

Editorial

Cities in Flux: Waste, the Shadow of Circularity, and the (Elusive) Promise of Sustainability

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1. Introduction

The transition to a circular economy has emerged as a critical strategy for addressing the escalating challenges posed by resource depletion [1,2], environmental degradation [3,4], and increasing waste generation [5,6]. At the heart of this paradigm shift lies waste management—a sector deeply intertwined with urban sustainability [7,8], resource efficiency [9,10], and public health [11,12]. Moving beyond traditional linear models, where resources are extracted, used, and discarded [13], the circular economy (Figure 1) promotes the continuous use and recovery of materials, aiming to decouple economic growth from environmental harm [14,15].

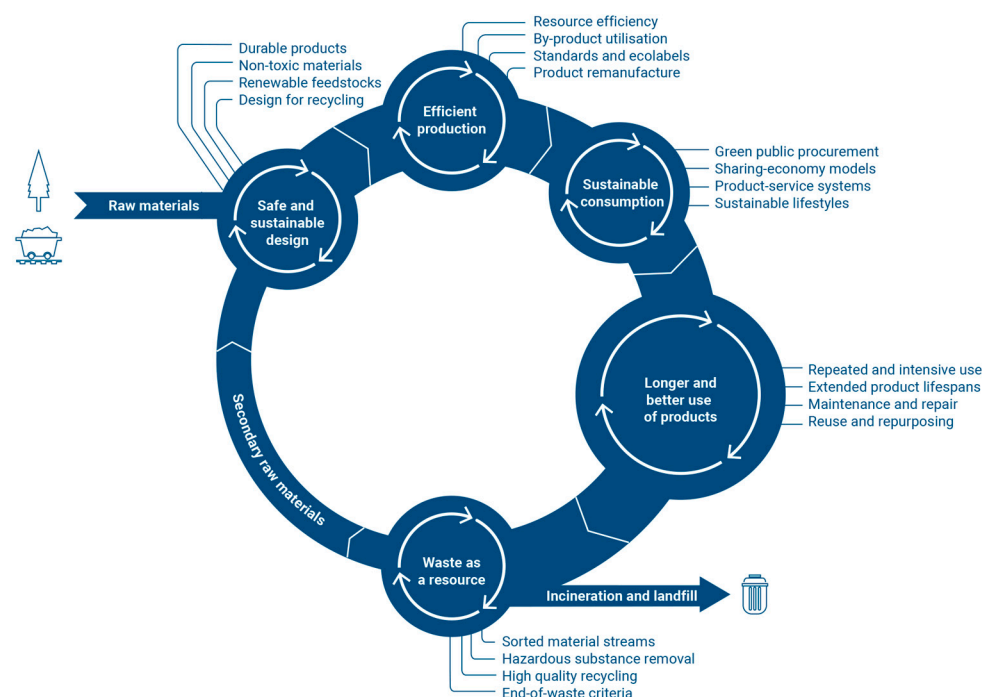


Figure 1. The European Environmental Agency vision for a circular economy in Europe.

Europe has made significant strides in advancing circular economy principles through frameworks such as the European Green Deal [16,17] and the Circular Economy Action Plan [18,19]. These initiatives aim to mitigate climate change [20,21], reduce biodiversity loss [22,23], and foster sustainable economic practices [24,25]. Despite these efforts, key challenges remain. The EU’s material circularity rate has stagnated at 11.8% [26], recycling



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processes often fail to close the loop effectively [27], and public engagement with waste prevention remains limited overall [28]. Bridging the gap between policy frameworks and tangible outcomes requires evidence-based strategies that integrate technological innovation, public awareness, and regulatory alignment.

Waste management is inherently complex [29], drawing on principles and practices from diverse fields such as environmental science [30], urban planning [31], geography [32], economics [33], social behavior [34], and cultural norms [35]. Its multidimensional nature requires a system-based approach, where technological solutions, policy strategies, spatial considerations, and cultural dynamics are seamlessly integrated to address the challenges of resource efficiency, waste prevention and reduction, and environmental sustainability [36].

