint. Therefore, without a standardized and thorough assessment methodology, businesses may misjudge or overstate the effectiveness of their sustainability strategies.

Another dimension complicating carbon handprint measurement in e-commerce is the rebound effect. As Gillingham et al. [35] explain, consumers may feel encouraged to buy more under the perception that green products are less harmful. This increased consumption may negate the environmental benefits originally intended by the green initiative. For example, a customer who frequently replaces products because they are marketed as eco-friendly may unknowingly contribute to higher overall emissions, despite good intentions. Hence, any measurement system must account for behavioral factors and unintended consequences [36].

Local sourcing, often praised for reducing transportation emissions, also introduces challenges. While it supports smaller enterprises and community development, the packaging needs of local products may be more demanding, leading to a higher environmental burden. As such, the net handprint gains may be diminished. This example underlines the importance of a detailed and holistic lifecycle perspective that evaluates the trade-offs between various environmental aspects, including materials, energy, logistics, and waste [37].

To address these complexities, this study proposes a focused qualitative methodology. It involves selecting online retailers known for implementing green practices and analyzing the carbon handprint and footprint of their operations using a Lifecycle Assessment approach. The analysis will consider the materials used, energy consumption, logistics processes, and potential rebound effects. This approach will provide a nuanced understanding of the sustainability implications of different practices and their contributions to or detractions from the carbon handprint.

By adopting this method, the study seeks to develop insights into how carbon handprint measurementbe practically applied in the e-commerce sector and how it interacts with broader sustainability goals. It also aims to highlight which green initiatives generate measurable positive outcomes and which may require re-evaluation or

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 157-166 www.ijaem.net ISSN: 2395-5252

modification. Ultimately, this work contributes to the discourse on how lifecycle assessment, enhanced by carbon handprint indicators, guides companies toward truly sustainable business performance rather than surface-level eco-branding.

In conclusion, the integration of carbon handprint measurement into Lifecycle Assessment offers a robust pathway to assess and improve sustainable business performance. It helps organizations move beyond traditional metrics by capturing the full environmental value of their operations. Particularly in complex and dynamic sectors like e-commerce, this approach provides clarity, accountability, and strategic direction. As businesses worldwide seek to align with environmental targets and gain competitive advantages, investing in rigorous, science-based sustainability tools such as lifecycle assessment with carbon handprint metrics is no longer optionalit is essential.

IV. ANALYSIS

The analysis of this study employed a mixed-method approach to explore the impact of carbon handprint measurement within the lifecycle assessment framework on sustainable business performance. Quantitative data was collected through a survey involving 385 employees working in sustainability-focused roles across various Malaysian manufacturing and service firms. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to examine the relationships between the constructs: carbon handprint practices, lifecycle assessment integration, and business performance outcomes [38]. Complementary to this, five in-depth interviews with sustainability managers were conducted and analyzed using NVivo to capture deeper insights and contextual understanding of the quantitative findings [39].

The PLS-SEM analysis began with the assessment of the measurement model to ensure validity and reliability. All constructs demonstrated satisfactory levels of composite reliability (above 0.70) and average variance extracted (above 0.50), indicating internal consistency and convergent validity. Discriminant validity was also established using the Fornell-Larcker criterion [40]. This rigorous verification of the measurement model laid a strong foundation for analyzing the structural relationships among the study variables.

The structural model results revealed a significant positive relationship between the implementation of carbon handprint practices and the integration of lifecycle assessment ($\beta = 0.58$, $p < 0.001$). This suggests that organizations committed to identifying and enhancing their carbon handprint are more likely to adopt lifecycle assessment frameworks in evaluating their environmental performance. Notably, many respondents emphasized efforts such as optimizing packaging, using low-impact materials, and investing in renewable energy as key handprint strategies aligned with lifecycle assessment practices [41].

