

ECO-INNOVATION IN PACKAGING: TRENDS AND CHALLENGES IN THE CIRCULAR ECONOMY

Dominik JEZIERSKI

Kielce University of Technology; djezierski@tu.kielce.pl, ORCID: 0009-0002-6344-4939

Purpose: Amid growing concerns over climate change, resource scarcity and plastic waste, the packaging industry faces mounting pressure to transition towards more sustainable solutions. This paper aims to explore the role of eco-innovation in driving this transformation, with a particular focus on its integration into the circular economy framework.

Design/ methodology/ approach: This study is based on a systematic review of the literature, drawing on peer-reviewed academic publications, industry reports, and policy documents. The analysis focuses on identifying the main trends, challenges and opportunities relating to eco-innovation in the packaging sector, and its links with the principles of the Circular Economy (CE), eco-design and Life Cycle Assessment (LCA).

Findings: The review reveals dynamic growth in eco-innovation initiatives within the packaging industry, driven by regulatory pressure, consumer awareness, and technological advancement. Key areas of innovation include biodegradable and recyclable materials, active and intelligent packaging, and circular business models. However, challenges remain, particularly with regard to implementation, standardisation and cost-effectiveness.

Research limitations/ implications: The scope of this study is limited by its reliance on secondary data and available literature, which may overlook some emerging industry practices. Future research could involve quantitative assessments of eco-innovations, or case studies could be conducted to evaluate their real-world application and effectiveness.

Practical implications: The findings could help packaging companies, designers and policymakers to identify areas for innovation and investment. The study highlights practical ways to implement circular principles in packaging design and materials management.

Social implications: Eco-innovation promotes sustainable packaging solutions that reduce environmental pollution and the depletion of resources. It has the power to influence both consumer behaviour and regulatory frameworks. It also supports broader sustainability goals and corporate responsibility initiatives.

Originality/ value: This article contributes a comprehensive overview of eco-innovation in the packaging industry within the context of the circular economy. It offers value to researchers, practitioners and decision-makers seeking to understand and implement sustainable packaging strategies.

Keywords: eco-innovation, packaging, circular economy, life cycle assessment, eco-design.

Category of the paper: Literature review.

1. Introduction

The world today is facing environmental challenges such as climate change, the depletion of natural resources and a sharp increase in waste, particularly plastic waste. The packaging industry is a major contributor to these problems, generating almost a third of the world's plastic waste (Baranski et al., 2011; Miller, 2022).

In response to mounting environmental challenges, including climate change, the depletion of natural resources and excessive waste production and management, particularly of plastics, the concept of eco-innovation emerged in literature in the early 1990s (Dostatni, Rybaczewska-Błażejowska, 2020). Initially, eco-innovation was primarily viewed as a means of reducing environmental risks, but its definition has since broadened to include wider economic advantages and business competitiveness (Fatma, Haleem, 2023; Kemp, Pearson, 2007). Today, it is defined as a strategic enabler of firms' competitiveness and sustainable development goals (Dostatni, Rybaczewska-Błażejowska, 2020).

The concept of eco-innovation is closely linked to the idea of the circular economy (CE), which involves moving away from the traditional 'take-make-waste' model towards regenerative approaches that prioritise reusing, repairing, renewing and recycling materials and products (Baranski et al., 2011; Padilla-Rivera et al., 2024). Eco-innovations are a key driver of this transformation, with the aim of creating closed packaging circuits and addressing the causes of excessive waste production (Dostatni, Rybaczewska-Błażejowska, 2020). The integration of eco-innovations into global sustainability frameworks, such as the UN Sustainable Development Goals (SDGs), demonstrates a worldwide consensus on environmental priorities (Hollanders, Es-Sadki, 2021; Fatma, Haleem, 2023).

Dynamic developments in packaging eco-innovation, the rapid pace of new regulations (e.g. Extended Producer Responsibility – EPR – legislation), evolving consumer preferences for sustainable products and ongoing technological advances in materials and processes, creates a unique environment for accelerated transformation (Pokharel et al., 2023; Versino et al., 2023; Cordeiro et al., 2025; Ahmed, 2018; Kachook, 2025).

