Regional Circular Economy Knowledge Hubs As Future Enablers Of The Green Transition In EGTC-Based Cross-Border Cooperation

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The European Union's transition towards a circular economy necessitates profound technological, institutional, and societal transformations. Regional circular economy knowledge hubs are emerging as potential instruments to facilitate this transition, particularly within EGTC-based cross-border cooperation networks, although their practical implementation remains limited. This paper employs Multi-Level Perspective to explore the prospective role of such hubs, situating them within broader socio-technical landscapes, regional regimes, and niche innovations. Analysis suggests that knowledge hubs could enable the alignment of local competencies, industrial experimentation, and policy frameworks, fostering the development of resilient, regionally embedded circular economy models. By bridging emerging niche practices and established regional structures, these hubs may support the stabilization of sustainable innovations, enhance cross-border learning, and promote inclusive regional development. The research also identifies potential challenges, including institutional fragmentation, uneven resource distribution, and varying levels of stakeholder engagement, which could constrain their future effectiveness. Policy implications highlight the importance of strategically supporting experimental, multi-level initiatives, reinforcing the institutional embedding of knowledge hubs, and encouraging the replication and scaling of successful practices across regions. Although largely conceptual, regional circular economy knowledge hubs could represent a strategic pathway for advancing green transition, enhancing regional resilience, and promoting socially responsible, sustainable development across European territories.

Keywords:
circular economy,
regional knowledge hub,
green transition,
EGTC,
Multi-Level Perspective

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1 Introduction

The accelerating ecological crisis, increasing resource constraints, and intensifying geopolitical uncertainties have reinforced the urgency of the European Union's green transition agenda (Innella et al., 2024). The transformation towards a circular economy is not merely a technological adjustment but a systemic socio-technical transition requiring coordinated changes across production systems, governance structures, and societal practices (De Felice & Petrillo, 2021; Macher & Szigeti, 2025a). Within this broader transformation, regional scales have emerged as critical arenas for experimentation, institutional innovation, and policy implementation (Crowther et al., 2021). While the circular economy has been extensively discussed in relation to industrial symbiosis, waste valorisation (Macher et al., 2023), and sustainable production models, less attention has been devoted to the institutional architectures that enable regional-level coordination and cross-border alignment (Södergren & Palm, 2021). This gap is particularly relevant in the context of European cross-border regions, where economic interdependencies, asymmetric development levels, and fragmented governance arrangements complicate the operationalisation of circular strategies (Teixeira, 2025; Vanhamäki et al., 2021). European Groupings of Territorial Cooperation (EGTCs) were established to facilitate structured cross-border collaboration, yet their potential role in advancing systemic sustainability transitions remains underexplored (Jańczak, 2016; Øjvind Nielsen et al., 2024).

Existing research on socio-technical transitions, particularly within the Multi-Level Perspective (MLP), has highlighted the importance of niche experimentation, regime destabilisation, and landscape pressures in driving transformation processes (Andersen et al., 2026; F. Geels, 2024; Radtke, 2025). However, the meso-level governance mechanisms that mediate between emerging niche innovations and established regional regimes have received comparatively limited analytical attention, especially in cross-border institutional settings (Bui, 2021; Derudder & Liu, 2025). In this respect, regional circular economy knowledge hubs may represent a missing institutional intermediary capable of facilitating coordination, knowledge circulation, and policy alignment across administrative boundaries (Barrie et al., 2022; Teixeira, 2025). Regional knowledge hubs can be conceptualised as structured platforms that integrate academic expertise, industrial experimentation, policy frameworks, and civil society engagement within territorially embedded networks (Hegyi &

Mariussen, 2021). When embedded in EGTC-based cooperation structures, such hubs may function as cross-border transition intermediaries, enabling the stabilisation and scaling of circular innovations while fostering institutional learning across regions (Cramer, 2020; Dąbrowski et al., 2019). Rather than operating as isolated innovation clusters, they may contribute to the gradual reconfiguration of regional socio-technical regimes by bridging fragmented governance environments and supporting coordinated experimentation (Engels et al., 2019).