The increasing focus on waste management, reflected in evolving policies (such as the “Extended Producer Responsibility” [37], the “Pay-As-You-Throw” [38], the “Ban on Single-Use Plastics” [39], the “Green Public Procurement” [40], etc.), strategic research investments (such as the A2UFood Project (UIA02-115), the LIFE-IP CEI Greece Project (LIFE18 IPE/GR/000013), the GREENHORT Project (PRIN 2022—grant 2022WHTNZZT), the BBHORT Project (PRIN 2022 PNRR—grant P2022P52XK), the Horizon Europe RECON-MATIC Project (Grant agreement ID: 101058580), the WiedergeBORN Project, etc.) and its prominence in global discussions and high-level forums (such as the “United Nations Environment Assembly”, the “Global Waste Management Outlook”, the “International Solid Waste Association World Congress”, the “International Conference on Sustainable Solid Waste Management”, the “RETASTE—Rethink Food Resources, Loses, and Waste Conference”, etc.), underscores its critical role in mitigating climate change and advancing environmental justice. For example, at the very recent COP29, the inclusion of waste management in the agenda for the first time emphasized the potential for targeted interventions, such as organic waste diversion and high-quality recycling, to substantially reduce methane emissions while enhancing environmental justice. However, achieving such outcomes requires comprehensive strategies that align policy goals with practical implementation.

The Special Issue entitled “Waste Management Policy for Sustainable (Peri-)Urban Development and the Circular Economy” examines these complexities through 12 diverse contributions, which reveal both persistent gaps and emerging solutions, emphasizing the need for interdisciplinary approaches that balance ambition with feasibility.

Key insights from this collection demonstrate that progress in waste management depends on addressing three interconnected dimensions. First, public awareness must shift beyond recycling to encompass waste prevention and reduction. Second, regulatory frameworks must evolve to support innovation while remaining adaptable to regional and local contexts. Finally, systemic approaches that integrate behavioral, technological, and policy considerations are essential to achieving meaningful and scalable impacts.

This Special Issue contributes to a growing body of knowledge that seeks to transform waste management into a driver of sustainable urban development. By critically examining policy, practice, and innovation, the collected works provide a foundation for advancing circular economy principles in (peri-)urban contexts, offering actionable pathways toward a more resilient and sustainable future.

2. Synopsis of Contributions

This Special Issue brings together 12 contributions authored by 53 researchers representing institutions across Europe (Greece, Cyprus, Germany, Italy, and the United Kingdom), Asia (China and Thailand), Africa (South Africa), and North America (the United States). This geographic diversity reflects the global importance of waste management and the varied approaches to addressing its challenges within different cultural, economic, and environmental contexts. With an average of 4.4 authors per paper, the contributions

exemplify the collective effort required to tackle the multifaceted issues associated with waste management.

Spanning 18 months from the initial call for papers to the final publication, this Special Issue highlights the sustained effort and interdisciplinary collaboration that shaped its content. The contributions reflect cutting-edge research and state-of-the-art methodologies, addressing the most pressing challenges and emerging opportunities in waste management and the circular economy. Their innovative approaches and findings provide valuable insights into the current landscape and future directions of sustainable (peri-)urban development.

The current synopsis is organized into four thematic sections. The first addresses policy and implementation challenges, focusing on systemic barriers and regulatory frameworks. The second highlights technological innovations and waste valorization, emphasizing advancements in materials, processes, and decision-support systems. The third explores behavioral and social dynamics, examining public awareness, consumer behavior, and societal engagement. Finally, the Section 2.4 provides systematic reviews and frameworks, offering comprehensive evaluations and methodologies to guide future research and practice.

This thematic organization facilitates a deeper understanding of the Special Issue's diverse contributions, showcasing their collective effort to advance sustainable waste management and the principles of a circular economy.

2.1. Policy and Implementation Challenges

The contributions in this section uncover critical tensions between the ambition of waste management policies and their practical implementation across diverse contexts. They reveal how systemic issues—ranging from governance and funding constraints to regulatory misalignments—undermine efforts to transition toward a circular economy.

One recurring insight is the disconnect between localized successes and their scalability. For instance, the WiedergeBORN project in Germany demonstrated the potential of local circularity initiatives but also highlighted the institutional and regulatory barriers that limit their broader applicability. This suggests that localized experiments are often constrained by fragmented policy environments and insufficient support mechanisms, reflecting broader challenges in harmonizing multi-level governance structures.

