

Circular Bioeconomy and Knowledge Management: A Comparative Study of Evolving Practices

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Abstract: Circular bioeconomy (CBE) represents a pathway toward sustainable development by integrating circular economy principles with bio-based resource utilisation to reduce waste and optimise value creation. This paper examines how knowledge management (KM) practices enable systemic change within circular bioeconomy ecosystems, focusing on knowledge creation, sharing and strategic application. Building on insights from the foundational CITISYSTEM 2023 study, which explored stakeholder perspectives on circularity and knowledge flows, we compare the data collected in 2023 for the 2024 study with new, more comprehensive data collected in 2025. This comparative approach provides a longitudinal view of the evolving practices, technological adoption and cultural dynamics shaping the transition towards circularity. The results show that policy development between 2023 and 2025 varied significantly across regions. Three regions – Päijät-Häme (Finland), Košice (Slovakia) and Catalonia (Spain) – introduced updates or expanded implementation tools that strengthened strategic coherence and operational capacity. Others, such as Gorenjska (Slovenia) and Central Macedonia (Greece), saw little or no formal policy change. Stakeholder collaboration also differed widely. Regions with strong, diverse networks – such as Flanders (Belgium), Catalonia (Spain) and Košice (Slovakia) – were able to share knowledge more effectively and maintain more active policy environments, while regions with limited or fragmented networks progressed more slowly. By analysing trends over time, this study highlights the critical role of KM in fostering organisational learning, innovation and resilience within circular bioeconomy contexts. It underscores the importance of integrating KM into educational frameworks and governance structures to effectively support the continuity and scaling of circular practices. Practical insights into the current situation in the six diverse EU regions are provided for academia, industry and policymakers to leverage KM as a strategic enabler of broader systemic transformation. Overall, this comparative study contributes to understanding how knowledge ecosystems evolve and how they can accelerate the transition toward a more sustainable, inclusive, bio-based economy.

Keywords: Circular bioeconomy, Knowledge management, Knowledge sharing, Comparative analysis

1. Introduction

In recent years, the circular bioeconomy (CBE) has emerged as a key topic across Europe, driven largely by concerns about the excessive use of non-renewable resources and the resulting greenhouse gas emissions. At the same time, substantial quantities of biomass remain unvalorised, leading to unnecessary losses of natural resources and reduced efficiency in resource use (Mesa et al., 2024).

The European Bioeconomy Strategy increasingly emphasises the concept of CBE as a cornerstone for achieving resource-efficient biomass utilisation and climate neutrality. CBE represents a transformative approach that integrates circular economy principles with sustainable bioeconomy practices, aiming to reduce waste and maximise value creation across sectors such as agriculture, forestry, fisheries, aquaculture and industry (European Commission, 2025a; Tikkanen, 2025). The approach is central to the European Green Deal and the updated EU Bioeconomy Strategy, which prioritises circularity, resilience and industrial competitiveness (European Commission, 2025b).

Although the interest in the integration of the CBE is widespread, significant variations between countries and regions in Europe are evident (Eliasson et al., 2025; Haapea and Medkova, 2024). This heterogeneity depends on the following different factors: the development and consolidation of CBE in national policies; governance models; the objectives and phases of the regional strategies (Sánchez López, 2022); and differences in resources, infrastructures and technologies depending on the level of development and system maturity. Considering the situation, the need for studies comparing and sharing the CBE state in different regions is evident. Furthermore, longitudinal studies evaluating the evolution of strategies and knowledge over the years are equally important (Ferraz and Pyka, 2023).

The transition to a CBE depends on the capacity to create, share and apply knowledge. In this context, M enables and supports the development of the CBE in the system. KM is a powerful tool with which to generate, create and establish mechanisms to use, adapt and organise information and learning (Atiku, 2020).

The transition to a CBE can be boosted through different applications in KM. For instance, referring to waste management, the use of indicators or monitoring systems improves the selective collection of organic matter (improving the quality and quantity of it and reducing impurities in it). The strengthening of public awareness through dissemination actions (Interreg Europe, 2025). The use of technological systems to ameliorate the results (Haapea and Medkova, 2024).