This article aims to conduct a comprehensive and systematic literature review of recent trends and advances in eco-innovation within the packaging industry. It will focus on innovations in materials and eco-design principles, the role of Life Cycle Assessment (LCA) and the challenges and opportunities presented by the CE model.

This article is based on a systematic literature review methodology to identify, analyse and synthesise recent trends in eco-innovation in the packaging industry (NCCMT, 2014; Phillips, Barker, 2021; Duke University, 2025). The review process was designed to be transparent, rigorous and replicable, following standards for developing systematic literature reviews, including PRISMA and PRISMA-S guidelines (NCCMT, 2014).

The review process began with the formulation of the following research question: What are the current developments in eco-innovation in the packaging industry, focusing on material innovation, eco-design principles, life cycle assessment applications, and the challenges and opportunities of the circular economy? A comprehensive scientific literature search strategy was then developed based on this question, involving searching multiple databases such as Web of Science, Scopus and ResearchGate (NCCMT, 2014). Sources of scientific publications, such as the repositories of academic publishers Springer Nature and Elsevier, were also searched. Combinations of keywords and terms from the fields of eco-innovation, sustainable packaging, the CE, LCA and eco-design were used to maximise the coverage and relevance of the results (Page et al., 2021; Rethlefsen et al., 2019). The search was limited to English and Polish publications from 2010 onwards (Pokharel et al., 2023; Versino et al., 2023; Cordeiro et al., 2025; Ahmed, 2018; Kachook, 2025). The reference lists of the included articles were manually reviewed to identify additional studies. The websites of key organisations such as the Sustainable Packaging Coalition,ecoinvent, and the European Commission were also consulted. The search strategy was documented according to the PRISMA-S guidelines (Page et al., 2021; Rethlefsen et al., 2019).

Clear inclusion and exclusion criteria were defined to ensure the consistency and relevance of the included studies. The review included peer-reviewed scientific articles, conference papers and credible reports focusing on eco-innovation in the packaging industry; advances in materials; eco-design principles; the application of LCA or CE; and challenges and opportunities. Studies not directly related to packaging, opinion articles, and duplicates were excluded (NCCMT, 2014; Duke University, 2025). The selection process consisted of two phases: first, titles and abstracts were reviewed to eliminate publications that did not meet the criteria; then, a detailed analysis of the full texts of the remaining publications was conducted. A standardised data collection form was developed to gather information on authors, year of publication, study type, and key eco-innovation findings, as well as advances in materials, eco-design principles, LCA applications, and CE challenges and opportunities. The quality of each study was assessed qualitatively, taking into account methodological rigour and relevance. The data were synthesised narratively to allow recurring themes to be extracted and areas for further research to be identified (NCCMT, 2014).

2. Key areas of eco-innovation in packaging

The concept of eco-innovation is rooted in the broader concept of innovation, first defined by Joseph Schumpeter in 1911 (Drucker, 1992). The term began to permeate environmental research in the mid-1990s (Fussler, James, 1996). Initially, eco-innovation was defined as innovation aimed at reducing environmental damage (Yap et al., 2023; Dostatni, Rybaczevska-

Błażejowska, 2020). Rennings (2000) subsequently expanded this definition to include the introduction of new ideas, products and processes that mitigate negative environmental impacts. Over time, the definition has evolved to become more comprehensive, encompassing the production, assimilation or operation of a product, process, service or business method that is new to the organisation and leads to a reduction in environmental risk throughout the lifecycle (Kemp, Pearson, 2007). The European Commission (2013) defined eco-innovation as any innovation that leads to sustainable development by reducing negative environmental impacts or increasing resource efficiency. More recent approaches emphasise that eco-innovation promotes sustainable economic growth while mitigating environmental impacts, making it a key tool for companies aiming to achieve the Sustainable Development Goals (Fatma, Haleem, 2023). Eco-innovation can be classified in various ways, including product, process, and business eco-innovation (OECD, 2018), as well as marketing, organisational (European Commission, 2009), technological, social, and institutional (Dostatni, Rybaczewska-Błażejowska, 2020). Measuring eco-innovation, especially on a national or regional scale, poses many challenges (Smol et al., 2017). At the macro and meso levels, indicators such as the Global Innovation Index (GII) and the European Innovation Scoreboard (EIS) are employed, whereas the Community Innovation Survey (CIS) and LCA are used at the micro level. The latter is a key tool for measuring eco-efficiency (Dostatni, Rybaczewska-Błażejowska, 2020; Rybaczewska-Błażejowska, 2019).

