Systemic, multi-stakeholder collaboration to achieve zero-waste cities and decarbonised industrial systems

Christina Krenn[1],

Johannes Fresner[2],

Fernando Burgoa Francisco[3],

Dr. Rembrandt Koppelaar[4]

[1] *STENUM GmbH, Anton Kleinoschegstraße 21, A-8051 Graz, Christina.krenn@stenum.at*

[2] *STENUM GmbH, Anton Kleinoschegstraße 21, A-8051 Graz, Johannes.fresner@stenum.at*

Fundación CARTIF, Parque Tecnológico de Boecillo, parcela 205, CP: 47151, Boecillo (Valladolid). Spain ferbur@cartif.es

[n] *EcoWise Ltd, 184 Shepherds Bush Road,W6 7NL , London, UK ,*
rembrandt.koppelaar@eco-wise.co.uk

Abstract

Achieving zero-waste cities and decarbonised industrial systems requires a systemic shift from linear to circular value chains, enabled by multi-stakeholder collaboration. The United Circles project, funded by the EU Horizon Europe programme (Grant 101178798), pioneers new governance models to drive this transition. Coordinated by CARTIF (Spain) with 48 partners, the project promotes urban-industrial symbiosis through mission-driven networks called Hubs4Circularity.

United Circles positions a neutral, facilitating Hub4Circularity as essential for coordinating diverse stakeholders—governments, industry, academia, and the waste sector—to ensure equitable participation and decision-making. These hubs manage stakeholder engagement, technology evaluation, investment mobilisation, and implementation oversight, fostering systemic knowledge exchange and network formation. The project targets three key material streams: construction and demolition waste, urban and industrial wastewater, and food waste, supporting 15 innovative circular solutions such as 3D-printed recycled construction materials, wastewater resource recovery, and bioplastics from used cooking oil. These solutions are embedded within regional hubs to scale adoption, attract investment, and enhance resilience.

United Circles aims to demonstrate near-zero-waste cities through commercial-scale pilots; reduce resource consumption (e.g., 50% freshwater savings and 90% solid waste recycling at a Spanish wastewater site); foster healthier, low-emission urban environments; and strengthen international cooperation aligned with the European Green Deal. Pilots in Spain, Italy, and Turkey validate these interventions, while “mirror” and “seed” hubs in Hungary, South Africa, Lebanon, and Austria support contextual adaptation and broader uptake of the hub model.

This paper presents the conceptual foundation and strategic implementation of the Hubs4Circularity model, highlighting its transformative potential to scale circular practices across diverse socio-economic contexts. It underscores the necessity of a neutral, multi-stakeholder governance structure and details the tools, frameworks, and support mechanisms critical for effective hub operation.

1. Introduction

Urban and industrial systems worldwide face urgent pressures to eliminate waste, reduce carbon emissions, and improve resource efficiency. These challenges require a fundamental transformation from the traditional linear economy—characterized by "take-make-dispose" resource flows—to circular economy models that keep materials in use, regenerate natural systems, and decarbonize production (Ellen MacArthur Foundation, 2013).

This transition is inherently complex, involving multiple actors operating across different sectors and governance levels. It demands systemic collaboration that transcends organizational boundaries, sectors, and geographical regions. Achieving zero-waste cities and decarbonised industrial systems hinges on governance models capable of orchestrating diverse stakeholders around shared goals, equitable participation, and collective action (Kirchherr, Reike & Hekkert, 2017).

The United Circles project, funded by the EU Horizon Europe programme (Grant 101178798), directly addresses these challenges by pioneering new governance mechanisms centred on mission-driven "Hubs4Circularity." These hubs function as neutral, facilitating bodies coordinating stakeholders to co-create and scale circular solutions embedded in regional industrial and urban contexts.

2. The United Circles project

United Circles brings together 48 partners across Europe and beyond, coordinated by CARTIF (Spain), with a shared mission to accelerate circular urban-industrial symbiosis. The project focuses on three priority material streams: construction and demolition waste, urban and industrial wastewater, and food waste. Through 15 innovative circular solutions—ranging from 3D-printed construction materials using recycled aggregates, resource recovery from wastewater, to bioplastics derived from used cooking oil—United Circles demonstrates the scalability and economic viability of circular innovations.