Understanding KM as a key enabler of CBE development, this study compares how six European regions have developed their CBE-related policies and stakeholder structures over time. This study addresses the following research question: How have KM practices and stakeholder involvement supported the development of CBE policies across six European regions between 2023 and 2025?

2. Literature Review

Bioeconomy refers to the sustainable production and utilisation of renewable biological resources, encompassing their conversion into value-added products. This includes the transformation of biowaste into food, feed, bio-based materials and bioenergy. By promoting the efficient use of biological resources, the bioeconomy aims to reduce dependency on fossil-based inputs while fostering innovation in bio-based sectors (Carus and Dammer, 2018). Complementing this, *the circular economy* (CE) is defined as an economic model that seeks to minimise waste generation and retain products, materials and resources in the economy for as long as possible through strategies such as reuse, recycling and recovery (European Commission, 2015). Together, these concepts form the basis of a CBE, which integrates biological resource use with circularity principles to enable more sustainable, low-carbon and resource-efficient systems. Recent literature highlights CBE as a key pathway supporting climate neutrality, waste reduction and regenerative resource flows (Srivastav et al., 2025).

The transition to bioeconomy models has been supported for decades. Research has shown that closing nutrient loops in local bioeconomy systems can reduce dependence on non-renewable resources while enabling the production of local food and high-value bio-based products (European Commission, 2016; 2018). Agriculture remains central to this transition as it is the value chain most strongly associated with bioeconomy in Europe from the stakeholder point of view (Briers et al., 2024).

KM and capacity building are essential in the transition towards a circular bioeconomy as they enable the creation, transfer, application and dissemination of transformative innovations (Haapea and Medkova, 2024). Both can contribute to and guide the adoption of policies and strategies, and they can contribute to mature systems evolving.

The development of a mature system in a CBE depends on the governance. At the same time, it must be fed and boosted through KM and capacity building (Chembessi, 2023). According to this, monitoring and quantifying the progress and implementation of a CBE is an interesting strategy for adaptative governance (Kardung et al., 2021).

KM operates not only within institutional and policy frameworks but also across technical innovation processes and social interactions. For example, KM supports information flows across different levels of governance and society, connecting citizens as primary beneficiaries, universities and public and private organisations as the producers and disseminators of knowledge, and governmental institutions as the actors responsible for translating this knowledge into effective policies and innovative circular practices (Atiku, 2020).

Practical KM mechanisms include open platforms, regional forums and bioeconomy hubs that support communication, awareness, networking and interregional learning (Interreg Europe, 2024a, 2024b; Hofer et al., 2025). KM also supports technological development by transferring scientific knowledge into applications and by enabling interregional learning that accelerates CBE innovation (Interreg Europe, 2024c; Haapea and Medkova, 2024).

Recent research shows that learning and KM are not only supportive tools but also core elements related to how the CE actually advances in practice. They shape how people and organisations understand problems, experiment with new ideas and share solutions across sectors and regions, making them central to any genuine transition toward circularity. Chembessi (2023) further noted that studying how learning happens, what motivates actors to share knowledge and how information circulates within and between regions can offer valuable insights into shaping more coherent and effective CE strategies. Such reflections can help clarify how practical transition pathways emerge and how regions can strengthen their shift toward more sustainable production and consumption systems (Chembessi, 2023).

This study examines how six regions create, share and apply knowledge across two time points. KM is understood here as stakeholder-based knowledge sharing, monitoring and reporting, dissemination, inter-organisational coordination and structured platforms that support learning and exchange in the CBE transition.

In this study, policy development, stakeholder involvement, and knowledge sharing are understood as interconnected elements of CBE transition. Policy frameworks create the institutional conditions for action, stakeholder involvement brings together the actors needed for implementation and knowledge sharing enables coordination, learning and adaptation across these actors. Together, these elements shape the capacity of regions to advance a CBE transition.