In the field of environmentally friendly packaging materials, the main focus is on finding alternative sources, primarily from renewable resources (Dostatni, Rybaczewska-Błażejowska, 2020). Plant-based bioplastics are developing rapidly, including biodegradable options such as polylactic acid (PLA), polyhydroxybutyrate (PHB) and polyhydroxyalkanoates (PHA), as well as non-biodegradable bio-polyolefins such as bio-polyethylene (bio-PE), bio-polypropylene (bio-PP) and bio-polyethylene terephthalate (bio-PET). These materials have the potential to reduce our dependence on fossil fuels (Cordeiro et al., 2025; Ahmed, 2018; Miller, 2022). Algae-based bioplastics (Yap et al., 2023) and the use of natural materials such as cellulose and bamboo are also advancing (Kędzia, Turek, 2022). The growing interest in biodegradable packaging that meets compostability criteria is a response to the huge amount of waste that does not undergo natural decomposition processes (Dostatni, Rybaczewska-Błażejowska, 2020; Kędzia, Turek, 2022). However, the adoption of these materials is hindered by high prices, limited functional properties, a lack of regulatory support, insufficient consumer knowledge and inadequate infrastructure for industrial composting (Kędzia, Turek, 2022). The use of recycled materials such as rPET and recycled HDPE is also increasing (Kachook, 2025). Around 84% of total PET recycling is accounted for by mechanical recycling of PET (Sadeghi et al., 2021). There is a strong trend towards fibre-based solutions (paper and cardboard) for different types of packaging. There is also a growing demand for mono-material packaging, which is simpler to collect, sort, and recycle. Significant barriers include challenges in sourcing recycled materials and declining consumer confidence in the recycling system. Extended

Producer Responsibility legislation aims to encourage the use of packaging containing a higher proportion of recycled or renewable materials by introducing eco-modulation fees. Multi-material packaging is difficult to separate, posing a challenge to sustainability and leading to a shift towards mono-material packaging and the emergence of specialised recyclers (Kachook, 2025, Dostatni, Rybaczewska-Błażejowska, 2020).

Eco-design is a key strategy for incorporating environmental considerations into product development, with the aim of reducing greenhouse gas emissions and optimising environmental performance throughout a product's life cycle (Pogačar, Gregor-Svetec, 2025; Wei Lun Lee et al., 2023). Key principles include reducing the use of energy and materials, reusing materials, improving product design, and recycling and recovering energy and raw materials (Dostatni, Rybaczewska-Błażejowska, 2020). In practice, material reduction can be achieved by optimising consumption, eliminating unnecessary printing and employing glueless assembly techniques (Pogačar, Gregor-Svetec, 2025). There is also a growing trend towards reuse and refill systems, particularly in the alcohol and cosmetics sectors (Kachook, 2025). Innovative packaging systems, such as active (AP) and intelligent (IP) packaging, play a pivotal role in eco-design. AP interacts with food to extend its shelf life, while IP provides real-time information about the quality and condition of packaged food. These systems promote sustainability by enhancing food safety, extending shelf life and reducing food waste, which is a significant contributor to greenhouse gas emissions (Pokharel et al., 2023; Hemachandra et al., 2024).

Life cycle assessment is a standardised, quantitative management method in line with the international environmental standards ISO 14040:2006 and ISO 14044:2006. It is used to evaluate the potential environmental impact of products and processes throughout their life cycles (Stramarkou et al., 2022; ISO, 2006). LCA is used to evaluate the environmental performance of products and processes, particularly in packaging (Stramarkou et al., 2022). It can be used to compare materials, identify key environmental factors and evaluate trade-offs (Miller, 2022; Cappiello et al., 2022; Paiano et al., 2021; Wei Lun Lee et al., 2023). LCA is also employed in eco-design and to support green procurement (Wei Lun Lee et al., 2023; Rybaczewska-Błażejowska, 2019). It plays a pivotal role in ecodesign evaluation and material selection, facilitating the identification of environmental critical points and suggesting enhancements throughout the packaging lifecycle (Dostatni, Rybaczewska-Błażejowska, 2020). Adopting a comprehensive approach to environmental impact assessment can help to prevent the transfer of environmental issues (Stramarkou et al., 2022; Wei Lun Lee et al., 2023). However, the reliability of LCA results depends on the specificity of local variables and data availability (Miller, 2022; Jezierski, Rybaczewska-Błażejowska, 2022).