Central to the project are the Hubs4Circularity, regional networks acting as convenors and coordinators to facilitate collaboration among governments, industry, academia, investors, and the waste sector. These hubs:

- Engage stakeholders through inclusive dialogue and participatory decision-making processes
- Evaluate and validate circular technologies and innovations
- Mobilize investments and align financial mechanisms with project needs
- Oversee pilot implementation and monitor environmental and social impacts
- Facilitate systemic knowledge sharing and network development

The project implements commercial-scale pilots in Spain, Italy, and Turkey to demonstrate near-zero-waste urban-industrial symbiosis, achieving significant reductions in resource use such as 50% freshwater savings and 90% recycling of solid waste at a Spanish wastewater treatment facility. Additionally, "mirror" and "seed" hubs in Hungary, South Africa, Lebanon, and Austria support regional adaptation and broader uptake of the hub model.

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3. Different levels of hubs: Demonstrator, mirror, and seed

These hubs coordinate stakeholders including governments, industry, academia, and the waste sector to ensure equitable participation and decision-making (Galera & Borzillo, 2009; Reed, 2008). Functions of these hubs encompass stakeholder engagement, technology evaluation, investment mobilisation, and implementation oversight, facilitating systemic knowledge sharing and network formation The United Circles project recognizes the diversity of regional contexts and stages of circular economy development by establishing three distinct levels of hubs, each with tailored objectives and activities.

Demonstrator hubs

Demonstrator hubs serve as technical innovation centres where commercial-scale pilot projects showcase circular solutions in real-world settings. Examples include:

- Reusing fibres recovered from wastewater to create construction materials
- Transforming used cooking oil into valuable biochemicals and bioplastics
- Collecting and processing construction and demolition waste as substitutes for traditional agglomerates and rehydrated cement paste

These hubs integrate advanced technical expertise and established stakeholder networks to validate technologies and business models, creating replicable blueprints for circular industrial symbiosis.

Mirror hubs

Mirror hubs replicate the experiences and best practices developed by demonstrator hubs in different socio-economic and geographical contexts. Their focus is on adapting proven circular solutions to local conditions and facilitating knowledge transfer. By leveraging existing models, mirror hubs accelerate uptake and reduce implementation risks, tailoring circular strategies to regional needs.

Seed hubs

Seed hubs start from the ground up. These hubs focus on building foundational capacities, raising awareness, and developing nascent stakeholder networks. Seed hubs explore locally relevant circular opportunities and gradually develop pilot projects, drawing upon lessons from demonstrator and mirror hubs to avoid pitfalls and optimize impact.

The coexistence of these three hub types reflects United Circles' commitment to flexibility, inclusiveness, and scalability across a wide spectrum of technical, social, and economic backgrounds.

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4. Varied technical and social backgrounds

Each hub operates within distinct technical, institutional, and cultural contexts. Demonstrator hubs typically involve industrialized regions with advanced infrastructure and strong institutional frameworks, enabling rapid technology deployment and stakeholder coordination.

Conversely, mirror and seed hubs often face challenges such as limited technical capacity, fragmented institutional arrangements, and socio-economic vulnerabilities. These differences necessitate customized governance approaches, capacity-building efforts, and stakeholder engagement strategies to ensure that circular initiatives are both technically feasible and socially acceptable.

Understanding and addressing these contextual differences is critical to designing hubs that are inclusive, responsive, and capable of generating sustained impact across diverse settings.

5. Lessons learned: Towards a methodology, manual, and training curriculum

United Circles is driven by the ambition to transform its wealth of diverse experiences into practical, actionable resources that can inspire and guide future circular hub initiatives around the world. At the heart of this effort is the development of a structured methodology that brings order and clarity to complex processes such as stakeholder engagement, technology validation, investment facilitation, and pilot implementation across multi-level hubs. This methodology distils lessons learned into a coherent framework of best practices, governance principles, and adaptive management strategies, offering a solid foundation for future projects.

Alongside the methodology, the project is creating a comprehensive manual designed to serve hub operators, policymakers, and practitioners. This guide addresses the full spectrum of challenges involved in establishing and running Hubs4Circularity, from governance frameworks and technical integration to fostering social engagement. By combining policy insights with practical, hands-on advice, the manual ensures that those leading circular initiatives are equipped to anticipate obstacles and navigate them effectively.

