E-Conom — Online tudományos folyóirat | E-Conom — Online Scientific Journal
Tanulmányok a gazdaság- és társadalomtudományok területéről | Studies on the Economic and Social Sciences
Vol. 14, No. 1, 2025, pp. 149-155
ISSN 2063-644X — DOI: 10.17836/EC.2025.1.008

Industry 4.0 Technologies for Environmental Sustainability – A Book Review

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[Adele Parmentola, Ilaria Tutore: *Industry 4.0 Technologies for Environmental Sustainability*. Springer Cham, 2023 | ISBN 978-3-031-40009-4. | DOI 10.1007/978-3-031-40010-0]

KEYWORDS

- 4.0 (I4.0)
- Digital Technologies
- Environmental Sustainability
- Sustainable Development Goals (SDGs)
- Book Review

ABSTRACT

The book Industry 4.0 Technologies for Environmental Sustainability by Adele Parmentola and Ilaria Tutore (Springer, 2023) analyses the ambivalent effects of digital technologies of the fourth industrial revolution on environmental sustainability. Based on a systematic literature review (SLR) and bibliometric analysis, the authors show that Industry 4.0 (I4.0) technologies such as IoT, big data, blockchain and additive manufacturing can contribute significantly to increased efficiency, resource conservation and transparency. At the same time, potential negative effects, such as high energy consumption or unintended environmental impacts, are addressed. The results are structured along macro, meso, supply chain and micro levels. A key contribution is the case study analysis on the role of blockchain in the context of environmental Sustainability Development Goals (SDGs). The work provides a differentiated, practical contribution to the scientific debate, highlights gaps in research and offers companies impetus for the sustainable use of digital technologies.

JEL-codes: O32, Q01, Q55, M11, L86, Q56

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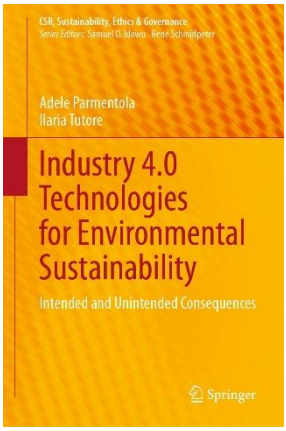
Introduction



Digitalisation in the industrial context, summarised under the term Industry 4.0 (I4.0), is increasingly seen not only as a driver of innovation and efficiency, but also as a potential lever for environmental sustainability. The book Industry 4.0 Technologies for Environmental Sustainability by Adele Parmentola and Ilaria Tutore, published in 2023 in the Springer series CSR, Sustainability, Ethics & Governance systematically focuses on this aspect. It aims to provide companies and researchers with a differentiated understanding of the intended and unintended effects of I4.0 technologies on the environment and sustainability.

Content

The book has 85 pages and is structured into four core chapters, each building on the last to form a coherent framework for analysing the interplay between I4.0 and environmental sustainability.

The first chapter, Environmental Sustainability and Firms' Competitive Advantage, outlines theoretical foundations and key concepts such as the Sustainable Development Goals (SDGs), triple bottom line (TBL), and circular economy (CE). Frameworks like ReSOLVE (Ellen MacArthur Foundation et al., 2015) and 9Rs (Potting et al., 2017) serve as structuring approaches. Orsato's (2006) strategy types are particularly relevant: Eco-efficiency, Beyond Compliance Leadership, Eco-branding, Environmental Cost Leadership. Internal and external drivers of sustainable behaviour, including regulation, stakeholder pressure, and cost factors, are explored. The chapter highlights the role of innovation, especially green and open innovation, as levers for ecological proactivity and competitiveness.

Chapter 2, *Fourth Industrial Revolution and Firms' Digitalisation*, explores Industry 4.0's impact on competitiveness and sustainability. It describes the shift to cyber-physical systems and digital integration across value chains. Key technologies include Big Data, autonomous robots, simulation, IoT, cybersecurity, cloud computing, additive manufacturing, and augmented reality. These enable real-time optimisation and new business models. Ad-

vantages include shorter time-to-market, enhanced services, and SME opportunities. Sustainability aspects span economic (efficiency gains), social (better working conditions, upskilling), and ecological (reduced resource use). However, high energy and material demands of digital infrastructure pose challenges, revealing a double-edged impact.

