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RESEARCH ARTICLE

The Territorial Circular Ecosystem: Foundations for a Systemic and Place-Based Approach to Circular Economy

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Abstract

This article introduces the concept of the Territorial Circular Ecosystem (TCE) as a framework to understand the conditions that support the deployment of circular economy principles at the local level. It draws on the legacy of local production systems, from Marshallian districts to more recent approaches such as green clusters and industrial symbioses. These models have contributed to the ecological transition of economic systems but continue to show important limitations regarding for example the coordination of actors, the integration of stakeholders, and the implementation of circular strategies based on the 10R. The TCE framework defines a set of components and relational mechanisms rooted in territorial dynamics. It places emphasis on various types of local cooperation, geographical and organized proximities, institutional support, and societal involvement. This contribution establishes a conceptual foundation for the analysis of local circular systems and provides useful orientations for public policy and future empirical research.

Keywords Circular Economy · Territorial Governance · Local Production Systems · Industrial Symbiosis · Proximity · Green Clusters · Territorial Circular Ecosystem

1. Introduction

The transition toward more sustainable development models has brought the concept of Circular Economy (CE) to the forefront of academic, political, and industrial debates (Hachaichi & Bourdin, 2023). CE represents a paradigm shift[3] from the traditional linear model of "take, make, dispose" toward a restorative and regenerative system (Geissdoerfer et al., 2017; Kirchherr et al., 2018). It aims to minimize the use of finite resources, extend the lifespan of products, and reduce waste by promoting reuse, repair, recycling, and closed-loop material flows. Initially rooted in environmental engineering and industrial ecology (Frosch & Gallopoulos, 1989; Ayres & Ayres, 2002), the CE has progressively become a multidimensional concept involving technical, social, economic, and institutional dimensions.

Our conceptualization of the Territorial Circular Ecosystem (TCE) stresses that place-based circularity can embody a genuine paradigm shift. It goes further than the 3R strategies, with a systemic reorganization of production and consumption flows that challenges the linear and globalized economic model. We are more closed to the 10R[4] strategies defined by Kirchherr et al. (2017) including the elimination of non-essential products, the optimization of resources use, the minimization of resources consumption, the extension of products life, the avoiding of replacement when possible, the restoration of a product to functional conditions,

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3 We use this term here in the sense of Lakatos (1970), where scientific progress occurs through the progressive setting of research programs. A comparison in the economic field would be that of the diffusion of technological paradigms, as can be found in Rogers (2003) for example.

4 Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.

the dismantling and rebuilding of reusable components, the recycling by diverting a products original function, the recycling of process material into secondary raw material and the energy recovering from waste.

While CE is often approached through sectoral or technological lenses, an increasing number of studies emphasize the importance of place-based approaches in its implementation (Bourdin et al., 2022). The local or territorial dimension of CE is gaining momentum, driven by the recognition that proximity can foster trust, collaboration, and resource efficiency (Cerceau et al., 2018; Jambou et al., 2022). Indeed, the effectiveness of circular strategies often depends on local contexts, institutional frameworks, and pre-existing industrial, social, and governance arrangements (Moreau et al., 2017; Niang et al., 2023). This opens the way to the development of place-based CE systems grounded in the specific characteristics of territories. In that sense, local circular ecosystems contribute to a broader reconfiguration of the global economy through a network of localized, place-sensitive economies.

However, despite the richness of empirical cases and theoretical frameworks, there remains a lack of integrative conceptualization of what constitutes a circular ecosystem. Existing models often focus either on production and innovation dynamics (e.g., clusters: Porter, 2003; Giuliani & Bell, 2005), on environmental performance through resource flows (e.g., industrial symbioses: Chertow, 2000; Jacobsen, 2006), or on sectoral transitions in green technologies (e.g., green clusters: Harris & Albrecht, 2015). Yet, few attempts articulate all these dimensions together—economic, ecological, spatial, and institutional—in a coherent territorial framework. Moreover, issues of governance, coordination among heterogeneous stakeholders, and long-term social embeddedness remain underexplored (Morales et al., 2019; Arfaoui et al., 2024; Chembessi et al., 2024; Bourdin & Jacquet, 2025).

This article addresses this conceptual and empirical gap by proposing the notion of Territorial Circular Ecosystem (TCE). Building on the long tradition of local production systems (Marshall, 1920; Becattini, 2004), industrial ecology (Chertow, 2000; Paquin & Howard-Grenville, 2012), and recent advances in the territorial dimension of CE studies (Bourdin et al., 2022; Davies et al., 2024), we aim to provide a comprehensive analytical tool for characterizing territorialized CE initiatives (Bourdin & Torre, 2025). A TCE is conceived as a dynamic and systemic network of firms, public institutions, civil society actors, and material flows that interact within a given spatial context to foster resource circularity and reduce environmental externalities. Our ambition is twofold: (i) to define and analyze the characteristics of such local systems through a conceptual synthesis of prior models, and (ii) to identify the institutional and organizational conditions for the implementation of effective CE strategies/projects at the local level.