The transition to a CE in the packaging industry poses a number of challenges. These include economic issues such as high investment costs and higher prices for CE products; regulatory issues such as inadequate policies; awareness issues such as a lack of education and consumer reluctance to change; and implementation issues such as difficulties in

implementation (Padilla-Rivera et al., 2024; Kędzia, Turek, 2022). A widespread lack of education and awareness of the CE hinders both consumer demand and manufacturers' ability to provide solutions. The CE is perceived as a challenging theoretical concept to implement in practice. Despite these challenges, however, most stakeholders remain optimistic about the future of the CE. Innovation and technology are seen as key drivers of the CE model, and cross-sector collaboration and investment in research and development are essential. There is a clear opportunity for policymakers to create a more comprehensive regulatory framework that includes business incentives and regulations to ensure sustainability (Padilla-Rivera et al., 2024). EPR schemes incorporating an eco-modulation mechanism can effectively encourage the design of more sustainable packaging by levying fees according to environmental impact (Kachook, 2025).

3. Results

A systematic review of the literature confirms that eco-innovation in the packaging industry is developing rapidly in response to global environmental challenges and the need for a transition to a CE. Table 1 summarises the key characteristics, potential environmental benefits and challenges of implementing eco-innovation in the packaging sector.

Table 1.
Eco-innovation in packaging – key areas, benefits and challenges

Eco-innovation	Characteristics/examples	Environmental benefits	Implementation challenges
Evolution and typology	Extended definitions (economic, competitive). Typologies (product, process, social, institutional). Regional CE indicators.	Integration with the SDGs. Holistic approach. Monitorable transformation	Complexity of measurement. Need for a multidisciplinary approach.
Packaging materials	Bioplastics (PLA, PHB, bio-PE, algae). Recycled materials (rPET, rHDPE). Fibrous solutions. Monomaterials.	Reducing the use of fossil raw materials. Closing the material cycle. Improving recycling efficiency.	High costs. Limited functionality. Lack of infrastructure. Low consumer confidence in recycling.
Eco-design	Optimisation of material consumption. Glueless constructions. Refillable systems. Active and intelligent packaging.	Minimise resource consumption. Extend product life cycle. Reduce food waste.	Complexity of the design process. Need to change consumer behaviour.
Life Cycle Assessment	ISO 14040/ 44 methods. Comparison of material alternatives. Identification of key factors. Avoidance of burden shifting.	Quantitative impact assessment. Support for design decisions. Increasing the precision of environmental analyses.	High dependence on local data. Complexity of analysis. Need for contextual interpretation.

Cont. table 1.

Circular economy	Moving away from a linear model. Investment in technology. Sector cooperation; EPR regulation and eco-modulation.	New business models. Resource efficiency. Promoting sustainability.	High initial costs. Inadequate regulation. Lack of consumer awareness. Implementation difficulties. Social issues.
-------------------------	---	---	--

Source: Own study.

As shown in Table 1, eco-innovation in packaging emerges as a complex and multidimensional process. While innovative solutions offer clear environmental benefits, their practical implementation is frequently hindered by technical, economic, and behavioural barriers. These findings form the basis for the subsequent discussion on how such challenges may be addressed through systemic and cross-sectoral efforts.

4. Discussion

The findings of the literature review indicate that the packaging industry is undergoing a complex and dynamic transformation driven by a shift towards sustainability and the CE. Key trends such as the development of bio-based and recycled materials, eco-design and LCA are closely linked and reinforce each other, indicating systemic change rather than individual developments.