Despite their conceptual promise, the practical implementation of regional circular economy knowledge hubs remains limited, and their systemic role within cross-border governance architectures has not yet been thoroughly theorised (Dąbrowski et al., 2019). This paper addresses this gap by exploring how such hubs could function within EGTC-based cooperation frameworks and by situating them within the MLP on sustainability transitions. By integrating transition theory with cross-border governance analysis, the paper aims to advance the understanding of meso-level institutional innovation in the context of the green transition. The central research question guiding this paper is:

RQ: How can regional circular economy knowledge hubs operate as enabling intermediaries of the green transition within EGTC-based cross-border cooperation structures?

To answer this question, the paper develops a conceptual framework that positions knowledge hubs at the intersection of niche experimentation and regional regime transformation. It examines the enabling and constraining institutional conditions shaping their emergence, analyses their potential contribution to resilience and inclusive regional development, and discusses policy implications for scaling and institutional embedding. By focusing on cross-border cooperation structures, this paper contributes to three strands of literature: (1) circular economy governance at the regional scale, (2) socio-technical transition theory, particularly the MLP, and (3) cross-border institutional innovation within the European Union. In doing so, it proposes a refined understanding of regional knowledge hubs as strategic enablers of the green transition and as potential catalysts for territorially embedded, socially responsible, and resilient circular economy pathways.

2 Theoretical Background

The transition towards a circular economy represents a systemic transformation that extends beyond technological substitution or incremental efficiency improvements (Jakubowski & Miszczuk, 2021). It entails a reconfiguration of production-consumption systems, institutional arrangements, and socio-economic coordination mechanisms (Plotnic & Crudu, 2024). As such, the circular economy can be interpreted within the broader framework of sustainability transitions, where structural change unfolds through dynamic interactions between innovation niches, established regimes, and exogenous landscape pressures (Chizaryfard et al., 2021). The MLP provides a useful analytical lens for understanding these processes. Within this framework, landscape-level developments, such as climate change (Sipos et al., 2023), resource scarcity, and European Union policy commitments, exert pressure on dominant socio-technical regimes (F. Geels, 2024; Macher & Szigeti, 2025b). These regimes, composed of stabilised industrial structures, regulatory frameworks, and behavioural patterns, tend to resist radical transformation due to path dependencies and institutional lock-in (Kanger et al., 2020). Change often emerges through niche-level experimentation, where protected spaces allow novel technologies, governance models, and organisational forms to develop and mature. Transition occurs when landscape pressures destabilise regimes and niche innovations gain sufficient momentum to diffuse and reconfigure existing systems (Westley et al., 2011). While the MLP has been widely applied to national energy transitions and sectoral transformations (Pécsinger et al., 2025), its regional and cross-border governance dimensions remain comparatively underexplored (De Propris & Bailey, 2021; Vähäkari et al., 2020). Regions are not merely passive arenas where transitions unfold; they are active sites of coordination, experimentation, and institutional learning (Grandin & Sareen, 2020). Industrial ecosystems, labour markets, innovation capacities, and policy competences are territorially embedded, making regional governance structures crucial in mediating between niche innovation and regime transformation (Song & Zhao, 2024). In this respect, meso-level institutional arrangements play a pivotal role in aligning actors, mobilising resources, and stabilising emerging practices (Battilana et al., 2009; Foulds et al., 2025).