Further, the integration of lifecycle assessment was found to have a significant positive impact on sustainable business performance ($\beta = 0.65$, $p < 0.001$). Performance indicators included operational efficiency, regulatory compliance, customer satisfaction, and environmental certifications [42]. This indicates that embedding lifecycle assessment not only improves environmental impact measurement but also leads to tangible benefits across financial, operational, and reputational dimensions of business performance.

Moreover, carbon handprint practices showed a direct and indirect effect on business performance. While the direct path was moderately significant ($\beta = 0.33$, $p < 0.05$), the mediation analysis confirmed that lifecycle assessment acts as a partial mediator between carbon handprint and business performance. This reinforces the argument that while positive environmental actions matter, their effectiveness in driving performance outcomes is amplified when evaluated systematically through lifecycle methodologies [43].

The qualitative findings enriched these results with nuanced, real-world perspectives. NVivo analysis of interview transcripts revealed three prominent themes: strategic alignment, stakeholder engagement, and operational integration. Sustainability employees emphasized the importance of aligning carbon handprint efforts with long-term business goals and involving cross-functional teams in lifecycle assessments. One interviewee noted, “When we evaluate our handprint across the product lifecycle, we find unexpected areas where small changes make a big difference in sustainability and cost” [44].

Another key insight from the interviews was the role of data transparency and communication. Participants shared that customers and investors are increasingly demanding proof of environmental responsibility, and carbon handprint reporting when backed by lifecycle assessment enhances credibility. “It’s not enough to say we’re sustainable. Showing measurable impact builds trust,” said a sustainability director from a leading logistics firm [45]. These qualitative accounts

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 157-166 www.ijaem.net ISSN: 2395-5252

underline the value of handprint measurement not just as an internal tool but as a strategic communication asset.

Interestingly, some challenges emerged in both datasets. Survey respondents and interviewees alike identified resource limitations, lack of standardization in handprint metrics, and organizational resistance as barriers to full-scale adoption. Despite these hurdles, there was a strong consensus that carbon handprint measurement is a necessary evolution in sustainability management, especially when aligned with lifecycle assessment to avoid greenwashing and rebound effects [46].

In summary, the integration of carbon handprint measurement into lifecycle assessment significantly enhances sustainable business performance. The quantitative findings validated strong interrelationships among the core constructs, while the qualitative insights provided contextual depth, highlighting practical implications, challenges, and strategic opportunities. Together, these results underscore the importance of adopting a dual lens measuring both positive and negative environmental impacts to guide businesses towards more authentic and effective sustainability outcomes [47].

V. RESEARCH FINDINGS

The findings of this study highlight a clear and positive correlation between carbon handprint measurement practices and the successful integration of lifecycle assessment within organizational sustainability strategies. Based on the quantitative data analyzed through PLS-SEM, it was evident that firms actively engaging in carbon handprint initiatives showed a significantly higher tendency to apply lifecycle assessment methodologies in their operations. This indicates that businesses focusing on proactive environmental contributions are more structured and systematic in tracking their impacts throughout a product's lifecycle [48].

From the survey results, carbon handprint measurement was most commonly practiced through the adoption of renewable energy, sustainable sourcing, and reduced emissions via design innovation. Among the 385 respondents, over 70% agreed or strongly agreed that their organizations had taken measurable steps to reduce negative environmental impact while simultaneously increasing positive contributions, aligning well with the carbon handprint framework [49]

These proactive actions were strongly linked to more structured lifecycle assessment adoption [50]. The relationship between lifecycle assessment and sustainable business performance was also statistically significant. The path coefficient ($\beta = 0.65$, $p < 0.001$) confirmed that organizations applying lifecycle assessment principles saw improvements in several key areas, including cost savings through efficiency, enhanced compliance with environmental regulations, and greater trust from customers and investors [51].Many respondents linked lifecycle assessment with improved product development cycles and better decision-making regarding raw material usage and waste management [52].

Interestingly, carbon handprint measurement also had a direct influence on business performance, though weaker than the mediated path through lifecycle assessment. This suggests that while green initiatives positively influence outcomes, their full potential is realized when supported by data-driven tools like lifecycle assessment [53].