Expanding the definition of eco-innovation to include economic and competitive benefits turns sustainability from an ethical duty into a business goal (Kemp, Pearson, 2007; Fatma, Haleem, 2023). Including social and institutional classifications alongside traditional technological and organisational categories recognises that transitioning to sustainability necessitates systemic behavioural, governance and collaborative changes, as well as technological advances. The increasing complexity and multi-level nature of eco-innovation measurement frameworks, which range from macro-level indicators to micro-level LCA and regional CE economy indicators, reflects the maturation of the field and the need for context-specific data that goes beyond general trends.

In the field of materials, a dual-track development strategy encompassing both ‘drop-in’ bio-based plastics and entirely new biodegradable polymers strikes a pragmatic balance between utilising existing infrastructure and achieving radical circularity (Ahmed, 2018). However, the high cost and limited properties of biodegradable materials, coupled with a lack of infrastructure and consumer awareness, suggest that technological advances in materials must be accompanied by investments in education and infrastructure (Kędzia, Turek, 2022). Rather than expecting a single disruptive innovation, the industry is adopting differentiated material strategies, focusing particularly on monomaterials and fibre-based solutions, which are better suited to the limitations of the current recycling infrastructure. The trend towards fibre-

based solutions and the emphasis on monomaterial packaging directly addresses the challenges associated with recycling multi-material packaging (Kachook, 2025). Simplifying the material composition of packaging makes it easier to sort and process, which is essential for increasing recycling efficiency and closing the material cycle.

Eco-design principles extend beyond material selection to prioritise reduction, reuse, and multifunctionality. The growing popularity of refill systems and multifunctional packaging signifies a substantial paradigm shift, shifting the focus from single-use products to maximising their lifespan and minimising the demand for new production (Pogačar, Gregor-Svetec, 2025; Kachook, 2025). The integration of active and smart packaging into eco-design principles shows how advanced technologies can promote sustainability and reduce environmental impact by minimising food waste throughout the supply chain (Pokharel et al., 2023; Hemachandra et al., 2024). Despite the potential material footprint of active and smart packaging, the growing emphasis on these technologies represents a significant change in eco-design thinking, shifting the focus from the environmental impact of the packaging itself to that of the packaged product (e.g. food waste).

Life cycle assessment is an indispensable tool in this process. It provides comprehensive data for environmental impact assessment and supports informed design decisions (Stramarkou et al., 2022; Wei Lun Lee et al., 2023). However, it is important to bear in mind that the reliability of LCA results depends heavily on the specificity of local variables and the availability of data. This means that generalised, global studies may only be illustrative and require contextual verification (Rybczewska-Błażejowska, Jezierski, 2024; Jezierski, Rybczewska-Błażejowska, 2022; Miller, 2022). The plastic bottle versus paper bottle case study clearly demonstrates the risk of transferring environmental problems in LCA. It shows that improving sustainability is often about optimising complex systems rather than identifying simple ‘good versus bad’ material choices. This requires constant re-evaluation and context-specific solutions (Jezierski, Rybczewska-Błażejowska, 2022).

The challenges of transitioning to a CE are multidimensional and include economic, regulatory, awareness-related and implementation-related barriers (Padilla-Rivera et al., 2024; Kędzia, Turek, 2022). These challenges demonstrate that the transition to a CE is a complex socio-economic and political issue rather than a purely technological one. This means that technological innovation alone will be insufficient; coordinated action in terms of policy, education and market incentives is also required. The multifaceted barriers to implementing the CE reveal a fundamental gap between theoretical aspirations and practical realities. This strongly suggests that technological solutions alone are insufficient, and that systemic, behavioural, and policy changes are also required. Nevertheless, the general optimism and opportunities arising from innovation, policy reinforcement (e.g. extended producer responsibility), cross-sectoral collaboration, and local adaptation point to real prospects for success. Adopting existing informal practices (e.g. repair) to implement the CE suggests

a culturally integrated, bottom-up approach that can complement top-down policies and technological advancements (Padilla-Rivera et al., 2024).