3. Methodology

Altogether eight partners representing six EU regions participated in collecting the data for this study (Table 1). These partners represent public authorities and academia; thus, they played a crucial role in identifying and inviting the relevant stakeholders to participate in the survey. This approach helped to ensure that the survey captured a comprehensive and diverse range of perspectives on KM practices and the implementation of circular economy principles across different regions. The selected material was analysed using a structured qualitative comparative approach.

Two surveys were conducted for this CITISYSTEM study. Survey 1 assessed the situation in 2023 and was distributed online via Webropol software between June 2023 and February 2024. Project partners (Table 1) were responsible for submitting the responses. To make participation smoother, the survey was also provided as a Word document. This allowed partners to translate the questions when necessary and to collect information through phone calls, emails or in-person discussions with their stakeholders. Survey 2 described the situation in 2025 and followed a different approach. Instead of an online form, partners received an Excel file containing all responses from Survey 1. They added the updated information into a parallel column, making changes between the two years easy to compare. After receiving the completed files, we contacted partners individually by email or phone whenever clarification was needed.

Table 1: CITISYSTEM 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
Technical University of Košice	Slovakia		X	X
BSC, Business Support Centre Ltd, 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

The survey aimed to gather insight on KM practices, policy instruments and supporting strategies (roadmaps, action plans) for the CBE, the key stakeholders involved, challenges, circularity and related aspects. The full survey consisted of 103 questions, including conditional and open-ended question formats to obtain contextual detail and allow a qualitative comparison across countries and governance levels (Fraser, 2024). Although the full survey contained 103 questions, this article only includes the questions that directly addressed the study's research focus: policy and strategy frameworks, stakeholder involvement, circularity provisions and implementation instruments (such as action plans and roadmaps). The research focus items were selected because they enabled a consistent comparison of knowledge-related governance practices across the six regions and the two time points.

The analysis proceeded in three stages. First, the responses relevant to this article were grouped into four analytical categories: policy and strategy frameworks, stakeholder involvement, circularity-related provisions

and implementation instruments. Second, the 2023 and 2025 responses were compared within each region to identify changes over time. Third, the six regions were compared across these categories in order to identify similarities, differences and broader patterns in CBE development and knowledge-sharing structures. The comparison was guided by predefined analytical categories derived from the research objective rather than by formal coding procedures.

4. Results

This section presents comparative findings on how CBE-related policies have evolved across six European regions between 2023 and 2025 and examines the role of stakeholder involvement in supporting knowledge sharing during this period. Across the six regions, three broad patterns can be observed. First, regions with clearer policy updates tended to show stronger coordination and more structured knowledge-sharing arrangements. Second, regions with broader and more institutionalised stakeholder networks demonstrated a greater capacity to sustain policy development. Third, regions with limited stakeholder diversity and weaker coordination structures showed fewer policy changes and slower progress in implementation. The patterns suggest that policy development and knowledge-sharing capacity are closely linked in CBE governance.

4.1 Regional Policy Developments

Only two regions, Flanders and Catalonia, have a standalone regional bioeconomy strategy. They have also participated in other broader surveys focusing on the bioeconomy (Briers et al., 2024). In all the other studied regions, bioeconomy priorities remain integrated into broader regional policy instruments. At the regional level (Table 2), three regions achieved clear and significant policy updates during the period.

In Päijät-Häme, Finland, the earlier Circular Economy Roadmap was replaced by the Green Transition Programme (GTP) in 2024. This shift created a single, more coherent framework for environmental, carbon neutrality and circular activities, and regular monitoring and reporting. The new GTP integrates the CBE by embedding bio-based resource circulation into its key themes (material cycles, forests and land use, and a sustainable food system), making CBE a central pillar of the region's transition strategy.

