

Enhancing Biowaste Management Through Knowledge Management: A Cross-national Comparison of six European Countries

Kristiina Brusila-Meltovaara¹, Katerina Medkova¹, Hongmei Quer² and Rafaela Cáceres²

¹LAB University of Applied Science, Lahti, Finland

²Institute of Agrifood Research and Technology (IRTA), Barcelona, Spain

kristiina.brusila-meltovaara@lab.fi

Katerina.medkova@lab.fi

hongmei.quer@irta.cat

rafaela.caceres@irta.cat

Abstract: Purpose: This study examines how knowledge management (KM) supports the implementation of separate biowaste collection across governance levels in six European countries in the context of the EU requirements effective from 1.1.2024. Methodology: Within the CITISYSTEM project, two comparable data collection rounds (2023 and 2025) were carried out by eight partners using a structured questionnaire and follow-up clarifications, enabling a cross-national and longitudinal comparison at national, regional, and city levels. Findings: The results show convergence in regulatory direction (separate collection, quality improvement and alignment with circular economy goals) but an uneven pace of implementation. Clear policy and operational progress within the two-year window was most visible in Lahti and Mechelen at the city level, and in Flanders and Catalonia at the regional level, while other cases show incremental or no recorded change. Contribution: By specifying where KM-enabled practices (e.g., cross-level coordination, indicators/data reporting, digital tools and citizen engagement) are most evident, the study offers a comparative view of how learning and knowledge sharing can accelerate compliance and system performance in multi-level biowaste governance.

Keywords: Biowaste, Knowledge management, Knowledge sharing, Comparative analysis, Europe

1. Introduction

Data from 2023 indicate that municipal waste generation has reached 511 kg per inhabitant per year (European Commission, 2025). Approximately 34% of this waste stream are organic materials (European Environment Agency, 2020), consisting of plant and animal residues. For decades, the management of these materials largely relied on end-of-pipe disposal methods, namely landfilling and incineration. However, many studies show that these disposal-based methods overlook a basic natural process: returning organic matter and nutrients back to the soil. Moreover, the current methods lead to a long-term negative impact on the environment (Vaverková et al, 2026). The accumulation of organic matter in landfills contributes to groundwater pollution and leachate production containing organic compounds and other contaminants (Ilgwegbe et al, 2024), while also emitting methane, carbon dioxide, odorous compounds, and other pollutants (Lakhout, 2026) that pose risks to human health (Pan et al, 2023). On the other hand, incineration not only generates contaminated ash requiring landfilling but also produces gases that contribute to greenhouse gas emissions and other pollutants (Vele et al, 2025).

To respond to the multi-actor and multi-level nature of biowaste governance, this study draws on multi-level governance as an analytical lens (i.e., the distribution of authority and coordination across national, regional and municipal arenas) and complements it with a public-sector KM perspective which emphasises knowledge formation through collecting, interpreting and sharing information for policy and implementation. In this paper, KM is examined specifically through (1) cross-level coordination and role clarity, (2) knowledge sharing and learning between organisations and regions, and (3) information infrastructures such as indicators, data reporting and digital tools that support monitoring, citizen engagement and continuous improvement.

In addition, the annual global demand for resources is 1.75 times higher than the Earth's capacity can sustainably provide (Jiménez-Rosado et al, 2023). In other words, the planet can no longer sustain the current rate of consumption, and growing pollution only intensifies the problem. Therefore, it is necessary to rethink the traditional linear economic system (European Environment Agency, 2020). One opportunity lies in transforming biowaste into stable, useful products, which can partly replace the resources needed in agricultural applications (Jiménez-Rosado et al, 2023).

Therefore, in recent decades, European countries have started using new approaches to make better use of the nutrients and organic matter in biowaste and to reduce pollution (Molina-Peñate & Sánchez, 2025). This shift is

not only achieved by scientific and technological progress, but also by supportive policies and programmes that make these changes possible (Haapea & Medkova, 2024).