Although advances in packaging technologies and regulatory frameworks encourage the implementation of eco-innovation, consumer behaviour plays a significant role in this process. Studies show that many consumers are reluctant to use eco-friendly packaging due to higher costs, a lack of information, attachment to familiar solutions, scepticism towards ‘eco’ labels and concerns about product aesthetics (Kędzia, Turek, 2022; Padilla-Rivera et al., 2024). Conversely, certain groups of consumers (e.g. younger generations and those with higher levels of education) are more likely to make pro-environmental choices (Fatma, Haleem, 2023; Jarzabek, Stolarska-Szeląg, 2024). Understanding the social and psychological factors that influence purchasing decisions is crucial for the successful implementation of CE packaging solutions. A sociological perspective also emphasises the importance of ‘social consent’ and group norms in determining the acceptance of new solutions (Stolarska-Szeląg, 2022).

5. Conclusion and recommendations

The results of the systematic literature review indicate that eco-innovation in the packaging industry is a dynamic and multifaceted field that is crucial for the transition to CE. Significant progress has been made in developing sustainable materials, applying eco-design principles and using environmental assessment methods such as LCA. However, the full implementation of these innovations faces major economic, regulatory and behavioural barriers. This suggests that the transformation involves not only technology, but also complex socio-economic and political dimensions, requiring coordinated action at multiple levels.

In order to increase the practical relevance of this study and address the identified challenges, the recommendations set out in Table 2 should be implemented. These recommendations have been ranked according to their expected impact and feasibility.

Table 2.
Priority actions for accelerating eco-innovation in packaging

Priority level	Recommended action	Rationale
High impact/ high feasibility	Integrate eco-design principles into standard packaging development processes	Reduces environmental impact and resource use across the life cycle
	Enforce EPR schemes with eco-modulation	Provides economic incentives aligned with sustainability goals
	Launch consumer education and awareness campaigns	Addresses resistance due to knowledge gaps, trust issues, and habitual behaviour
High impact/ medium feasibility	Develop standardised sustainability metrics and harmonised LCA databases	Improves comparability and credibility of eco-innovation efforts
	Invest in scalable infrastructure for recycling and composting bio-based materials	Enables practical implementation of new packaging materials

Cont. table 2.

Medium impact/ high feasibility	Promote industry-wide collaboration and best practice sharing through cross-sectoral platforms	Accelerates the diffusion of innovation and avoids duplication of effort
	Conduct targeted empirical studies on consumer behaviour and preferences regarding eco-packaging	Provides evidence for policy, design, and communication strategies
High impact/ low feasibility	Integrate CE principles into national and EU-level packaging legislation with measurable targets	Provides systemic change, but requires strong political will and stakeholder alignment

Source: Own study.

Implementing these recommendations could significantly improve the uptake and impact of eco-innovation in the packaging sector. Further research should examine the socio-economic factors influencing adoption and evaluate the long-term environmental performance of new materials. The effectiveness of policy instruments and behavioural interventions in different contexts should also be assessed.

References

1. Ahmed, S. (Ed.). (2018). *Bio-based materials for food packaging: Green and sustainable advanced packaging materials*. Singapore: Springer. <https://doi.org/10.1007/978-981-13-1909-9>.
2. Barański, A., Gworek, B., Bojanowicz-Bablok, A. (2011). *Ocena cyklu życia: Teoria i praktyka* [In Polish]. Publishing house of the Institute of Environmental Protection.
3. Cappiello, G., Aversa, C., Genovesi, A., Barletta, M. (2022). Life cycle assessment (LCA) of bio-based packaging solutions for extended shelf-life (ESL) milk. *Environmental Science and Pollution Research*, 29, 18617-18628. <https://doi.org/10.1007/s11356-021-17094-1>.
4. Cordeiro, A., Hussain, M., Ramachandran, T., Beemkumar, N., Kumar, R., Karthikeyan, A., Bupesh Raja, V.K., Thatoi, D.N., Mahapatro, A., Nanda, J., Prakash, C., Patil, A.Y. (2025). Advancements in packaging materials: Trends, sustainability, and future prospects. *Circular Economy and Sustainability*. <https://doi.org/10.1007/s43615-025-00586-4>.
5. Dostatni, E., Rybaczewska-Błazejowska, M. (2020). *Tworzenie ekoinnowacji* [In Polish]. Polish Economic Publishing House.
6. Drucker, P.F. (1992). *Innowacja i przedsiębiorczość: Praktyka i zasady* [In Polish]. Polish Economic Publishing House.
7. Duke University (2025). *Systematic reviews: Manuals and reporting guidelines*. Duke University Medical Center Library. Retrieved from: <https://guides.mclibrary.duke.edu/sysreview/manuals>, July 5, 2025.
8. European Commission (2009). *Eco-innovation*. Retrieved from: https://ec.europa.eu/environment/pubs/pdf/factsheets/eco_innovation/pl.pdf, May 26, 2021.