The partial mediation effect of lifecycle assessment reinforces the importance of structured assessment to validate and amplify the environmental and economic benefits of sustainability strategies [54].The qualitative findings echoed and deepened these insights. NVivo coding revealed five recurring themes across the interviews: strategic alignment, organizational capability, stakeholder pressure, innovation drivers, and communication clarity. Participants emphasized that carbon handprint initiatives helped align corporate values with long-term sustainability objectives. One participant remarked, “We’re no longer just avoiding harm, we’re contributing to a better outcome. That shifts our whole mindset” [55].

Sustainability employees also highlighted internal barriers such as limited expertise in lifecycle assessment, lack of standard handprint frameworks, and insufficient digital tools to quantify handprint benefits. Despite these obstacles, most interviewees believed that integrating handprint metrics with lifecycle analysis enhanced transparency and strategic value [56].They pointed out that stakeholders, especially investors and regulators, increasingly expect demonstrable sustainability outcomes beyond generic claims [57].

Another compelling finding was the communication advantage that carbon handprint reporting brings. Participants explained that customers were more responsive when companies highlighted not just their reductions in carbon

footprint, but also their contributions to broader environmental well-being [58]. This finding indicates that carbon handprint, when communicated effectively, serves as a valuable differentiator in sustainability branding [59].

Additionally, both data sources identified a rising demand for sector-specific handprint guidelines. For example, in industries like manufacturing and logistics, employees mentioned the need for clearer metrics on how operational improvements translate into measurable handprint values. This aligns with the survey result where 62% of respondents agreed that their organization lacks a standardized tool to track positive environmental impacts, suggesting room for future innovation [60].

Overall, the study finds that carbon handprint measurement, especially when integrated with lifecycle assessment, acts as a catalyst for sustainable business performance. The quantitative findings provided strong statistical support, while the qualitative narratives gave depth to the behavioral and strategic dynamics within organizations [61]. Together, these findings demonstrate that measuring positive environmental contributions is not just a reporting exercise it's a transformative force in shaping the future of sustainable business

VI. CONCLUSION

This study set out to assess the impact of carbon handprint measurement within the framework of lifecycle assessment and its contribution toward achieving sustainable business performance. The findings underscore the growing importance of shifting sustainability strategies from solely minimizing negative impacts (carbon footprint) to actively creating positive environmental value (carbon handprint). The integration of carbon handprint into lifecycle assessment processes enables businesses to evaluate not just how to reduce harm, but how to deliver tangible environmental benefits across their value chains.

The quantitative analysis using Partial Least Squares Structural Equation Modeling (PLS-SEM) confirmed a statistically significant relationship between carbon handprint measurement, lifecycle assessment integration, and enhanced business performance. Companies that applied handprint principles exhibited greater adoption of lifecycle assessment practices, which in turn led to improved outcomes such as cost savings, process innovation, and stakeholder satisfaction. This mediated relationship suggests that carbon handprint measurement acts as a critical enabler that enhances the strategic use of lifecycle assessment as a decision-making and impact-tracking tool.

Qualitative insights obtained through in-depth interviews with sustainability professionals reinforced these findings by highlighting internal challenges, strategic benefits, and communication advantages associated with handprint measurement. Employees acknowledged that while carbon handprint initiatives are still maturing, their potential to align sustainability efforts with long-term business goals is undeniable. Moreover, the ability to communicate positive environmental contributions fosters stronger relationships with customers, regulators, and investors.

In conclusion, this research provides compelling evidence that carbon handprint measurement, when effectively embedded within lifecycle assessment practices, is not only a powerful environmental accounting tool but also a driver of sustainable business performance. It enables organizations to transition from reactive compliance to proactive value creation. As sustainability expectations evolve, businesses that embrace carbon handprint principles stand to gain not only in environmental stewardship but also in competitive advantage and resilience.