The objective of the European Green Deal (European Commission, 2019) is to make Europe the first climate-neutral continent in the world. This involves the transformation of the EU into a modern, resource-efficient and competitive economy. Among other objectives, this Deal intends to cut emissions by at least 50% by 2030, while legally binding the 2050 neutrality goal. The programme invests in innovation, clean technology and green infrastructure while ensuring a just transition for the communities. The European Bioeconomy Strategy will contribute to the European Green Deal significantly. As this Strategy intends to replace fossil-based resources with sustainable biological ones for a circular, climate-neutral economy, the initiative is fully linked to the circularity of biowaste in cities and rural areas (European Commission, 2026a).

Cities are increasingly at the centre of the circular bioeconomy transition, in particular, through the management of biowaste and other bio-based resources. Across Europe, responsibilities for policy design, service provision, infrastructure, and data reporting are distributed across city, regional, and national levels, in ways that often do not align with administrative boundaries (Haapea & Medkova, 2024; Meisterl et al, 2024; Suárez et al, 2023). While national frameworks typically set legal obligations and targets, implementation frequently relies on inter-municipal or regional arrangements, resulting in unclear governance boundaries. This multi-level complexity complicates local action, data comparability, and policy evaluation, underscoring the need for a clearer understanding of how biowaste governance operates across governance levels in practice (Haapea & Medkova, 2024).

2. Literature Review

According to EU Directive 2018/851, biowaste comprises of biodegradable garden and park waste, as well as food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises, and comparable waste from food processing plants. In practice, these materials are often grouped into two main fractions: garden and park waste, and food and kitchen waste. As stated earlier, the appropriate management of these organic waste fractions is closely related to the principles outlined in the EU policies and programmes. The source separation of organic matter is essential for obtaining outputs safely applicable in agriculture (European Commission, 2026b).

It is urgent to speed up the process of improving biowaste management. Several policies already call for diverting biodegradable waste away from landfilling and incineration, and for increasing overall recycling targets to 65% by 2035 (Interreg Europe, 2021). An effective and systemic transformation of waste management requires several measures: local policies aligned with EU, national, regional or city regulations; awareness-raising among citizens about proper source separation; efficient organic waste collection systems; the deployment of suitable treatment technologies such as composting or anaerobic digestion (decentralized or centralized treatment, depending on the local conditions); and the sustainable use of compost (Haapea and Medkova, 2024). Any new scenarios must meet existing regulations while also ensuring that resources are managed logically and responsibly, enabling organic materials to be returned to productive use. Moreover, these changes must be supported by strong knowledge management practices and capacity building efforts to ensure long-term effectiveness (Haapea & Medkova, 2024).

According to the EU Waste Framework Directive (European Parliament and Council 2018; European Parliament and Council 2008), biowaste has been required to be separately collected since 31 December 2023. Implementation across Member States is, however, uneven, and some countries make use of the Directive's permitted derogations, which allow exemptions where separate collection cannot be carried out for technical, environmental, or economic reasons (European Parliament and Council 2018; European Parliament and Council 2008).

Regarding knowledge management, it is key to consider different perspectives to support effective biowaste systems. For instance, using indicators can help improve the separation and recovery of organic matter (e.g., biowaste quality, quantity, impurities) (European Environment Agency, 2020). Public awareness activities also play an important role, as they help citizens understand how to sort biowaste (Interreg Europe, 2021). In addition, technological tools and digital systems can support better monitoring and enhance overall performance (Molina-Peñate & Sánchez, 2025). The indicators could also be combined with other assessments, such as surveys conducted with key actors in the biowaste sector (Fraser, 2024). At the same time, keeping track of new innovations, especially those ready for industrial application, and integrating them into policy

frameworks requires coordinated knowledge management between stakeholders (Haapea & Medkova, 2024), with technological advances providing additional opportunities for valorisation (Anbarasu et al, 2026).

Existing work broadly agrees that successful biowaste diversion depends on aligned regulation, a convenient collection infrastructure and sustained citizen participation, and that performance improves when systems are monitored and adapted using comparable indicators. At the same time, the literature tends to treat governance levels separately (EU/national frameworks versus local implementation) and often discusses digitalisation or stakeholder engagement as technical add-ons rather than as KM mechanisms that shape learning and coordination. This leaves a gap in understanding how knowledge is created, shared and operationalised across governance levels during implementation, and how this affects the pace and quality of compliance. By comparing six European contexts over two data points (2023/2025), this study synthesises these strands and links biowaste system changes to KM-enabled coordination, data practices, and cross-regional learning.