In Slovak's Košice Region, bioeconomy priorities are legally and strategically integrated into the Program of Economic and Social Development of the Košice Self-Governing Region (PHSR KSK 2023–2027). By 2025, PHRSR entered an active monitoring phase, shifting from planning to implementation with measurable targets in circular economy, biomass utilisation and regional waste infrastructure. PHRSR shows strong progress in innovation ecosystem development, though delays persist in waste management infrastructure and composting deployment. This transition is reinforced by the formal update of the RIS3 innovation strategy, which now allocates €40 million to biotechnology, sustainable forestry and waste-to-resource solutions, strengthening the innovation base necessary for regional bioeconomy growth.

Table 2: Regional-Level Biobased Policy Comparison

Region/ Country	Main Policy 2023	Policy 2025	Policy Update 2023–2025	Description of Update	Stakeholder Involvement
Päijät-Häme/ Finland	Circular Economy Roadmap (with the bio-circular economy as one of the core thematic pillars)	New Green Transition Programme (6/2024)	YES	Roadmap replaced with unified Green Transition Programme; policy consolidation and updated monitoring	Quadruple Helix, Regional Päijät-Häme CE Group, 10 municipalities, universities (LAB, LUT), waste management companies.
Košice Region/ Slovakia	PHRSR 2023–2027	PHRSR Monitoring Phase + RIS3 upgrade	YES	Shift from planning to active monitoring; €40M RIS3 funding for biotechnology, forestry & waste-to-resource innovation	Industry, academia (TUKE, UPJŠ), regional government bodies (VÚC, VAIA), NGOs, an innovation hub (ICKK)
Gorenjska/Slovenia	Regional Development Programme 2021–2027	Programme update in preparation	NO – no significant change	Preparatory analytical work but no new strategy adopted	Municipalities, a regional authority, limited

					cross-sector engagement
Flanders/Belgium	Bioeconomy Strategy + Circular Economy Strategy	Bioeconomy Monitor 2025 2 nd report update	A PARTIAL UPDATE – a monitoring update only	A new monitoring report was released; the policy framework itself was unchanged	A strong quintuple helix: public authorities, universities, clusters, industry & NGOs
Central Macedonia / Greece	RWMAP	RWMAP unchanged	NO – no significant change	No new measures or expansions reported	Municipalities, solid waste agencies, NGOs, limited private sector involvement
Catalonia/ Spain	Catalan Bioeconomy Strategy 2030 (EBC2030)	2025–2027 Action Plan (44 new actions) + New Catalan Biogas Strategy 2030	YES	The Action Plan expands ECB2030's scope with 10 transformative actions and 44 operational actions Biogas Strategy supports organic-waste valorisation and biogas production	Government, research centres, industry, NGOs, the agriculture sector.

In Catalonia, the EBC2030 strategy itself did not change between 2023 and 2025, but the publication of the new Action Plan expanded implementation through ten transformative actions and 44 operational actions. The update strengthens operational capability but does not alter the core EBC2030 strategy. The new Catalan Biogas Strategy 2024–2030 supports the goals of EBC2030 by promoting the valorisation of organic waste and the production of renewable biogas. Although it is a separate strategy, it is aligned with Catalonia's broader bioeconomy plans and helps advance EBC2030's objectives.

Flanders' circular economy strategy is implemented through the following six themed strategic agendas developed under Circular Flanders: circular construction, bioeconomy, circular chemistry and plastics, the manufacturing industry, the food chain and water cycles. At the same time, Flanders maintains a separate, dedicated Bioeconomy Strategy up to 2030 which defines long-term objectives for a sustainable regional bioeconomy and operates independently, though it is fully aligned with the broader circular economy strategy. The existing regional bioeconomy strategy remained in force, but the publication of the second *Bioeconomy Monitor* report in 2025 strengthened the evidence base for policy monitoring. Although this was not a new policy, it did improve the region's capacity to follow progress.

Two regions did not show significant policy change. In Gorenjska, Slovenia, preparations were underway to update the regional development programme later, but no new bioeconomic strategy or policy was formally adopted. In Central Macedonia, Greece, the regional waste management plan (RWMAP) stayed unchanged during this period. Taken together, these findings indicate that the most dynamic regions were not necessarily those with entirely new policy strategies, but those that strengthened implementation, monitoring and coordination mechanisms. Policy development therefore appears to depend not only on the existence of strategies but also on the institutional capacity to update, operationalise and follow them over time.