The third chapter, *I4.0 Technologies Adoption and Environmental Sustainability*, presents a systematic literature review (SLR) and bibliometric analysis. Research on this topic has grown rapidly since 2016. Main themes are categorised into macro (economic), meso (ecosystem), supply chain, and micro (technology application) levels. Most studies emphasise benefits, while unintended consequences of digitalisation – the 'environmental dark side'- remain underexplored.

The final chapter, *Unveiling the Positive and Negative Effects of Blockchain Technologies on Environmental Sustainability in Practice*, investigates blockchain's role through case studies across seven domains, including supply chains, energy, finance, and climate change. Blockchain supports sustainability via transparency, traceability, and decentralised data. It aligns with SDGs such as clean water (SDG 6), renewable energy (SDG 7), and sustainable consumption (SDG 12). However, energy-intensive mining and implementation hurdles are acknowledged as critical drawbacks.

Scientific Classification

The authors, recognized experts in sustainability and digital transformation, employ an SLR and bibliometric analysis to identify research trends and derive robust findings. Noteworthy is the integrative approach combining technological, organizational, and regulatory aspects.

Compared to other titles in Springer's "CSR, Sustainability, Ethics & Governance" series, which tend to emphasize ethical, normative, or strategic CSR perspectives, *Industry 4.0 Technologies for Environmental Sustainability* stands out for its strong focus on digital technologies such as IoT, AI, and blockchain in the context of environmental sustainability. It offers a practical, management-oriented perspective and highlights both the opportunities and potential risks of digitalization, especially for SMEs in the manufacturing sector.

However, the book differs not only from normative CSR literature, but also from other established scientific works such as Stock and Seliger (2016),

who view Industry 4.0 from a more production-technical perspective, or Oláh et al. (2020), who analyse its influence on environmental compatibility, this book stands out for its business-oriented foundation. Likely due to its recent publication, the book has only been cited four times so far. However, this does not diminish its potential relevance.

It connects technological feasibility with corporate strategy and shows how digital innovations can be integrated into strategic sustainability efforts, offering a differentiated analysis and important starting points for further research. Although the TBL concept is acknowledged, the title already suggests the clear focus on ecological aspects. Social and economic dimensions are addressed selectively, primarily in Chapter 2.4. The book mainly highlights the positive environmental effects of digitalization, but potential negative impacts such as rebound effects or indirect burdens are briefly discussed. A deeper examination of systemic limitations (see Allwood & Cullen, 2012; Ness, 2023) would have further enhanced the contribution. Moreover, it remains unclear to what extent digital efficiency improvements yield absolute environmental benefits without structural changes in production and consumption.

Critical Evaluation

Despite its strengths, the book exhibits certain content-related limitations. The presentation often remains focused on technological potential and pays insufficient attention to the political and cultural prerequisites necessary for sustainable transformations. The social dimension of sustainability is mentioned only marginally, although the acceptance of new technologies and changes in consumption and production patterns are crucial success factors.

Furthermore, while the authors do acknowledge risks such as digital lock-in effects, energy-intensive IT infrastructures, and regulatory uncertainties, these issues are not discussed in sufficient depth. A stronger connection to current debates on greenwashing and the systemic tensions between growth, digitalization, and sustainability (see Nygaard & Silkoset, 2023) would have added additional depth and critical perspective to the book.

Applicability in Business Practice

The book offers valuable insights for companies aiming to leverage Industry 4.0 technologies to achieve their sustainability goals. Practical concepts such as the CE, the 'Digital Thread' and the 'Digital Compass' are presented as instruments to make processes more transparent, flexible, and resource efficient. The authors illustrate how companies can use big data and IoT to detect inefficiencies, optimize resource allocation, and integrate sustainability metrics into operational decision-making. These concepts are already being applied in practice, particularly in the automotive industry, which faces growing regulatory requirements alongside ambitious sustainability targets. BMW's iFACTORY strategy, for example, connects all phases of vehicle development and production through digital twins, IoT, and AI-driven real-time data analysis (BMW Group, 2022, 2023). Audi's Smart Production initiative pursues similar goals with end-to-end data integration to make production more agile, efficient, and resource-saving (Audi AG, 2022).

However, the question remains to what extent these approaches are scalable and adaptable for SMEs. While the book addresses this aspect, it does not sufficiently demonstrate empirical evidence or detailed case studies for the SME context. The idea of linking data throughout the entire product life cycle is equally relevant for smaller companies, which could benefit from standardized cloud solutions, IoT applications, and platform technologies to enhance resource use, supply chain traceability, and compliance without requiring complex IT infrastructures. This scalability also applies to other frameworks introduced in the book, such as CE models, the Digital Compass, and blockchain-based transparency tools. Nevertheless, future research should investigate the practical applicability of these models in different industries and company sizes, with particular attention to sector-specific challenges, implementation barriers, and risks like greenwashing.