Cross-border regions introduce additional complexity into transition processes. Administrative fragmentation, regulatory asymmetries, and uneven economic development can hinder coordinated sustainability strategies (Hu & Pikalo, 2025; Korhonen et al., 2021). At the same time, cross-border cooperation offers opportunities for complementary specialisation, shared infrastructure development, and knowledge exchange (Rammal et al., 2023). In this context, EGTCs constitute formalised governance frameworks designed to facilitate structured collaboration across national boundaries. Although primarily established to support territorial cohesion and project coordination, EGTCs may also provide institutional platforms for sustainability-oriented transformation (Evrard, 2016). Their hybrid nature, positioned between local, regional, and supranational governance levels, makes them particularly relevant for analysing multi-level transition dynamics (Topaloglou & Ioannidis, 2022; Yasmin et al., 2022). In this context, regional circular economy knowledge hubs can be conceptualised as potential transition intermediaries embedded within cross-border governance structures (Joltreau et al., 2025; Kern et al., 2020). Transition intermediaries are actors or platforms that facilitate interaction between niche innovators and regime actors, coordinate experimentation, and contribute to the diffusion and stabilisation of sustainable practices (Ehnert, 2023). When institutionally anchored within EGTC-based cooperation frameworks, knowledge hubs may enhance cross-border learning, reduce institutional fragmentation, and align regional development strategies with circular economy objectives (Eckardt & Gritsch, 2016). By integrating academic expertise, industrial experimentation, policy coordination, and stakeholder engagement, they can function as meso-level mechanisms that translate landscape pressures into territorially embedded transformation pathways (Jalonen & Uusikylä, 2025).

Despite the growing recognition of intermediaries in sustainability transitions, limited attention has been paid to their role in cross-border institutional settings (Kanda et al., 2020). The theoretical challenge lies in understanding how such hubs can simultaneously operate across governance scales, reconcile divergent regulatory environments, and contribute to regime reconfiguration without formal legislative authority (Jordana, 2017). Addressing this gap requires integrating transition theory with cross-border governance analysis, thereby extending the MLP framework towards a more territorially sensitive and institutionally nuanced perspective (Laur & Kanda, 2025).

By positioning regional circular economy knowledge hubs within EGTC-based cooperation structures, this paper advances the conceptualisation of meso-level institutional innovation in the green transition (Heurkens & Dąbrowski, 2020). It argues that such hubs may not merely support incremental innovation but can act as enabling infrastructures that mediate between niche experimentation and regional regime transformation, fostering resilience, inclusiveness, and long-term sustainability across European cross-border territories (Coenen et al., 2012; F. W. Geels, 2002).

3 Conceptual Framework

Building upon the MLP, this section develops a conceptual framework that positions regional circular economy knowledge hubs as cross-border transition intermediaries embedded within EGTC-based governance structures. Within the conventional MLP framework, niche innovations emerge in protected spaces, regimes stabilise dominant socio-technical configurations, and landscape pressures destabilise existing systems (El Bilali, 2019; Figueira et al., 2025). However, the framework pays comparatively limited attention to the institutional mechanisms that facilitate interaction between niches and regimes at the regional scale, particularly in cross-border contexts where governance fragmentation and regulatory asymmetries prevail. This paper argues that regional circular economy knowledge hubs may function as structured meso-level infrastructures capable of mediating these interactions. Conceptually, the proposed model introduces an intermediate governance layer situated between niche experimentation and regime transformation, embedded within cross-border cooperation structures. In this configuration:

- Landscape pressures (EU Green Deal objectives, climate neutrality commitments, resource security concerns) generate transformation imperatives.
- Regional socio-technical regimes reflect territorially embedded industrial systems, regulatory traditions, and institutional arrangements.
- Circular economy niches consist of experimental business models, technological pilots, and collaborative innovation initiatives.

- EGTC-based governance structures provide formalised cross-border coordination platforms.
- Regional circular economy knowledge hubs operate within this cross-border governance field as transition intermediaries.

Unlike isolated innovation clusters, knowledge hubs are conceptualised here as institutionalised coordination mechanisms with four interrelated functions:

- Alignment function: synchronising policy frameworks, regional development strategies, and industrial priorities across borders.
- Translation function: converting landscape-level sustainability objectives into regionally operationalised initiatives.
- Stabilisation function: supporting the institutional embedding and scaling of niche innovations within existing regimes.
- Learning and diffusion function: facilitating cross-border knowledge exchange and cumulative institutional learning.