4.2 Knowledge Sharing Through Stakeholder Involvement

Sustainable regional development can be seen as an exchange ecosystem in which businesses and diverse stakeholders provide reciprocal access to knowledge and resources, generating value at both organisational and systemic levels. Knowledge sharing across environmental, social and economic dimensions strengthens stakeholder engagement and enhances coordinated responses to sustainability challenges (Sorrano et al., 2025). From a policy perspective, stakeholder knowledge sharing is not only a normative principle but a practical governance challenge. Effective bioeconomy governance depends on sustained knowledge exchange between policymakers, businesses, researchers and civil society actors, supported by participatory instruments such as stakeholder dialogues, living labs and co-production processes (Gerdes et al., 2018).

Across the participating regions, the survey shows differences in how stakeholders' networks support knowledge exchange within the circular and bioeconomy developments. Some regions demonstrate highly developed and diverse networks that actively support knowledge exchange, while others still work with more limited groups, which slows learning and implementation (Table 2).

Flanders is one of the strongest examples of benefiting from a long-standing and mature structure that involves universities, innovation platforms and clusters, sector federations, industry, NGOs, data providers and even European institutions (such as the Joint Research Centre, the NOVA Institute, Eurostat, FAO). For instance, the Flemish Bioeconomy Monitor report was jointly developed by Flemish government departments and agencies; research institutions (including VITO, ILVO) and universities sector federations representing food, chemistry, textiles, forestry and more; numerous companies ranging from established bioindustry players to SMEs; and European partners such as the Joint Research Centre and Eurostat. Complementing this with circular economy activities, Circular Flanders operates as a quintuple-helix partnership involving public authorities, universities, research institutes, NGOs, sector federations and entrepreneurial networks. Although formally administered by OVAM, it functions as a collaborative platform where strategies and action plans are co-created rather than top-down imposed. This broad and interconnected ecosystem allows knowledge to circulate continuously and positions Flanders among the strongest knowledge-exchange regions in the study.

The stakeholder landscape in the Košice Region has broadened in recent years, extending beyond regional authorities, such as the Košice Self-Governing Region, to national bodies like the Research and Innovation Authority. Academic institutions (TUKE and UPJŠ) contribute actively as founding partners of the Innovation Center of the Košice Region, a regional innovation hub that connects universities, regional government, research organisations and industry. Alongside academia and public administration, industry actors and NGOs are increasingly engaged through this expanded ecosystem. As the region entered a more structured monitoring phase, this broader stakeholder network has enabled more continuous feedback and better coordination of innovation activities.

Catalonia brings together government departments, research centres, private industry, NGOs and the agricultural sector. This multi-actor cooperation enables the region to effectively implement the EBC2030 Strategy and the expanded 2025–2027 Action Plan. Because so many actors are involved across different value chains, from biomass use to bioenergy and new biobased products, the region can coordinate its efforts and keep development moving in the right direction. In addition, the competent administration organises at least one congress (the Bioeconomy Congress) in Lleida and/or Vic; these events are not only a powerful tool with which to show and to facilitate the collaboration among the stakeholders, they also allow the stakeholders to present posters to show their improvements.

In Finland, stakeholder cooperation is mainly organised through the Päijät-Häme Circular Economy Group, which brings together municipalities, universities (LAB, LUT, HY), Salpakierto Waste Management, development organisations and other regional actors. This group has long served as the core platform for sharing information, aligning projects and updating regional priorities. It played an important role in preparing and refining the Circular Economy Roadmap and continues to support the region's shift toward the newer Green Transition Programme. According to the survey, collaboration within the group works well, but the region still struggles with limited human and financial resources. These constraints make it challenging to broaden participation or scale up knowledge-sharing activities even though the structures for cooperation are firmly in place. Despite this, the group remains the key driver connecting local authorities, research actors and businesses, and it ensures that regional learning continues in a steady, coordinated way.

