

Innovations in Waste Management: Mapping the Path Toward a Circular Economy

Marco Ciro Liscio ^{1,2}, Francesco Perugini ¹, Paolo Sospiro ^{1,2,3}

¹ C.I.I./Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche, Ancona, Via Brecce Bianche 12, 60131, Italy

² EUAbout, Bruxelles, 1000, Belgium

³ Università Telematica eCampus, Novedrate (CO), 22060, Italy

Keywords: Waste Management, Innovation Mapping, Circular Economy, SPAR-4-SLR, Patents.

Presenting author email: f.perugini@staff.univpm.it

Abstract

In recent decades, the management of waste has emerged as one of the most pressing and complex challenges in the pursuit of environmental sustainability and economic development. As global populations and consumption patterns grow, the corresponding increase in waste production poses significant threats to ecosystems, public health, and resource availability. Addressing this issue necessitates the implementation of innovative strategies aimed at improving the efficiency of waste-related processes, including collection, treatment, disposal, and recycling. These innovations play a pivotal role in reducing the environmental footprint of waste management activities while also fostering the transition to a circular economy (Stahel, W. R., 2016; Geissdoerfer M., et al., 2017; Korhonen, J., et al., 2018).

Despite widespread acknowledgment of the importance of innovation in this sector, the practical implementation of new solutions faces challenges, needing a comprehensive understanding of the current landscape. Such an understanding must begin with a thorough examination of the concept of a circular economy and the tools it employs (Kirchherr, J., 2017; Lieder, M., et al. 2016). On this premises, the present study seeks to systematically map innovations within the waste management system by analysing insights from scientific literature and patent data, ultimately identifying areas for future research, development, and implementation.

The research framework is structured to address key gaps in the existing body of knowledge. The initial phase involves a systematic review of the scientific literature aimed at establishing the current state of innovation in waste management. This review is designed to identify predominant technological and methodological advancements, emerging trends, and evaluate of how these advancements align with global and regional policy frameworks. The aim is to support policy makers in their effort for waste management policies such as the European Union Waste Framework Directive (EU WFD) (European Parliament and Council, 2008), a cornerstone policy that emphasises the importance of waste prevention, adoption of waste management technologies, and the overarching goal of establishing a circular economy. By engaging with these dimensions, the review aims to construct a comprehensive understanding of the innovations that have been developed, with a focus on their integration into both policy and practice. The review follows SPAR-4-SLR protocol (Paul J., et al, 2021) to ensure methodological rigor, employing bibliometric tools to analyse trends in literature and to visualize geographic and temporal patterns in innovation.

The study then transitions to an analysis of patent activity, leveraging data from major international databases. This phase employs advanced bibliometric and data mining techniques to systematically map the geographic distribution of patented innovations, identify technological development trends, and highlight areas of concentration. Such an analysis offers insights into the dynamics of technological development, uncovering disparities in innovation and identifying key areas where research and investment are either concentrated or lacking. By doing so, this analysis sheds light on the factors driving innovation while also revealing the barriers that may be hindering progress in others.

To address the gaps identified in the innovation landscape, the study proceeds to explore opportunities for advancing the development and implementation of novel solutions. This exploration involves a critical examination of barriers to adoption, such as technological limitations, economic constraints, regulatory challenges, and social resistance. The study then proposes strategies to overcome these barriers, emphasizing the importance of scalable and adaptable solutions that can be tailored to diverse socio-economic and regulatory contexts. These strategies are designed to facilitate the seamless integration of innovative practices into existing waste management systems, thereby enhancing their efficiency and sustainability. The findings from this phase contribute to the formulation of recommendations aimed at aligning future research and development priorities with global sustainability objectives, evolving industry demands, and policy imperatives.

At the European level, the research undertakes a comparative analysis of its findings with those presented by Chioatto et al. (2024), who investigated the performance of EU regions in sustainable waste management using data envelopment analysis models. By examining correlations between the presence of innovation and high waste management performance, the study provides additional insights into the potential of innovation to drive systemic

improvements. This comparative analysis offers a deeper understanding of how innovative practices contribute to achieving the goals set forth by European policy frameworks, highlighting best practices and identifying opportunities for cross-regional learning and collaboration.

The study aspires to make a range of significant contributions to the field of waste management innovation. These include a detailed review of the current state of innovation, a geographical mapping of patented technologies, an in-depth analysis of barriers and opportunities for implementation, and the formulation of strategic recommendations for guiding future research and development efforts. By integrating insights from scientific literature and patent data, the research aims to provide a nuanced understanding of the innovation landscape, offering critical insights into technological advancements and their alignment with sustainability objectives. These findings are intended to serve as a valuable resource for a diverse audience, including researchers, policymakers, and industry stakeholders, promoting knowledge transfer and fostering the adoption of innovative solutions.

References

- Chioatto E., Fedele A., Liscio M.C., Sospiro P., (2024). Testing data envelopment analysis models on the performance of European Union regions in sustainable waste management. *Waste Management*, 175, 170-182. <https://doi.org/10.1016/j.wasman.2024.01.008>
- European Parliament and Council (2008). Directive 2008/98/EC on waste (Waste Framework Directive). Official Journal of the European Union.
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>
- Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232. <https://doi.org/10.1016/j.resconrec.2017.09.005>
- Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, 175, 544–552. <https://doi.org/10.1016/j.jclepro.2017.12.111>
- Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115, 36–51. <https://doi.org/10.1016/j.jclepro.2015.12.042>
- Paul J, Lim WM, O'Cass A, Hao AW, Bresciani S. (2021) "Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR)." *Int J Consum Stud.*;45:O1–O16. <https://doi.org/10.1111/ijcs.12695>
- Stahel, W. R. (2016). The circular economy. *Nature News*, 531(7595), 435. <https://doi.org/10.1038/531435a>