Governance emerges as a central obstacle in less resourced contexts, as evidenced by the analysis of the South African municipalities. This study provided insights into how a lack of financial resources, poor institutional coordination, and inadequate infrastructure prevent the effective implementation of integrated waste management plans, stressing the need for robust institutional frameworks that not only allocate resources equitably but also foster collaboration across public and private sectors.

Regulatory misalignments further exacerbate these challenges. For example, an examination of legal barriers in sustainable agriculture highlights how conflicting policies hinder the valorization of agri-food waste and pesticide reduction efforts. Such misalignments indeed reveal deeper structural issues, where short-term economic priorities often overshadow long-term sustainability goals, complicating the operationalization of circular economy principles.

These studies manage to collectively illustrate the complexities of embedding waste management within the broader framework of circular economy transitions. They emphasize the critical need for adaptive policies that are responsive to regional contexts, align with existing regulatory frameworks, and incentivize stakeholder engagement. Without addressing these systemic barriers, the potential of waste management to drive sustainability will remain unrealized, particularly in contexts where institutional and financial capacities are limited.

2.2. Technological Innovations and Waste Valorization

The contributions in this section explore the transformative role of technological advancements and innovative practices in waste management, focusing on their potential to enhance resource recovery, reduce environmental impacts, and support circular economy objectives. These studies critically assess the balance between technological feasibility and practical implementation, providing insights into the opportunities and constraints of integrating innovative solutions into existing systems.

One significant focus is the potential of organic waste valorization. Research on bioplastic production from food waste demonstrates the dual benefits of reducing waste volumes while generating high-value materials. However, the study also highlights critical challenges, including the need for standardized processes and market acceptance of bioplastics, which remain underdeveloped in many contexts. Similarly, an evaluation of the biodegradability of polylactic acid and compostable bags under industrial composting conditions underscores the importance of aligning product design with waste management infrastructure to maximize environmental benefits.

Technological decision-making tools emerge as another key innovation. A study on medical waste management introduces a fuzzy-based decision support system to optimize waste disposal practices, ensuring compliance with environmental standards while addressing safety concerns in high-risk contexts. This research emphasizes the importance of integrating technology into complex waste streams to achieve more effective and sustainable outcomes.

Despite these advancements, the contributions collectively emphasize that technology alone cannot solve systemic waste challenges. The innovative use of Plan-Do-Check-Act processes in (green) university practices, underscores the importance of systematic evaluation and continuous improvement in achieving sustainability benchmarks. The effectiveness of these innovations depends on supportive regulatory frameworks, adequate infrastructure, and public acceptance. For example, while innovations in material recycling and composting hold significant promise, their scalability often hinges on addressing logistical and economic constraints at the local level.

Overall, these studies underline the need for a system-based approach, where technological solutions are embedded within broader waste management strategies. By focusing on the intersection of innovation, regulation, and infrastructure, these contributions provide valuable pathways for advancing the role of technology in achieving circular economy objectives.

2.3. Behavioral and Social Dynamics

The contributions in this section examine the critical role of human behavior, societal norms, and community engagement in shaping waste management practices. They underscore that effective waste management and the transition to a circular economy require not only technological and regulatory solutions but also significant shifts in public awareness, consumer behavior, and collective action.

A central theme is the gap between awareness and behavior. Research from China highlights how policy promotion and internet use influence farmers' and residents' willingness to participate in waste classification, revealing that while awareness is increasing, behavior change remains uneven. This points to the importance of targeted educational campaigns and accessible infrastructure to bridge the gap between knowledge and action.

Public perceptions of waste management policies also emerge as a critical factor. A study on waste classification in Chinese prefecture-level cities shows how age, education, and exposure to policy initiatives influence residents' attitudes and practices. The analysis suggests that younger populations, who are more likely to access information via digital platforms, are more engaged in waste sorting, whereas older groups rely on traditional me-

dia and exhibit lower levels of participation. These insights call for tailored communication strategies that consider demographic and cultural differences to maximize impact.

The role of institutional and consumer practices in fostering sustainable behavior is further explored through a study of Germany's mandatory reusable packaging laws. While the policy has created opportunities for more sustainable consumption, the research highlights obstacles such as consumer resistance and operational challenges faced by businesses, emphasizing the need for policies that balance regulatory requirements with practical feasibility.