In practical terms, these functions may include joint mapping of regional material flows, cross-border pilot coordination, shared training activities, and mechanisms for integrating successful experiments into EGTC development strategies. Through these functions, knowledge hubs may reduce institutional fragmentation, mitigate asymmetries between neighbouring regions, and enhance the resilience of circular transition pathways. Importantly, their transformative capacity does not derive from hierarchical authority but from their ability to coordinate, convene, and structure multi-actor collaboration across governance levels. The framework thus reconceptualises regional knowledge hubs as enabling infrastructures of sustainability transitions rather than as passive knowledge repositories. By embedding niche experimentation within cross-border governance architectures, they may create semi-protected institutional environments that both shield emerging practices and expose them to regime-level actors, facilitating gradual structural reconfiguration. Based on this conceptualisation, the following theoretical propositions are advanced:

- Proposition 1: The effectiveness of regional circular economy knowledge hubs increases when they are institutionally embedded within formalised cross-border governance structures such as EGTCs.
- Proposition 2: Knowledge hubs enhance the stabilisation and diffusion of circular economy niche innovations by performing alignment and translation functions between landscape pressures and regional regimes.
- Proposition 3: In cross-border contexts characterised by institutional asymmetry, knowledge hubs mitigate governance fragmentation by facilitating structured multi-level coordination.
- Proposition 4: The long-term transformative impact of knowledge hubs depends on their capacity to institutionalise learning processes and integrate circular practices into regional development strategies.

These propositions extend the MLP by introducing a territorially grounded meso-level intermediary concept specific to cross-border sustainability governance. The model highlights that transition processes in European border regions are not solely driven by technological breakthroughs or top-down policy shifts, but also by the institutional quality of coordination mechanisms capable of linking experimentation with structural change.

4 Discussion

The conceptualisation of regional circular economy knowledge hubs as cross-border transition intermediaries has several theoretical and governance-related implications. First, it refines the application of the MLP by foregrounding the importance of territorially embedded meso-level coordination mechanisms in sustainability transitions. Rather than viewing regime transformation as the outcome of niche momentum combined with landscape destabilisation, the framework highlights the institutional infrastructures that condition whether such interactions become stabilised and scalable. In cross-border contexts, transition dynamics are shaped not only by technological innovation and policy ambition but also by institutional asymmetry and administrative fragmentation (Miörner et al., 2018). Border regions frequently operate under divergent regulatory systems, funding mechanisms, and strategic priorities. These structural differences can slow down or even inhibit the diffusion of circular economy practices. By operating within structured cooperation

platforms such as EGTCs, regional knowledge hubs may create a semi-integrated governance field capable of mitigating these asymmetries without requiring full institutional harmonisation (Arsova et al., 2022; Kruse & Wedemeier, 2023). This suggests that transition processes in border regions are mediated by the quality of coordination rather than by formal authority alone.

Second, the framework shifts the analytical focus from isolated innovation projects towards systemic alignment processes. Circular economy experimentation often remains confined to pilot initiatives or sector-specific collaborations (Webster & Pascucci, 2024). Without institutional embedding, such initiatives risk remaining marginal. Knowledge hubs, when strategically positioned within cross-border governance structures, may facilitate cumulative learning and policy coherence, thereby increasing the likelihood that niche practices influence regime-level configurations (Bui et al., 2016; Concilio et al., 2023). In this sense, their role extends beyond knowledge dissemination, they function as translation mechanisms that convert abstract sustainability objectives into territorially operational strategies. Illustrative applications may include joint circular pilot projects, shared regional training programmes, or cross-border industrial symbiosis initiatives coordinated within EGTC-based cooperation frameworks. Third, the model underscores the relational nature of resilience in cross-border green transitions. Resilience is not merely the capacity to withstand external shocks, but the ability to adapt through coordinated institutional learning (Biesbroek et al., 2017; Han et al., 2025). Knowledge hubs may enhance adaptive capacity by structuring multi-actor dialogue, fostering trust across borders, and integrating industrial experimentation into regional development agendas. This relational resilience is particularly relevant in European border regions facing economic disparities, demographic challenges, and uneven industrial specialisation (Ezcurra & Rios, 2019).