Complementing these resources is a specialized training curriculum, adapted from the SPIRE training matrix (SPIRE, 2023) and enriched with United Circles' on-the-ground experiences. This curriculum is designed to build the knowledge and skills stakeholders need to manage complex circular transitions, encompassing both technical innovation and collaborative governance. Together, the methodology, manual, and curriculum aim to enable the replication and scaling of successful circular hub models far beyond the project's current regions, fostering an interconnected global community committed to advancing circular economy practices.

The SPIRE initiative (Sustainable Process Industry through Resource and Energy Efficiency) offers a comprehensive training matrix tailored to building industrial symbiosis competencies (SPIRE, 2023). The matrix encompasses:

- Circular economy principles and relevant technologies
- Stakeholder engagement and collaborative network management
- Environmental, social, and economic impact assessment
- Regulatory and policy frameworks supporting circularity

United Circles adopts and adapts SPIRE's training framework to equip Hubs4Circularity members and stakeholders with the necessary skills to navigate complex collaboration processes, technology

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evaluation, and investment mobilisation. Capacity building is critical to overcome technical, institutional, and cultural barriers that commonly hinder circular economy implementation.

6. Lessons from Kalundborg industrial symbiosis

The Kalundborg industrial symbiosis network in Denmark stands as one of the most enduring and comprehensive real-world demonstrations of systemic circularity (Jacobsen, 2006; Lowe, 2012). Since the 1970s, it has shown how diverse public and private actors—including energy providers, chemical manufacturers, and municipal authorities—can collaborate to exchange water, energy, materials, and by-products in ways that generate environmental, economic, and social value. By integrating these exchanges into the core operations of each partner, Kalundborg has established a resilient and adaptive model for sustainable industrial cooperation (Lowe & Evans, 2010; Chertow, 2007).

Several key lessons from Kalundborg have informed the United Circles approach. Neutral facilitation and governance have proven essential for fostering trust, transparency, and joint ownership of outcomes, helping to prevent power imbalances that might undermine collaboration. The network's success also rests on its long-term, incremental evolution, supported by flexible governance structures capable of adapting to shifting conditions and emerging opportunities. In addition, the emphasis on shared value creation ensures that diverse actors are aligned through mutual benefits such as cost savings, improved resource efficiency, and environmental gains, rather than engaging in zero-sum competition.

Another defining feature of Kalundborg is its multi-level engagement, which spans strategic leadership, technical specialists, and operational staff. This breadth of involvement ensures that systemic innovations are not only designed but also implemented effectively in practice. These insights have reinforced the United Circles model's focus on establishing neutral, mission-driven hubs that can coordinate systemic collaboration across sectors and governance levels, enabling circular economy principles to take root and scale in diverse contexts.

7. Governance and operational mechanisms of Hubs4Circularity

The governance framework for Hubs4Circularity is built on the principles of neutrality, inclusiveness, transparency, and adaptive management (Ansell & Gash, 2008). These principles are laid out in a charter. The guiding values are considered essential to establishing trust, enabling equitable participation, and ensuring effective decision-making within multi-stakeholder environments. By embedding these principles into the hub's operations, governance structures can support both collaboration and long-term sustainability.

Neutral facilitation lies at the core of this model, with the hub balancing power dynamics and ideally preventing any single stakeholder from dominating the agenda. This neutrality supports open dialogue and mutual trust, which are critical to achieving shared goals. Participatory decision-making further strengthens collaboration by engaging stakeholders across multiple organizational levels—from policymakers and industry leaders to technical experts and operational teams—through structured forums, workshops, and digital platforms. Such multi-tier engagement promotes shared understanding, co-created solutions, and consensus-driven outcomes (Reed, 2008; Pahl-Wostl, 2009).

Given the inherently dynamic nature of industrial symbiosis, the hubs use iterative planning cycles and continuous feedback mechanisms to respond effectively to new challenges and opportunities. Transparency and accountability are maintained through open communication about objectives, decisions, investments, and results, ensuring legitimacy and sustained commitment from all

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participants. Robust metrics and monitoring systems further support performance tracking, learning, and ongoing improvement, anchoring governance in both rigor and trust.