9. European Commission (2013). *Ekoinnowacje, klucz do przyszłej konkurencyjności Europy* [In Polish]. Retrieved from: <https://ec.europa.eu/environment/pubs/pdf/factsheets/ecoinnovation/pl.pdf>, May 29, 2021.
10. Fatma, N., Haleem, A. (2023). Exploring the nexus of eco-innovation and sustainable development: A bibliometric review and analysis. *Sustainability*, 15(16), 12281. <https://doi.org/10.3390/su151612281>.
11. Fussler, C., James, P. (1996). *Driving eco-innovation: A breakthrough discipline for innovation and sustainability*. Pitman Publishing.
12. Hemachandra, S., Hadjikakou, M., Pettigrew, S. (2024). A scoping review of food packaging life cycle assessments that account for packaging-related food waste. *The International Journal of Life Cycle Assessment*, 29(10), 1899-1915. <https://doi.org/10.1007/s11367-024-02349-z>.
13. Hollanders, H., Es-Sadki, N. (2021). *European Innovation Scoreboard 2021*. Publications Office of the European Union.
14. ISO (2006). *Environmental management – Life cycle assessment – Principles and framework (ISO Standard No. 14040:2006)*. International Organization for Standardization.
15. Jarząbek, K., Stolarska-Szeląg, E. (2024). Influence of education on improving the employment prospects of individuals with disabilities. *Journal of International Studies*, 17(3), 38–50. <https://doi.org/10.14254/2071-8330.2024/17-3/2>.
16. Jezierski, D., Rybaczewska-Błazejowska, M. (2022). Assessment of new trends in product packaging using the LCA method: A case study of a conventional plastic bottle versus an eco-innovative paper bottle. *Communications of International Proceedings*, 5, Article 4051422.
17. Kachook, O. (2025). *2025 sustainable packaging trends report (Version 1.0) [Report]*. Sustainable Packaging Coalition and GreenBlue. https://sustainablepackaging.org/wp-content/uploads/2025/04/2025-Packaging-Innovations-Trends-Report_SPC_03_compressed.pdf
18. Kędzia, G., Turek, J. (2022). What hinders the development of a sustainable compostable packaging market? *European Journal of Sustainable Development*, 11(4), 180. <https://doi.org/10.14207/ejsd.2022.v11n4p180>.
19. Kemp, R., Pearson, P. (2007). *Final report MEI project about measuring eco-innovation (Deliverable 15, Project No. 044513)*. UM-MERIT. <https://lab.unu-merit.nl/wp-content/uploads/2021/05/Final-report-MEI-project-about-measuring-eco-innovation-1.pdf>
20. Miller, S.A. (2022). The capabilities and deficiencies of life cycle assessment to address the plastic problem. *Frontiers in Sustainability*, 3, 1007060. <https://doi.org/10.3389/frsus.2022.1007060>
21. NCCMT (2014). *Anatomy of a systematic review*. National Collaborating Centre for Methods and Tools. http://www.nccmt.ca/pubs/FactSheet_AnatomySR_EN_WEB.pdf