In this regard, cities play a key role in organic waste management by transforming urban metabolism and closing nutrient loops through local, innovative bioeconomy systems. This may contribute to replacing non-renewable resources in fertilizer production while enabling the production of local fresh food and high value bio-based products (Angouria-Tsorochidou et al, 2021). The project CITISYSTEM—Supporting Cities in Sustainable Biobased Systemic Change aims to collect and share knowledge gathered across participating countries (Interreg Europe, 2025a). This includes not only changes to policy instruments, but also good practices for improving the sustainability of cities, particularly focusing on biowaste management (Interreg Europe, 2025b).

3. Methodology

The data for these thematic studies were collected within the CITISYSTEM project, co-funded by Interreg Europe and led by the LAB University of Applied Sciences. The aim of this study was to understand how biowaste management and circular bioeconomy practices developed in different European regions between 2023 and 2025. Eight project partners from six EU countries contributed to the data collection (Table 1). These partners include municipalities, public authorities, universities, and research organisations engaged in biowaste management, circular bioeconomy development, and related policy or regional development work.

The study relied on expert input and institutional knowledge rather than a general population sample. Each project partner gathered information from relevant local and regional actors, such as municipal officials, waste management companies, researchers, and government representatives. The responses therefore reflect institutional knowledge and practical experience with biowaste governance in each region.

Sampling was purposive and organised through the project partnership: in each region, the partners consolidated the input from a small set of key informants who were directly involved in biowaste policy design, service provision, treatment infrastructure, monitoring or public communication. While the exact number of informants per region varied by context, respondents typically represented municipal or regional authorities, inter-municipal waste companies, and specialist organisations (e.g., research or development bodies). The unit of analysis in this article is therefore the regional/city case (reported by the partner), not individual citizens, which supports comparability between countries while reflecting practice-based expertise.

Data were collected through two survey rounds. Survey 1, describing the situation in 2023, was collected online between June 2023 and February 2024 using Webropol. Project partners were responsible for entering the answers. To increase flexibility, the questions were also sent as a Word document, allowing partners to translate questions and collect answers via phone, email, or face-to-face meetings before submitting consolidated responses. Survey 2 captured the 2025 situation, and followed a structured update rather than a separate online survey. Project partners received an Excel file containing their Survey 1 responses. Information for 2025 was entered into an adjacent column, enabling a direct comparison of changes over time while ensuring consistency across survey rounds. After both surveys were completed, individual follow-ups by email or phone were carried out with partners whenever clarifications were needed.

Table 1: Project partners

Partner	Country	Role / Notes	Participated in Survey 1 2023 (6/2023 – 2/2024)	Participated in Survey 2 2025 (8/2025 – 12/2025)
LAB University of Applied Sciences	Finland	Lead partner	X	X
City of Lahti	Finland		X	X

Partner	Country	Role / Notes	Participated in Survey 1 2023 (6/2023 – 2/2024)	Participated in Survey 2 2025 (8/2025 – 12/2025)
Technical University of Košice	Slovakia		X	X
BSC, Business Support Centre L.t.d., Kranj	Slovenia		X	X
City of Mechelen	Belgium		X	X
Regional Development Fund of Central Macedonia	Greece		X	X
CERCA Institute—Catalan Research Centres Institute	Spain	Until 31.8.2024	X	
IRTA Institute of Agrifood Research and Technology	Spain	From 1.9.2024		X

Stakeholders who contributed included local actors, waste management companies, universities, and government officials. The surveys explored knowledge management practices related to policy design, coordination, learning processes, and strategy developments in the circular bioeconomy and biowaste sectors, alongside practical aspects related to biowaste management, key stakeholders, challenges, and circularity-related topics.

A combination of conditional and open-ended questions were used as these are essential in capturing the full complexity and diversity of biowaste management practices, enabling a deeper and more meaningful comparative analysis across different contexts (Fraser, 2024). The full survey consisted of 103 distinct questions. While the survey covered a wide range of legal, policy, strategic, operational, and technological dimensions, this article draws only on a selected subset of questions. These selected questions explore the existence and content of biowaste regulations, strategies, and action plans, as well as stakeholder involvement in their development, supporting a comparative analysis of knowledge-driven developments across European regions over time.