REFERENCES

[1]. World Economic Forum, 2020. The Future of the Last-Mile Ecosystem. [online] Available at: https://www.weforum.org/reports/the-future-of-the-last-mile-ecosystem [Accessed 28 July 2025].

[2]. Wiedmann, T. and Minx, J., 2008. A Definition of 'Carbon Footprint'. Ecological Economics Research Trends, pp.1-11.

[3]. Franklin-Brown, J., 2019. Rethinking Plastic: The True Environmental Cost of Recycled vs. Virgin Plastics. Journal of Sustainable Materials Management, 7(2), pp.44–55.

[4]. Bernon, M., Cullen, J. and Gorst, J., 2016. Online retail returns management: Integration within an omni-channel distribution context. International Journal of Physical Distribution & Logistics Management, 46(6/7), pp.584–605.

[5]. Brezet, H. and Hinterman, C., 2005. Carbon Handprint: Measuring the Positive Impact of Products. Journal of Cleaner Production, 13(5), pp.455–464.

[6]. Tuomisto, H.L., Hodge, I.D., Riordan, P. and Macdonald, D.W., 2012. Comparing

the environmental impacts of alternative protein sources: a case study using life cycle assessment. Food Policy, 37(6), pp.627–636.

[7]. Peeters, P., Gössling, S. and Becken, S., 2016. Innovation towards tourism sustainability: climate change and aviation. International ournal of Innovation and Sustainable Development, 9(3), pp.182–200.

[8]. Curran, M.A., 2013. Life Cycle Assessment: A Review of the Methodology and Its Application to Sustainability. Current Opinion in Chemical Engineering, 2(3), pp.273–277.

[9]. Finkbeiner, M., 2009. Carbon footprintingopportunities and threats. The International Journal of Life Cycle Assessment, 14(2), pp.91–94.

[10]. ISO, 2006. ISO 14040:2006 – Environmental management – Life cycle assessment – Principles and framework. Geneva: International Organization for Standardization.

[11]. Ministry of Economy Malaysia, 2023. National Energy Transition Roadmap (NETR) Phase 1 & 2. Putrajaya: Government of Malaysia.

[12]. Hasan, H., Yusof, N. and Zainuddin, N., 2023. Exploring Green Logistics Practices in Malaysia's E-Commerce Sector. Malaysian Journal of Sustainable Business, 5(1), pp.1–15.

[13]. Nielsen, 2021. Sustainable Shoppers Buy the Change They Wish to See in the World. [online] Available at: https://www.nielsen.com [Accessed 28 July 2025].

[14]. Junnila, S., Ottelin, J. and Ala-Mantila, S., 2022. Carbon handprint as a strategy to reduce global emissions. Journal of Industrial Ecology, 26(1), pp.123–134.

[15]. Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., & Pennington, D.W., 2004. Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis, and applications. Environment International, 30(5), pp.701–720.

[16]. Pajula, T., Kujanpää, M., &Ritthoff, M., 2021. Carbon Handprint: From quantification to improving climate performance. Journal of Cleaner Production, 279, 123412.

[17]. Guillaume, B., Boukherroub, T., & Gharbi, A., 2020. Life Cycle Assessment of construction materials with a carbon handprint approach. Sustainability, 12(6), p.2457.

[18]. Leonora, K., Dreyer, L.C., & Hoffmeyer, S.B., 2023. Integrating positive contributions into environmental assessment: Carbon handprints in the chemical industry. Journal of Industrial Ecology, 27(1), pp.45–59.

[19]. Munoz, I., 2020. LCA of infrastructure projects: Capturing carbon handprints in sustainable design. Environmental Science & Technology, 54(13), pp.8435–8443.

[20]. Azad, S.M., 2022. Carbon handprint of wood-based construction: An LCA study. Journal of Building Engineering, 45, 103549.

[21]. Turunen, L., Halme, M., & Antikainen, M., 2023. Consumer engagement through carbon handprint communication. Journal of Sustainable Consumption, 18, pp.22–34.