9. Social aspects and multi-stakeholder processes

The transition to a circular economy and the implementation of industrial symbiosis are not merely technical or economic processes, but fundamentally social endeavours (Agyeman, Bullard & Evans, 2002). The effectiveness and long-term viability of Hubs4Circularity depend on their capacity to engage stakeholders across sectors, disciplines, and organizational levels in inclusive and meaningful ways. Recognizing, understanding, and monitoring the social dimensions of this transition is therefore essential to ensuring that circular initiatives achieve legitimacy, foster collaboration, and generate shared value.

One critical dimension involves raising awareness of the opportunities and benefits of circular economy models. Through targeted outreach and educational initiatives, hubs can enhance understanding among diverse audiences—including policymakers, business leaders, frontline workers, and local communities—thereby fostering broader societal support (Mirata and Emtairah, 2005). Equally important is the role of multi-stakeholder dialogue in generating informed consensus (Boutilier & Thomson, 2011). By creating spaces where diverse perspectives, concerns, and aspirations can be openly expressed, hubs help build trust, facilitate negotiation of trade-offs, and align priorities around shared goals, resulting in stronger collective commitment.

In addition, hubs play a central role in empowering local champions who can act as leaders and catalysts in advancing circular practices. These individuals and organizations are vital for maintaining momentum and translating strategic visions into practical action. At the same time, hubs serve as cultural and sectoral bridges, translating between different institutional logics, terminologies, and working practices to enable effective communication and cooperation. Finally, by embedding principles of social equity into their governance and operations, hubs ensure fair and inclusive participation, helping to distribute the benefits and responsibilities of circular transitions more equitably. Together, these social dimensions highlight the need for systematic attention to social processes as an integral component of successful circular economy transformations.

10. Creating focused processes to implement industrial symbiosis

The Hubs4Circularity framework operationalizes stakeholder engagement through a systematic, integrated methodological approach designed to transform collaboration into concrete, measurable outcomes. It combines participatory processes with analytical rigor, ensuring that industrial symbiosis opportunities are not only identified but also implemented and scaled. Opportunity mapping serves as the foundational step. Here participatory workshops are paired with advanced data analytics to identify feasible synergies in resource flows and cross-sector collaboration potentials. This process is followed by pilot project development, in which selected circular solutions are co-designed with stakeholders and implemented at commercial scale within pilot hubs, enabling real-world validation. Investment mobilisation is then facilitated through the hub's role as an intermediary, strategically connecting project developers with investors, aligning funding with vetted opportunities, and mitigating financial and operational risks. Finally, systematic monitoring and continuous learning mechanisms are embedded to evaluate environmental, economic, and social impacts, enabling iterative refinement and evidence-based scaling of successful initiatives.

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The novelty of this integrated methodological approach lies in its ability to merge participatory engagement with structured decision-making, bridging the gap between consultation and implementation. This model establishes a coherent process that embeds collaboration within a cycle of opportunity identification, co-creation, resource mobilisation, and iterative improvement. This integration ensures that multi-stakeholder interaction is not an end but a driver of tangible progress toward systemic circularity. By combining governance neutrality with analytical mapping, co-design practices, and robust evaluation frameworks, the methodology provides both the structure and the flexibility needed to adapt to diverse socio-economic and regulatory contexts.

Through the networked and iterative methodology, Hubs4Circularity offer a replicable and adaptable pathway for embedding circular systems at the territorial level and diffusing them across borders, thereby advancing a more systemic and resilient global circular transition. The model holds significant potential to accelerate the scaling of circular economy practices by embedding them into the structural fabric of regional and local value chains.

Figure 1 applies the Business Canvas model (Osterwalder, 2010) to a Hub4Circularity.