Finally, some regions still operate with very narrow stakeholder groups. In Central Macedonia, cooperation is mostly centred around municipalities, solid waste agencies and NGOs, and there is little involvement from the private sector. In Gorenjska, involvement is mostly limited to municipalities and the regional authority, with wider stakeholder participation remaining limited. In both cases, the lack of a broader network restricts opportunities to exchange knowledge, and this may both slow the adoption of new practices and limit the regions' ability to update or expand their policies. Overall, the findings suggest that stakeholder involvement functions as an important knowledge-sharing mechanism in governance. Regions with broader and more organised stakeholder networks are better able to sustain information exchange, coordinate implementation and maintain policy momentum. In contrast, regions with narrower stakeholder structures show more limited possibilities for learning, coordination and policy development.

5. Discussion

Across the six regions, circular bioeconomy is advancing at differing speeds, reflecting not only differences in formal policy frameworks but also variation in governance capacity, stakeholder diversity and the continuity of knowledge-sharing structures. Regions such as Flanders, Košice and Catalonia benefit from broader and more institutionalised stakeholder ecosystems that support coordination, monitoring and implementation, while regions with narrower stakeholder bases and weaker coordination structures appear to have fewer opportunities for continuous learning and adaptation. This suggests that regional progress depends not only on the existence of strategies but also on the capacity to sustain interaction, feedback and shared learning. The involvement of diverse actors is also important for improving both the quality of recyclable inputs and the value of outputs returned to the market (Angouria-Tsorochidou et al., 2021).

A common theme found through all regions is the role of stakeholder involvement (Sadeghzadeh et al., 2025). Regions with strong, long-lasting networks (Flanders being the best example) benefit from collective complementarity and intelligence. Another key issue to explore is the sector of the different stakeholders. Because circularity is a key issue for the agricultural sector and because agriculture plays a major role in some countries, the leadership of bioeconomy strategies may lie with agricultural authorities, such as is the case with the Agriculture and Livestock Department in Catalonia. It is thus essential to ensure strong representation from the agricultural sector. Regarding stakeholder involvement, four out of the six regions reported the participation of NGO associations. This finding highlights the potential role of NGOs in supporting implementation processes, particularly by contributing to knowledge sharing and fostering broader societal engagement in the transition towards a more circular society.

Another key driver for the implementation of bioeconomy strategies focused on residues is linked to the regulatory and institutional regime (Angouria-Tsorochidou et al., 2021). Future research should examine how stakeholder goals shape the implementation of bioeconomy policies (Briers et al., 2024).

6. Conclusion

Between 2023 and 2025, European regions took different paths in developing their CBE agendas. Some embraced change, while others kept existing structures in place. Several of the participating countries introduced new or updated policy frameworks, while others retained existing structures. The results confirm that evolution in CBE depends not only on the number of policy instruments but also on the degree of coordination, stakeholder engagement and knowledge-sharing mechanisms.

Social acceptance and citizen engagement can be seen as important enabling factors for the long-term success of CBE transitions. The study highlights clear differences in stakeholder involvement across the regions. The regions characterised by broader and more diverse stakeholder networks demonstrate stronger capacities for knowledge exchange, coordination and implementation. Overall, the findings suggest that inclusive governance and sustained knowledge exchange are important enabling factors for advancing CBE transitions and supporting regional progress. Knowledge sharing appears essential for long-term progress and policy implementation. The findings align with earlier research (Sorrano et al., 2025; Gerdes et al., 2018) emphasising that knowledge sharing across environmental, social and economic dimensions strengthens stakeholder engagement and supports coordinated responses to sustainability challenges. Sustained knowledge exchange between policymakers, businesses, researchers and civil society appears central to effective CBE implementation.

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AI Declaration: Copilot was used to help with translations from Finnish to English. Copilot was used to assist in the data analysis and visualisation 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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