Collectively, these studies highlight the interconnectedness of behavior, policy, and infrastructure. They demonstrate that fostering meaningful societal engagement requires more than individual behavior change; it demands systemic approaches that integrate public participation with supportive policies and accessible waste management systems. Addressing these behavioral and social dynamics is essential for embedding sustainability into everyday practices and ensuring the success of circular economy initiatives.

2.4. Systematic Reviews and Frameworks

The contributions in this section synthesize existing knowledge, identify persistent gaps, and propose structured approaches to guide future research and policy development.

A notable focus is on the inefficiencies in managing specific waste streams. A systematic review of food waste quantification in the food service industry reveals significant data inconsistencies and underreported waste volumes, which hinder the development of effective reduction strategies. The analysis calls for standardized methodologies and better monitoring systems to address these shortcomings and enhance resource efficiency. Similarly, a comprehensive evaluation of construction and demolition waste management practices highlights the potential for circularity in the sector but emphasizes the need for improved regulatory frameworks and market mechanisms to support the recycling and reuse of materials.

The interaction between legal frameworks and waste management practices is critically explored in a review of agri-food waste valorization. The study identifies regulatory inconsistencies as a key barrier to integrating waste reduction and pesticide use mitigation into agricultural practices. By highlighting the disconnect between policy intentions and practical implementation, the paper underscores the importance of regulatory alignment and policy coherence for advancing sustainable practices.

Frameworks for assessing public engagement in waste management are also examined. A case study of waste classification in Chinese cities evaluates residents' understanding of policies and the effectiveness of public awareness campaigns. The findings provide actionable insights for designing community-focused interventions that foster greater participation and compliance with waste management regulations.

These contributions collectively highlight the necessity of addressing waste management through integrated and multi-dimensional frameworks rather than relying on fragmented or isolated measures. They underscore the importance of aligning policies, standardizing methodologies, and fostering stakeholder collaboration to tackle systemic inefficiencies. By presenting tools for harmonizing data collection, enhancing regulatory coherence, and improving public engagement strategies, these reviews and frameworks provide a concrete foundation for embedding circular economy principles into waste management practices, while ensuring scalability and adaptability across different contexts.

The contributions to this Special Issue underscore the pivotal role of waste management in the broader transition toward a circular economy and sustainable (peri-)urban development. Collectively, they reveal both the challenges and opportunities inherent in

aligning policy, technology, behavior, and systemic frameworks to address the complexities of waste generation and resource efficiency.

A key takeaway is the urgent need for a more integrated and adaptive approach to waste management. While advancements in technology and policy frameworks offer promising pathways, their success depends on bridging the gaps between regulatory ambition and practical implementation. The studies highlight the importance of tailoring strategies to specific socio-economic and cultural contexts, fostering public engagement, and ensuring robust infrastructure to support the effective adoption of circular practices.

However, significant challenges remain. The slow progress in material circularity, the limited scalability of localized initiatives, and the persistent gaps in public understanding and behavior indicate that waste management continues to face systemic barriers. Addressing these requires not only improved governance and regulatory coherence but also a commitment to innovation and stakeholder collaboration at all levels.

Future research must prioritize interdisciplinary solutions that integrate technical, behavioral, and policy dimensions. Areas such as digital tools for waste tracking, advanced recycling technologies, and data-driven decision-making frameworks offer substantial potential for transforming waste management systems. Equally, greater attention must be given to the economic and social incentives that drive sustainable practices, ensuring that policies are both equitable and effective.

International collaboration is essential to accelerate progress, as waste management challenges transcend national borders. The lessons learned from diverse contexts in this Special Issue highlight the value of knowledge exchange and cooperative efforts to scale successful models globally. Furthermore, the integration of waste management into global climate agendas, as seen at COP29, provides a critical opportunity to align waste reduction strategies with broader environmental and social goals.

In closing, this Special Issue reaffirms the centrality of waste management in achieving a circular economy and sustainable urban futures. It calls for a concerted effort from policymakers, researchers, and practitioners to move beyond incremental improvements and embrace systemic, scalable solutions. By addressing these challenges with urgency and innovation, waste can be transformed from a liability into a vital resource for a more resilient and equitable world.

Conflicts of Interest: The author declares no conflicts of interest.

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