At the same time, the transformative potential of such hubs should not be overstated. Their effectiveness depends on stable funding mechanisms, political commitment, stakeholder engagement, and the ability to maintain legitimacy across administrative systems. Without sufficient institutional embedding, knowledge hubs risk functioning as project-based networks with limited structural impact (Pantiris et al., 2025; Tumpa & Naeni, 2025). Moreover, power asymmetries between neighbouring regions may influence agenda-setting processes, potentially reproducing existing development imbalances rather than mitigating them. The

discussion therefore points to a broader theoretical insight, sustainability transitions in cross-border regions require intermediary infrastructures capable of navigating institutional plurality. By conceptualising regional circular economy knowledge hubs as structured coordination mechanisms embedded in EGTC-based cooperation, this paper contributes to a more territorially sensitive interpretation of transition theory. It emphasises that the green transition in European border regions is not solely a matter of technological diffusion or regulatory reform, but also of institutional design and cross-border governance capacity. It situates regional circular economy knowledge hubs as potential enabling infrastructures of the green transition, capable of bridging niche experimentation and regional socio-technical regimes within complex cross-border governance environments.

5 Conclusions

The analysis presented in this paper suggests that regional circular economy knowledge hubs may represent a strategically significant yet currently underutilised governance instrument in advancing the green transition within cross-border regions. By conceptualising these hubs as transition intermediaries embedded in EGTC-based cooperation frameworks, the paper has extended the MLP towards a more territorially grounded and institutionally nuanced understanding of sustainability transformation. Knowledge hubs cannot function effectively as transformative intermediaries if they remain project-based or loosely coordinated networks. Their stabilising and alignment capacities depend on formal anchoring within cross-border governance architectures, predictable funding mechanisms, and clearly defined mandates. Policymakers should therefore prioritise integrating circular economy knowledge infrastructures into existing EGTC cooperation strategies rather than treating them as auxiliary innovation platforms.

Cross-border coordination requires structured translation mechanisms. Landscape-level sustainability objectives, such as climate neutrality, resource efficiency, and circular industrial policy, must be operationalised in ways that reflect regional industrial structures and socio-economic asymmetries. Knowledge hubs can perform this translation role by aligning regional development strategies, facilitating joint experimentation, and creating shared strategic narratives across administrative boundaries. Policy instruments should support these alignment processes through multi-level coordination schemes and dedicated cross-border funding streams. The

long-term transition capacity depends on institutionalised learning. Circular economy transformation is inherently iterative and path-dependent. Knowledge hubs may enhance regional resilience not simply by disseminating technical expertise but by embedding continuous learning, evaluation, and feedback mechanisms into cross-border governance structures. This requires sustained stakeholder engagement, transparency in decision-making processes, and mechanisms to integrate experimental outcomes into mainstream regional policy frameworks.

At the same time, several structural constraints must be acknowledged. Institutional fragmentation, uneven resource distribution, and political discontinuities may limit the effectiveness of cross-border knowledge infrastructures. Without strategic coordination, hubs risk reinforcing existing asymmetries between neighbouring regions rather than mitigating them. Furthermore, the absence of regulatory harmonisation may constrain scaling processes, even when collaborative platforms are present. These challenges underscore the need for carefully designed governance architectures that balance flexibility with institutional stability.

This paper contributes to sustainability transition research by introducing the concept of the cross-border transition intermediary as a meso-level institutional mechanism within the MLP. It highlights that regime transformation in European border regions is mediated not only by technological innovation and macro-level policy pressures but also by the quality of territorially embedded coordination infrastructures. By integrating transition theory with cross-border governance analysis, the paper advances a more spatially sensitive interpretation of circular economy transformation. Although largely conceptual, the proposed framework provides a foundation for future empirical research. Comparative case studies of EGTC-based cooperation structures, network analyses of stakeholder interactions, and longitudinal assessments of circular innovation scaling could further test and refine the propositions advanced here. Such investigations would deepen the understanding of how institutional design influences transition outcomes across diverse European territories.

Regional circular economy knowledge hubs have the potential to function as enabling infrastructures of the green transition in cross-border contexts. Their transformative capacity lies not in hierarchical authority, but in their ability to coordinate, align, and stabilise emerging circular practices within fragmented

governance environments. If strategically embedded and adequately supported, they may contribute to the development of resilient, inclusive, and territorially anchored circular economy pathways across European border regions.

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