In this context, future interdisciplinary research should more consistently consider economic and social dimensions in addition to ecological ones to reflect the holistic ambition of the SDGs.

While barriers for SMEs and industry-specific challenges remain underexplored, there is also a lack of empirical, quantitative analyses concerning rebound effects and indirect environmental impacts. Moving beyond theoretical discourse, such studies are essential to assess whether digital efficiency gains translate into absolute environmental improvements or are offset by increased consumption and demand-driven growth.

With the Corporate Sustainability Reporting Directive (CSRD) taking effect in 2024, the discussed transparency approaches gain further relevance, as it is essential for companies to develop credible, long-term sustainability strategies. Research should better align digital transformation strategies with the changing regulatory framework and examine how companies can meet these complex requirements without losing credibility or greenwashing.

Conclusion

The book Industry *4.0 Technologies for Environmental Sustainability* by Adele Parmentola and Ilaria Tutore is a well-founded, systematically structured contribution to the interface between digitalisation and environmental sustainability. By combining theoretical foundations, an SLR and practical case studies, it offers valuable insights for both research and business practice.

The authors provide a comprehensive analysis of the intended and unintended effects of Industry 4.0 technologies and link them thoughtfully to the SDGs.

The book identifies critical research gaps, which include the 'dark side' of digitalisation, such as rebound effects, data ethics concerns, and systemic limits to technological efficiency. Particularly for companies, the book remains an important starting point and provides practical approaches that could guide implementation.

However, both academia and industry are called upon to further empirically and practically resolve the highlighted contradictions between efficiency gains, regulatory compliance, and actual economical, ecological and social effectiveness, as well as the scalability and transferability of concepts like the digital thread, blockchain-based transparency tools, and CE frameworks across industries and company sizes. Only by addressing these questions, the transformative potential of Industry 4.0 technologies for sustainability can be comprehensively assessed.

References

Allwood, J., & Cullen, J. (2012). *Sustainable Materials – With Both Eyes Open*. UIT Cambridge. https://tinyurl.com/5a9enpm9

Audi AG. (2022). *Smart Production: How Audi Is Designing the Production of the Future.* Audi MediaCenter, BlogPost, 07/26/2022, https://tinyurl.com/bdysjtsc

BMW Group. (2022). *BMW iFactory. LEAN. GREEN. DIGITAL. – Master plan for the production of the future.* BMW Group, BlogPost, 29.04.2022, https://tinyurl.com/2f9at3k5

BMW Group. (2023). *So DIGITAL ist die BMW iFACTORY.* BMW Group, BlogPost, *31.05.2023,* https://tinyurl.com/yt6xubd3

Ellen MacArthur Foundation, McKinsey Center for Business and the Environment, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN), & Deutsche Post Foundation. (2015). *Growth within: A circular economy vision for a competitive Europe.* https://tinyurl.com/42vppanm

Ness, D. A. (2023). Technological efficiency limitations to climate mitigation: Why sufficiency is necessary. *Buildings & Cities*, 4(1). https://doi.org/10.5334/bc.297

Nygaard, A., & Silkoset, R. (2023). Sustainable development and greenwashing: How blockchain technology information can empower green consumers. *Business Strategy and the Environment*, 32(6), 3801–3813. https://doi.org/10.1002/bse.3338

Oláh, J., Aburumman, N., Popp, J., Khan, M. A., Haddad, H., & Kitukutha, N. (2020). Impact of Industry 4.0 on Environmental Sustainability. *Sustainability*, 12(11), Article 11. https://doi.org/10.3390/su12114674

Orsato, R. J. (2006). Competitive Environmental Strategies: When Does it Pay to Be Green? *California Management Review*, 48(2), 127–143. https://doi.org/10.2307/41166341

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular Economy: Measuring Innovation in the Product Chain* [Policy Report]. PBL Netherlands Environmental Assessment Agency. https://tinyurl.com/5cze8bme

Stock, T., & Seliger, G. (2016). *Opportunities of Sustainable Manufacturing in Industry 4.0.* 40, 536–541. Scopus. https://doi.org/10.1016/j.procir.2016.01.129

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