


# Chapter 2

## Harnessing Life Cycle Assessment for Sustainable Success in Industry 5.0: Integrating AI and Digital Transformation

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### ABSTRACT

*This chapter discovers the transformative role of Life Cycle Assessment (LCA) in proceeding sustainability within the context of Industry 5.0, stressing its incorporation with artificial intelligence (AI) and digital transformation. Industry 5.0, categorized by human-centric, sustainable innovation, presents new prospects for leveraging LCA to minimize environmental impacts across product lifecycles while nurturing competence and innovation. The synergy between LCA, AI, and technologies, for example, the Internet of Things (IoT) and digital twins, is emphasized, signifying how these tools improve data precision, predictive capabilities, and real-time decision-making. This study underscores the need for collaboration, skill development, and technological advancements by assessing the challenges of LCA adoption, which are complex and costly. Success stories and future trends exemplify the potential of AI-driven LCA in optimizing resource use, reducing emissions, and driving corporate responsibility.*

### INTRODUCTION

Industry 5.0 signifies a standard shift in the industrial landscape, moving beyond the efficiency-driven framework of Industry 4.0 to embrace a human-centric, maintainable, and inclusive method. It highlights the incorporation of innovative technologies such as the Internet of Things, Artificial Intelligence, and robotics while confirming that these innovations contribute positively to human well-being and environmental sustainability. In this situation, Life Cycle Assessment (LCA) is a critical tool to assess and advance the environmental performance of products, procedures, and systems throughout their life cycle. By thoroughly assessing the environmental effects of industrial activities from resource extraction to disposal, LCA provides valued insights supporting the sustainability intentions of Industry

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5.0 (Horvat et al., 2024). In Industry 5.0, the role of LCA ranges beyond conventional environmental valuations. Incorporating LCA with digital transformation technologies such as AI, big data analytics, and blockchain improves its scope and exactness, making it a principal tool for sustainable innovation. For instance, AI algorithms can evaluate vast datasets generated by LCA to uncover patterns and trends that inform eco-friendly design and production strategies. Similarly, IoT-enabled sensors can provide real-time data on resource consumption and emissions, feeding into dynamic LCA models that aid proactive decision-making. These enhancements allow businesses to evaluate their environmental impact more precisely and forecast and prevent possible problems, nurturing a continuous enhancement and sustainability culture (Gamberini & Pluchino, 2024).

## **BACKGROUND**

The transition to Industry 5.0 underlines the significance of integrating technological advancement with ecological balance. Unlike its predecessor, which mainly emphasized automation, data exchange, and cyber-physical systems, Industry 5.0 seeks to correspond these abilities with ethical, environmental, and social necessities. This evolution is driven by increasing awareness of worldwide problems such as climate change, resource depletion, and social inequality. Within this basis, LCA is an initial methodology to evaluate and alleviate the environmental effects of industrial procedures and products. It provides a detailed assessment of material and energy flows, letting firms identify hotspots of environmental degradation and implement strategies to decrease their ecological footprint. By integrating LCA into decision-making processes, firms can align their operations with circularity, resource efficiency, and sustainable development principles (Tariq, 2024). Furthermore, LCA plays a fundamental role in shaping sustainable business practices by offering a transparent framework for evaluating the ecological performance of products and services. This transparency is vital in an era where customers, investors, and regulators demand greater business accountability regarding their sustainability claims. Through LCA, organizations can substantiate their environmental commitments with data-driven evidence, enhancing their credibility and competitiveness in the market. Additionally, LCA informs the development of eco-labels, certifications, and sustainability standards, which are integral to promoting responsible consumption and production patterns. By adopting LCA as a core component of their sustainability strategies, companies can comply with regulatory requirements and position themselves as leaders in transitioning to a greener economy (Tariq, 2025).

The synergy between LCA and Industry 5.0 is further demonstrated by their shared focus on all-inclusive, systems-based thinking. Both models identify the interconnection of industrial procedures and the requirement to address sustainability issues from a lifecycle perspective. For example, LCA assesses the environmental effects of a product across all stages of its life cycle, from raw material abstraction and manufacturing to distribution, use, and end-of-life disposal. This cradle-to-grave method confirms that possible trade-offs and unintentional consequences are recognized and managed efficiently. In the context of Industry 5.0, such detailed evaluations are vital for designing robust and sustainable supply chains, improving resource utilization, and abating waste generation. Furthermore, integrating LCA with digital technologies improves its pertinency and significance in the Industry 5.0 landscape. For instance, blockchain technology can track and authenticate products' environmental performance throughout their life cycle, confirming transparency and responsibility across the value chain. It is specifically vital in industries with complex supply networks, where tracking the environmental footprint of raw materials

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