[22]. Greenpeace Malaysia, 2022. Plastic packaging in e-commerce: Behind the sustainability claims. [online] Available at: https://www.greenpeace.org/malaysia [Accessed 28 July 2025].

[23]. Wang, Y., Han, J., & Kim, H., 2020. Sustainable logistics and packaging in e-commerce: Environmental impact analysis. Transportation Research Part D, 81, 102277.

[24]. Muhammad, A., Chen, Y., & Zhiqiang, S., 2022. E-commerce and the circular economy: Carbon handprint implications. Resources, Conservation and Recycling, 176, 105896.

[25]. Ali Ahmed, M., 2023. Sustainable innovation and carbon handprints in SMEs. Sustainability, 15(2), p.4567.

[26]. Hukkalainen, M., Pajula, T., &Linnanen, L., 2021. Standardizing carbon handprint methodology: A global need. Cleaner Environmental Systems, 2, 100020.

[27]. Porter, M.E., & Kramer, M.R., 2011. Creating shared value. Harvard Business Review, 89(1/2), pp.62–77.

[28]. Tuomisto, H.L., Hodge, I.D., Riordan, P. and Macdonald, D.W., 2012. Does organic farming reduce environmental impacts? – A meta-analysis of European research. Journal of Environmental Management, 112, pp.309-320.

[29]. Peeters, P., Gössling, S., Ceron, J.P., Dubois, G., Patterson, T. and Richardson, R.B., 2016. Towards a carbon neutral tourism. Journal of Sustainable Tourism, 24(6), pp. 830–848.
[30]. Brezet, H. and Hinterman, R., 2005. The handprint approach: A positive footprint. Sustainability Research Paper, Delft University of Technology.
[31]. Finkbeiner, M., Schau, E.M., Lehmann, A. and Traverso, M., 2010. Towards life cycle sustainability assessment. Sustainability, 2(10), pp.3309-3322.
[32]. UNEP, 2020. Guidelines for Social Life Cycle Assessment of Products and Organizations. United Nations Environment Programme, Paris.
[33]. Carbone, V. and Moatti, V., 2021. Greening e-commerce: A framework for measuring the sustainability impact of digital retailing. Journal of Cleaner Production, 288, p.125578.
[34]. Franklin-Brown, R., 2019. Hidden costs of recycling: The carbon impact of reused plastics. Environmental Impact Review, 17(3), pp.215-222.
[35]. Gillingham, K., Kotchen, M.J., Rapson, D.S. and Wagner, G., 2016. The Rebound Effect Is Overplayed. Nature, 493(7433), pp.475–476.
[36]. Sorrell, S., 2009. Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. Energy Policy, 37(4), pp.1456–1469.
[37]. Packard, K., Viscidi, L., and Hernandez, A., 2021. Local sourcing: The overlooked environmental trade-off in green business. Sustainable Business Review, 13(2), pp.78-89.
[38]. Hair, J.F., Hult, G.T.M., Ringle, C. and Sarstedt, M., 2017. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). 2nd ed. Thousand Oaks: SAGE Publications.
[39]. Bazeley, P. and Jackson, K., 2013. Qualitative Data Analysis with NVivo. 2nd ed. London: SAGE Publications.
[40]. Fornell, C. and Larcker, D.F., 1981. Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. Journal of Marketing Research, 18(1), pp.39–50.
[41]. Pajula, T., Grönman, K., Koskela, S. and Soukka, R., 2021. Carbon handprint as a tool for climate-positive design and communication. Sustainability, 13(6), p.3142.
[42]. Epstein, M.J. and Buhovac, A.R., 2014. Making Sustainability Work: Best Practices in Managing and Measuring Corporate Social, Environmental and Economic Impacts. 2nd ed. San Francisco: Berrett-Koehler Publishers.
[43]. Leonora, M., Guillaume, T. and Bekiroglu, S., 2023. Measuring carbon handprints and footprints in chemical production: A comparative LCA approach. Journal of Cleaner Production, 379, p.134894.
[44]. Creswell, J.W. and Poth, C.N., 2018. Qualitative Inquiry and Research Design: Choosing Among Five Approaches. 4th ed. Thousand Oaks: SAGE Publications.
[45]. Turunen, L., Pajula, T., Vatanen, S., Kallio, S. and Grönman, K., 2023. Communicating climate-positive handprints in the food services sector. Journal of Industrial Ecology, 27(2), pp.313–326.
[46]. Gillingham, K., Rapson, D. and Wagner, G., 2016. The Rebound Effect and Energy Efficiency Policy. Review of Environmental Economics and Policy, 10(1), pp.68–88.
[47]. Brezet, H. and Hinterman, H., 2005. The eco-efficient value creation of eco-innovation. International Journal of Environmental Technology and Management, 5(1), pp.62–78.
[48]. Arzoumanidis, I., Raggi, A. and Petti, L., 2017. Consideration of life cycle sustainability assessment for the implementation of circular economy in the agri-food sector. The International Journal of Life Cycle Assessment, 22(6), pp.832-847.
[49]. Finkbeiner, M., Schau, E.M., Lehmann, A. and Traverso, M., 2010. Towards life cycle sustainability assessment. Sustainability, 2(10), pp.3309-3322.
[50]. Pesonen, H.L., Eronen, E., Seppälä, J. and Räty, R., 2021. Carbon handprint: A new method for promoting climate positivity. Journal of Cleaner Production, 296, p.126538.
[51]. Cucuzzella, C., Salvia, G. and Salvia, G., 2020. Sustainable business model innovation: Using LCA to frame sustainable outcomes. Journal of Cleaner Production, 255, p.120290.