The purpose of the article is to fill a gap in the literature on local production systems concerning the dimensions of CE, based on numerous field analyses concerning these relationships and their local anchoring. Its contribution lies in two main advances.

First, it provides a critical and comparative assessment of three major models of local production systems—industrial clusters, green clusters, and industrial symbioses. Each model is examined in light of its capacity to apply the core principles of the CE: reduce, reuse, and recycle. This analysis reveals both the strengths and the limitations of existing approaches, particularly in relation to resource conservation, the role of cooperation among local actors, and the capacity to extend product life cycles. It also clarifies the conceptual boundaries of these models and highlights the need for a more integrated and territorially grounded perspective.

Second, the article introduces the framework of the Territorial Circular Ecosystem (TCE). This concept brings together economic, environmental, spatial, and institutional dimensions within a unified "territorial logic". The TCE framework rests on three pillars: collaborative governance, the articulation of geographical and organized proximities, and the active involvement of a broad range of stakeholders—including firms, public authorities, civil society, and residents. It offers a coherent structure to analyze how circular practices can take root in specific territories and support systemic change. The approach allows local initiatives to move beyond isolated technical measures and to become part of long-term processes oriented toward ecological and economic resilience.

The article is structured as follows. Section I retraces the historical development of local production systems and their theoretical underpinnings. Section II discusses the integration of environmental considerations into these models, focusing on green clusters and industrial symbioses. Section III provides a comparative analysis of their contributions and shortcomings regarding CE dimensions. Section IV introduces the concept of Territorial Circular Ecosystem and elaborates its core components and governance mechanisms. The conclusion outlines the implications of this framework for local action and public policy, and opens new research avenues for territorial CE strategies.

2. Back to the basics: a short history of Local Production Systems

Local production systems have a long history, which can be dated from the beginning of Alfred Marshall's work at the end of the 19th century. It has taken various forms, with the highlighting of notions such as Industrial Districts, Growth Poles or Regional Complexes, at first, followed by a new generation dominated by the approach of Clusters and their declination in terms of Industrial ecosystems.[5]

2.1. The fathers of LPS: Marshall, Schumpeter and Perroux

Indeed, and as is often pointed out today, Marshall established, on the basis of his observations, a parallel between two situations, both of which generate externalities at the level of companies. The first is that of internal economies within a firm, which allow them in particular, through integration, to obtain greater returns to scale. This was a situation that gave rise to interesting and passionate debates over a whole period, which went as far as the questions of defining the boundaries of the firm (Coase, 1937) and vertical integration (Williamson, 1996). The second situation is that in which these externalities occur outside the firm, within a group or complex of firms, the linking of which also makes it possible to obtain economies of scale or variety. They are at the very origin of the studies on Local Production Systems.

Marshall specified that "… We may divide the economies arising from an increase in the scale of production of any kind of goods, into two classes - firstly, those dependent on the general development of the industry; and, secondly, those dependent on the resources of the individual houses of business engaged in it, on their organization and the efficiency of their management. We may call the former external economies… we now proceed to examine those very important external economies which can often be secured by the concentration of many small businesses of a similar character in particular localities …" (Marshall, 1920).

These groupings of small firms, located at a short distance from each other, were observed in particular at the time within the City of London institutional districts, hence the name district formation, which was to be attributed to them by Marshall. The interest of the districts was quickly established, and Marshall presented these groups as competitors or possible substitutes for large industrial enterprises. He attributed important virtues to these groupings of localized companies, which will lead him to refer to an industrial atmosphere particular to these local systems, or to evoke the idea, in connection with their spatial dimension, that "the secrets of industry are in the air" (ref). The approach of local production systems was born. However, it did not have an immediate posterity, because research that took into account the dimension of local external economies was rather directed towards the approach of economies of agglomeration (Weber, 1909), which remained vague enough to allude to local relations based above all on savings in transport costs.

The idea of the effectiveness of groupings or clusters of enterprises or technologies was to be found again a little later, in the 1930s, with the analysis of the role played by innovation in development processes initiated in Schumpeter's work. We know that Schumpeter (1934) considered that innovation (in different forms and not only technological as is often claimed) is the basis of evolution and progress within economies, and therefore of their development. A large part of literature is concentrated on the role and place of the figure of the entrepreneur in his approach, but he also emphasized, on several occasions, that innovations do not emerge alone and that they form grapes or clusters. Moreover, as Rosenberg (1982) will emphasize in particular, it is from the complementarity between different innovations that the main technological changes or revolutions are born: for example, the success of the railway was based on elements as different as the introduction of the steam engine, the production of steels strong enough to support the weight of locomotives or the improvement of machine clutches. It is therefore a systemic vision that is presented here, but without explicit spatial dimensions.