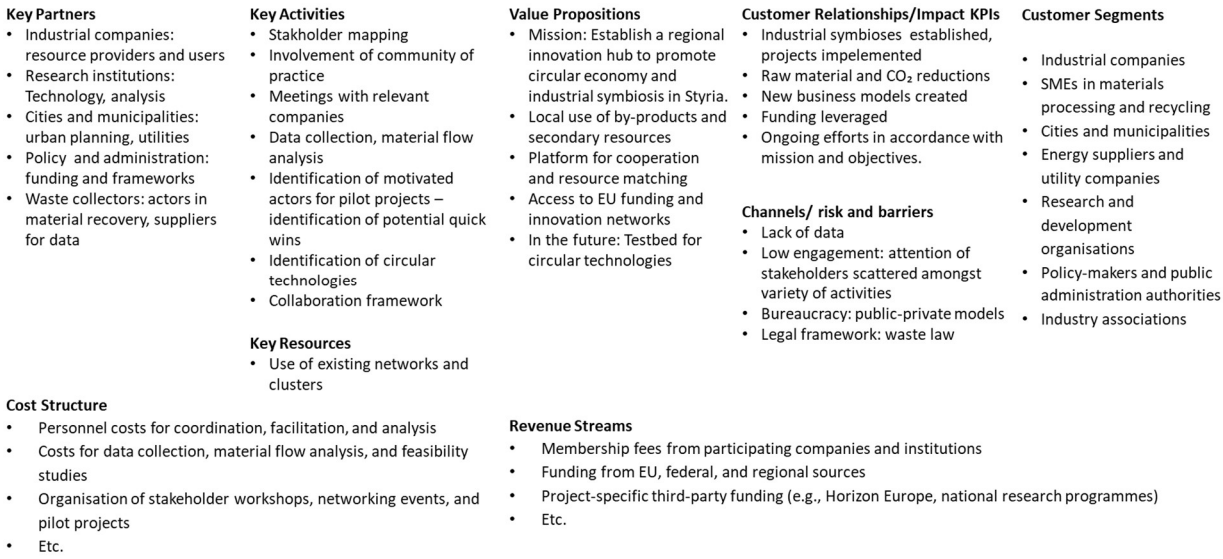

Figure 1: Example “Impact canvas” for a Hub4Circularity

11. Catalysts of social transformation

Beyond technical implementation, the hubs are catalysts for social transformation. They activate inclusive processes that engage a wide spectrum of actors—from large industrial players to SMEs, municipalities, civil society, and citizens. This democratization of circular innovation ensures that the benefits of circularity—such as job creation in recycling and bio-based sectors, improved urban environments, reduced pollution, and greater community resilience—are more equitably distributed. Hubs are not only scaling environmental performance but also reinforcing social cohesion and justice.

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To ensure legitimacy and impact, these processes must be systematically documented and evaluated. Hubs should implement participatory monitoring frameworks that capture both technical and social indicators, such as stakeholder engagement quality, co-creation outcomes, gender and inclusion metrics, and trust-building effectiveness. Storytelling methods, social impact case studies, and stakeholder feedback loops can complement quantitative metrics to surface qualitative dimensions of change. These insights should feed into a living methodology and toolkit that supports iterative improvement and knowledge transfer. Documenting how benefits are distributed—and to whom—builds transparency, informs policy, and strengthens the hubs' credibility as agents of inclusive circular transformation.

12. Towards an ISO technical committee document

The increasing adoption of circular economy hubs calls for standardized governance frameworks to ensure effectiveness, transparency, and replicability (ISO/TC 323, 2020). An ISO technical committee document on circular hub governance could:

- Define core principles and operational functions of circular economy hubs
- Establish criteria for neutrality, stakeholder inclusion, transparency, and accountability
- Provide guidelines for technology evaluation, investment facilitation, and impact monitoring
- Promote interoperability, data sharing, and best practice exchange across regions and sectors

United Circles proposes contributing its governance models, lessons from Kalundborg's industrial symbiosis, and the SPIRE training matrix to the development of ISO guidelines. Such a standard would foster global coherence, accelerate adoption, and build stakeholder confidence in circular hub initiatives.

Standardization will enhance replicability, foster trust in circular hub operations globally, and attract investments by reducing uncertainty. It aligns with the broader EU Green Deal objectives to promote systemic sustainability transitions through shared best practices and interoperability (European Commission, 2020).

13. Conclusion

The United Circles project's Hubs4Circularity represent a transformative governance innovation for scaling circular economy practices in urban-industrial systems. By fostering neutral, multi-stakeholder collaboration, integrating capacity building, and deploying structured operational processes, these hubs enable systemic transitions toward zero-waste, decarbonised cities.

Drawing on the exemplary experience of Kalundborg and the SPIRE training framework, United Circles demonstrates that effective governance and social engagement are critical success factors. Standardizing these governance models through ISO guidelines offers a promising pathway to accelerate circular economy adoption worldwide.

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