22. OECD, Eurostat (2018). *Oslo Manual 2018: Guidelines for collecting, reporting and using data on innovation*. OECD Publ. <https://doi.org/10.1787/9789264304604-en>.
23. Padilla-Rivera, A., Morales Brizard, M., Merveille, N., Güereca-Hernandez, L.P. (2024). Barriers, challenges, and opportunities in the adoption of the circular economy in Mexico: An analysis through social perception. *Recycling*, 9(5), 71. <https://doi.org/10.3390/recycling9050071>.
24. Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>.
25. Paiano, A., Gallucci, T., Pontrandolfo, A., Crovella, T., Lagioia, G. (2021). The environmental performance of glass and PET mineral water bottles in Italy. In: S.S. Muthu (Ed.), *Sustainable packaging* (pp. 1-30). Springer. https://doi.org/10.1007/978-981-16-4609-6_1
26. Phillips, V., Barker, E. (2021). Systematic reviews: Structure, form and content. *J. of Perioperative Practice*, 31(9), 349-353. <https://doi.org/10.1177/1750458921994693>.
27. Pogačar, A., Gregor-Svetec, D. (2025). Eco-friendly design for sustainable gift packaging. *Applied Sciences*, 15(6), 2973. <https://doi.org/10.3390/app15062973>
28. Pokharel, B., Keerthi, R.S.S., Abunamous, Z.H.H. (2023). Advancements in food processing technologies: Enhancing safety, quality, and sustainability. *International Journal of Scientific Research in Engineering and Management (IJSREM)*, 7(6). <https://doi.org/10.55041/IJSREM23682>
29. Rennings, K. (2000). Redefining innovation – eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2), 319-332. [https://doi.org/10.1016/S0921-8009\(99\)00112-3](https://doi.org/10.1016/S0921-8009(99)00112-3)
30. Rethlefsen, M., Ayala, A.P., Kirtley, S., Koffel, J., Waffenschmidt, S. (2019). *PRISMA-S: PRISMA search reporting extension*. OSF. <https://doi.org/10.17605/OSF.IO/YGN9W>
31. Rybaczewska-Błazejowska, M. (2019). *Eco-innovation and eco-efficiency in the frame of life cycle assessment*. Publishing House of Kielce University of Technology.
32. Rybaczewska-Błazejowska, M., Jezierski, D. (2024). Comparison of ReCiPe 2016, ILCD 2011, CML-IA baseline and IMPACT 2002+ LCIA methods: A case study based on the electricity consumption mix in Europe. *International Journal of Life Cycle Assessment*, 29, 1799-1817. <https://doi.org/10.1007/s11367-024-02326-6>
33. Sadeghi, B., Marfavi, Y., AliAkbari, R., Kowsari, E., Ajdari, F.B., Ramakrishna, S. (2021). Recent studies on recycled PET fibers: Production and applications: A review. *Materials Circular Economy*, 3(4), <https://doi.org/10.1007/s42824-020-00014-y>
34. Smol, M., Kulczycka, J., Avdiushchenko, A. (2017). Circular economy indicators in relation to eco-innovation in European regions. *Clean Technologies and Environmental Policy*, 19(4), 669-678. <https://doi.org/10.1007/s10098-016-1323-8>

35. Stolarska-Szeląg, E. (2022). Gemba walk in manufacturing companies – Implementation process and benefits. *Humanitas University's Research Papers Management*, 23(4), 63-76. <https://doi.org/10.5604/01.3001.0016.2178>
36. Stramarkou, M., Boukouvalas, C., Koskinakis, S.E., Serifi, O., Bekiris, V., Tsamis, C., Krokida, M. (2022). Life cycle assessment and preliminary cost evaluation of a smart packaging system. *Sustainability*, 14(12), 7080. <https://doi.org/10.3390/su14127080>
37. Versino, F., Ortega, F., Monroy, Y., Rivero, S., López, O.V., García, M.A. (2023). Sustainable and bio-based food packaging: A review on past and current design innovations. *Foods*, 12(5), 1057. <https://doi.org/10.3390/foods12051057>
38. Wei Lun Lee, A., Ying Chung, S., Shee Tan, Y., Mun Ho Koh, S., Feng Lu, W., Sze Choong Low, J. (2023). Enhancing the environmental sustainability of product through ecodesign: A systematic review. *Journal of Engineering Design*, 34(10), 814-843. <https://doi.org/10.1080/09544828.2023.2261094>
39. Yap, X.Y., Gew, L.T., Khalid, M., Yow, Y.-Y. (2023). Algae-based bioplastic for packaging: A decade of development and challenges (2010-2020). *Journal of Polymers and the Environment*, 31, 833-851. <https://doi.org/10.1007/s10924-022-02620-0>.