4. Results

4.1 National, Regional and City Levels

Across all six countries, biowaste is understood in a very similar way: it refers mainly to biodegradable food, kitchen and garden waste from households, hospitality services, retail, and food processing. Although each region regulates the details differently, the direction of policy is the same everywhere: better separate collection, better quality of the material collected, and stronger alignment with EU waste and circular economy goals.

In Spain/Catalonia and Belgium/Flanders, most decisions and implementation for biowaste related policy are coordinated at the regional level rather than centrally at the national level. Both regions have introduced updates or new strategic frameworks on biowaste or organic waste management since 2023 (Table 2). In Catalonia, this also includes the new 2024 Biogas Strategy and its 2024–2026 Action Plan, which advance the circular bioeconomy by converting organic waste, agricultural residues, and manure into renewable biogas and biomethane, reinforcing waste valorisation and supporting new biobased value chains. Belgium does not have a national waste law; waste management is regulated at the regional level, and in Flanders, this framework is defined by the Materials Decree and its implementing regulation VLAREMA. The most recent update, VLAREMA 9 (2023), introduced new concepts such as farm composting, although further rules are still under preparation, and regulations are being updated for waste management. The other four countries/regions (Finland, Slovakia, Slovenia, and Greece) maintained existing strategies, focusing on incremental improvements, infrastructure investments, and ongoing monitoring (Table 2).

Table 2: Biowaste Related Policy Status and Changes (2023–2025)—Regional Level

Region/ Country	Regulatory Level	Change Regional Level	Changes in Regional Level Policies
Päijät-Häme/ Finland	Regional + Local implementation under national Waste Act	NO	Lahti Regional Waste Board issues waste and biowaste regulations in the inter-municipal area
Košice/ Slovakia	National + Local implementation	NO	National Waste Act obliges all municipalities to collect kitchen biowaste separately from 2021
Gorenjska / Slovenia	National	NO	Waste regulated by Environmental Protection Act and national decrees (e.g., Decree on Organic Kitchen and Garden Waste, Treatment of Biodegradable Waste); municipalities provide services only
Central Macedonia/ Greece	National	NO	Separate biowaste collection mandated by national laws (e.g., Waste Management and Environmental Protection, Modernization of Environmental Legislation, Integrated Framework for Waste Management, Circular Economy, and Environmental Protection)
Flanders/ Belgium	Regional (Flemish)	YES	Biowaste obligations set by Flemish Materials Decree and VLAREMA/ VLAREMA 9 (2023) introduced new concepts; Mechelen to start separate biowaste collection in 2026.
Catalonia/ Spain	Regional (Catalan)	YES	Biowaste separation mandated by Catalan Waste Laws (6/1993, 9/2008) and enforced by the Waste Agency of Catalonia (ARC) and related strategies and programmes/Catalan Biogas Strategy and 2024-2030 Action Plan—valorising municipal biowaste.

Consistent with the study's focus on knowledge management, digitalization and knowledge-sharing practices are increasingly integrated to support compliance, stakeholder engagement, and data-driven improvements. Integration occurs at all governance levels, but the most visible and effective implementation such as community engagement tools, occurs on the regional and city/municipality levels, where activities and practices directly impact compliance, participation and system efficiency. On the city and municipality levels, biowaste policy status changes based on the questionnaire results, could only be observed for Lahti, Košice and Mechelen (Table 2).

By 2025, all regions had implemented or were preparing for separate biowaste collection. Košice (Slovakia) and Lahti (Finland) have operational citywide systems, while Mechelen (Belgium) is expanding from only home/community composting to a mandatory, digitally monitored collection system starting from 2026. In Catalonia (Spain) and Central Macedonia (Greece), separate collection is mature or expanding, with ongoing infrastructure investments. Digital tools and knowledge management practices are increasingly integrated, particularly at the regional and municipal levels. Examples include digital monitoring platforms in Central Macedonia and Catalonia, and citizen feedback hotlines in Košice. This integration supports compliance, data-driven improvements, and stakeholder engagement.