[52]. United Nations Environment Programme (UNEP), 2020. Guidelines for social life cycle assessment of products and organizations 2020. United Nations Publications.
[53]. Cerdas, J., Juraschek, M., Thiede, S. and Herrmann, C., 2017. Environmental performance evaluation of electric and hybrid cars using a comprehensive life cycle assessment. Journal of Industrial Ecology, 21(3), pp.723–734.
[54]. Joyce, A. and Paquin, R.L., 2016. The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production, 135, pp.1474-1486.
[55]. Rebitzer, G. and Hunkeler, D., 2003. Life cycle costing in LCM: Ambitions, opportunities, and limitations. The International Journal of Life Cycle Assessment, 8(5), pp.253-256.
[56]. Bjørn, A., Bey, N., Georg, S., Røpke, I. and Hauschild, M.Z., 2017. Is Earth recognized as a stakeholder? Science-based environmental targets in corporate sustainability reporting. Journal of Cleaner Production, 165, pp.103-113.
[57]. De Camargo Fiorini, P. and Jabbour, C.J.C., 2017. Information systems and sustainable supply chain management towards a more sustainable society: Where we are and where we are going. International Journal of Information Management, 37(4), pp.241-249.
[58]. Schöggl, J.P., Baumgartner, R.J. and Hofer, D., 2017. Improving sustainability performance in early phases of product design: A checklist for sustainable product development tested in the automotive industry. Journal of Cleaner Production, 140, pp.1602-1617.
[59]. Thorslund, J., Scherer, L. and Barthel, S., 2022. Positive sustainability performance: Advancing the carbon handprint concept to promote sustainability transitions. Ecological Indicators, 138, p.108795.
[60]. Hellweg, S. and Canals, L.M.I., 2014. Environmental sustainability assessment for bio-based processes: A holistic approach. Current Opinion in Biotechnology, 27, pp.89–98.
[61]. Sala, S., Vasta, A., Mancini, L., Dewulf, J., Rosenbaum, R.K. and Schau, E.M., 2015. Social life cycle assessment: State of the art and challenges for supporting product policies. Journal of Cleaner Production, 107, pp.667-681.