4.2 Multi-level Governance of Biowaste: Regional and City Level Differences and Recent Developments

Across the regions included in this study, the regulation of municipal waste, including biowaste, operates at diverse administrative levels. Some cities, like Košice, regulate biowaste through their own municipal ordinances. Others rely mainly on regional-level regulations, as seen in Catalonia or parts of Gorenjska, where municipalities carry out implementation but do not create the regulations themselves. In Greece, municipalities operate under national legislation, and the EU Waste Framework Directive is implemented through Regional and Local Waste Management Plans. In Thessaloniki and Central Macedonia, FoDSA (Regional Association of Solid Waste Management Agencies) leads regional biowaste systems and plans supporting municipalities.

Unique arrangements exist in Lahti and Mechelen, both operate within inter-municipal structures, though in different ways. In Lahti, biowaste rules are issued by the Lahti Region Waste Board, meaning the same regulation applies across several neighbouring municipalities. This creates a hybrid model where decisions are made

collectively, yet the system remains tailored to local conditions. In Mechelen, the inter-municipal company is responsible for collection and treatment, while following the regional Flemish framework.

Two substantial changes (Table 3) have been achieved since Survey 1 in Lahti, where concrete regulatory and operational updates took place. The city applied new regulations valid from 1 October 2025, intensifying separate biowaste collection and linking longer mixed waste collection intervals to a requirement for biowaste separation or composting. In addition, from July 2024, separate collection became compulsory for small multi-unit and single-family homes in urban areas within the inter-municipal area. These improvements make Lahti one of the few areas with clear, documented progress during the comparison period.

Table 3: Biowaste Related Policy Status and Changes (2023–2025)—City Level

City/ Country	Regulatory Level	Change City Level	Changes in City Level Policies
Lahti/ Finland	Regional + Local implementation under national Waste Act	YES	<i>From 7/2024, separate biowaste collection became compulsory for small multi-unit and single-family homes in urban areas.</i> <i>New rules (10/2025) tightened Lahti's biowaste requirements by linking longer mixed waste intervals to mandatory sorting or composting.</i>
Košice/ Slovakia	National + Local implementation	YES	<i>General Binding Regulation No. 238 (2023) on the management of municipal waste and small construction waste in the City of Košice introduced mandatory biowaste separation; system operational since Jan 2023.</i> <i>The Košice Climate City Contract (2024) and 2030 Climate Neutrality Action Plan of the City of Košice promote climate neutrality by 2030 through circular bioresource use, including biomass valorisation, green waste recovery, and nature-based solutions.</i>
Kranj/ Slovenia	National	NO	No major changes reported, ongoing promotion of composting.
Thessaloniki/ Greece	National	NO	Municipal biowaste collection and composting ongoing; no major change, infrastructure investments continue. Upcoming Regional Waste Management Plan amendment will add a Holistic Separate Collection Plan: FODSA collects biowaste in municipalities <30,000; larger municipalities collect themselves or may delegate to FODSA.
Mechelen/ Belgium	Regional (Flemish)	YES	<i>Separate biowaste collection to start in 1/2026; previously only community/home composting promoted.</i>
Barcelona/ Spain (Catalonia)	Regional (Catalan)	NO	Selective biowaste collection ongoing; no major change, focus on improving participation and infrastructure.

Mechelen also progressed significantly between 2023 and 2025 (Table 3). The city confirmed that its temporary postponement for separate biowaste collection had ended. According to the 2025 update, citywide household biowaste collection will start on 1 January 2026, moving from planning to action. Mechelen does not have its own biowaste regulations but applies the Flemish VLAREMA regional rules. Mechelen deviates from Flemish regulations by using public biowaste containers in dense areas where door-to-door collection is not feasible, an approach which is permitted through an official exemption.

In Košice, the changes were more gradual. The 2023 responses focused on the rollout of compulsory kitchen biowaste collection introduced in January 2023. By 2025, the emphasis shifted towards reporting results (Table 3). The system is fully operational across all districts, the obligation has been met, and more than 2,400 tons of biowaste were collected in 2023. Košice continued to advance operationally, though without major new decisions.

By contrast, Kranj/ Gorenjska and Thessaloniki/ Central Macedonia show no recorded changes from 2023 to 2025. Their entries for biowaste regulation, upcoming regulations, and strategic planning remained unchanged. Gorenjska did not report any updates within the survey cycle. Thessaloniki continues to operate under national legislation, with implementation managed by the regional FoDSA authority. Given the relatively short period of two years, the lack of visible change may simply reflect the naturally slow pace of municipal and regional waste system reforms.

4.3 Citizen Engagement, Infrastructure Requirements, and Remaining Challenges

All regions report active community engagement through educational campaigns, participatory planning, and feedback mechanisms. These measures are seen as essential for improving biowaste separation rates and

system efficiency, especially during transitions to new collection models. Cities also need practical collection systems, such as enough bins, accessible models like door-to-door, or solutions for dense urban areas. Some places plan or consider economic incentives, especially pay-as-you-throw schemes, to encourage proper sorting. A few regions also need to expand their processing capacity to handle increasing biowaste volumes. Common challenges across all regions include resource constraints, infrastructure gaps and adapting regulations to local needs. Some areas, such as Košice and Mechelen, report rapid progress but also face issues related to scaling up, ensuring quality, and maintaining citizen motivation.

5. Discussion

The findings of this study highlight that policy frameworks for biowaste management are converging, primarily due to EU directives, which strongly influence the development of national strategies. However, the pace and depth of implementation vary significantly between countries, cities and regions. While the EU sets targets for its member states, local adaptation is critical for success. Slovakia's and Belgium's phased rollout in Mechelen are examples of how national and regional authorities balance compliance with the practical constraints they face. Some regions, such as Lahti (Finland) and Catalonia (Spain), focus on incremental improvements and quality enhancement. This means working on two fronts: first, increasing the amount of organic material that ends up in the appropriate biowaste bins, and second, reducing the share of impurities mixed into that material. In short, good source separation is essential. It directly affects the quality of the compost produced and ensures that biowaste can safely return to agricultural systems.

The integration of digital tools highlights a shift from traditional, voluntary systems to mandatory, performance-managed models. These innovations improve operational efficiency and enable more precise data collection. Knowledge management, through regular updates, and cross-border learning, is increasingly recognized as a driver of continuous improvement. Collaboration between government, academia, industry, citizens can be observed in several regions. Community engagement is not only a best practice but also a necessity for successful transitions and sustained participation. Recommendations from the findings are to share best practices and lessons learned across regions to enhance and accelerate the achievement of the EU Circular economy goals. Furthermore, investments in infrastructure should be encouraged as well as capacity building to further support transitions.

From a theoretical standpoint, the cross-case comparison suggests that KM matters most where governance responsibilities are fragmented: progress is associated with mechanisms that translate EU-level requirements into locally actionable routines, such as shared indicators, structured reporting, and regular cross-actor feedback loops. This supports a view of KM not only as an internal organisational practice but as an inter-organisational capability that enables knowledge formation and coordinated implementation across governance levels. Practically, the findings point to three levers for regions and cities: (1) clarify mandates and interfaces between national, regional and inter-municipal actors; (2) invest in data infrastructure (quality/impurity measures, participation rates, service coverage) and digital tools that make performance visible; and (3) institutionalise learning through peer exchange and targeted citizen engagement to improve both capture rates and material quality.

6. Conclusion

This study analysed biowaste governance and recent developments across six European regions using survey waves conducted in 2023 and 2025. On the regional level, only Flanders and Catalonia reported noticeable progress in their biowaste systems, while others showed little or no change, maintaining existing frameworks. At the city level, the greatest developments took place in Lahti and Mechelen, with a partial change seen in Košice. Barcelona, Kranj, and Thessaloniki reported no new city-level regulations in the period, continuing their implementation under existing national or regional rules. For Slovenia and Greece, no new steps were recorded at any administrative level during the review period.

This suggests that for several regions the two-year window may simply have been too short for major policy or system changes. This does not necessarily indicate a lack of progress but rather reflects that waste-system reforms move slowly, and many regions are still working through the plans they already have in place. Overall, progress relies on combining clear communication, convenient infrastructure, capacity building, and supportive policies.

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AI Declaration: Copilot was used to help with translations from Finnish to English and in the ideation stage of the paper. Copilot was used to assist in the data analysis and visualization processes. Copilot was used to identify trends and patterns in the dataset. The authors reviewed and interpreted the AI-generated results to ensure their accuracy and relevance to the research objectives.

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