It was Perroux who, in the 1950s, introduced the spatial or regional dimension with his definition and analysis of growth poles (Perroux, 1970). An evolutionist, Perroux wanted to give spatial content to Schumpeter's analysis of development processes, based on the idea that development does not unfold everywhere at the same speed and with the same modalities. The approach to growth poles covers both theoretical analysis and economic policy principles. It is based on the idea that the conjunction of different

[5] This choice is based on our theoretical and applied expertise and an examination of the literature, confirmed by Google Scholar citations: Clusters: 8,3 M citations; Local production systems: 7 M; Science parks: 5,9 M; Industrial ecosystems: 4,3 M; Industrial Districts: 3,4 M; Regional complexes: 2,5 M; Growth poles: 1,7 M, etc.

firms at the regional level, and in particular their input-output relationships around a large driving firm, will allow the development of the region by spreading the effects of growth from one firm to another (Torre, 2025). However, not all regions can claim this type of development, and these systems are not infinitely replicable, because they require local resources and a strong local network of firms to avoid spreading effects. Thus, the economic policy recommendations consist of favoring a certain number of growth poles for each country, around key industries such as chemicals, the automotive industry or metallurgy, for example, and promoting the setting of a local input-output system guaranteeing localized growth effects.

2.2. From Industrial Districts to various forms of Clusters

This approach was very successful in terms of concrete actions and the setting of growth poles in different regions of the world, until the 80s. Largely centered on the relations between large firms and their subcontractors, it gave rise to epigones such as the analysis of industrial complexes (Stöhr, 1986). It was in the 80s that one noticed the reappearance of an approach more targeted at small firms, with the resurgence of Marshallian districts, also known as industrial districts. Using the example of the third Italy, Becattini (2004) and other authors have provided an analytical explanation for the success of the grouping of small firms with low technology, their competitiveness and their high productivity, including at the global level. If small Italian textile or ceramics companies are so successful, it is because they are able to organize themselves at the local level and to derive productive benefits from this alliance in terms of externalities, thus rediscovering Marshall's initial intuition (Bellandi & De Propis, 2017). The explanations put forward are based on a mix of economic and social conditions. On the one hand, extensive cooperation and information-sharing relationships, with a strong competence of human resources at the territorial level and the role of intermediaries, both internally and externally. On the other hand, favorable social conditions, with a sharing of social norms in terms of culture or religion, as well as the acceptance of low wages and a high degree of flexibility of work within the community.

As a result of this work, the idea of local production or innovation systems ended up imposing itself almost everywhere in the economic literature, especially since examples of this type of fabric were multiplying in reality, at two levels. 1) the discovery that many situations resembling that of the Italian districts existed all over the world, with small firms inserted in a local network of exchanges and cooperation; 2) the rise of local innovation systems, with examples such as Silicon Valley or Route 128, and local development policies based on the launching of science parks or technopoles, particularly in Europe and Asia, mainly based on high tech or knowledge activities. It was eventually accepted that the systemic dimension was important at the local level, and that geographical proximity was favorable to territorial development processes because it helps face-to-face relations, and thus the exchange of information or technological knowledge. In addition, the canonical form of districts was abandoned in favor of the highlighting of different categories of local systems, involving or not innovations, technology, large or small firms, and research laboratories (Markussen, 1996).

On the basis of these various studies, Porter (1985, 2003) introduced the very popular concept of clusters, defined as networks of firms and research institutions operating within related industries, situated in close geographical proximity. Their collaboration, sharing technologies, knowledge, and expertise, is supposed to enhance performance, competitiveness, and innovation. The notion of clusters rapidly gained widespread popularity due to its analytical flexibility and marketing appeal, and its conceptual vagueness may have contributed to its success. Over time, this idea extended beyond high-tech sectors and top-performing industries to include systems less focused on cutting-edge activities or with lower performance levels like food systems (Giuliani & Bell, 2005). Nowadays, clusters are broadly recognized as a useful framework to accelerate innovation and create competitive advantages, not just in high-tech industries but across a wide range of sectors. The concept of clusters further evolved into a strategic and policy tool (OECD, 2001). It has been widely adopted for designing economic policies that encourage the growth of local economies, improve industry dynamics, and foster cooperation between businesses, research institutions, and governments. The ongoing success of cluster-based strategies has led to their application in various regions worldwide, as they continue to provide a robust model for stimulating economic development and innovation at both local and national levels, even with their contemporary avatar in terms of Industrial ecosystems.

3. From clusters to symbioses: the attempts to introduce environmental and circular dimensions into local production systems

One of the identified limits of the notion of clusters (Martin & Sunley, 2003) lies in an apparent lack of interest for environmental or ecological questions. Further works have looked into this question. They follow two filiations: the first one is derived from and extends the analysis of the local production systems seen above, with an enrichment of the dimensions of sustainability. The second, more original and confidential,[6] has its roots in approaches in terms of industrial ecology. It very clearly considers and integrates the characteristics of circularity into its descriptions of local relations.

3.1. Green clusters: an environmental reinterpretation of the industrial cluster mode

The approach in terms of green clusters, which has had some success during the 2010s, aims in particular to address this weakness. The concept of green cluster is rooted in the broader idea of industrial clusters, with collaborations through local networks (Moss & Ziegler, 2012); however, these systems specifically focus on the integration of environmental goals and practices into their core operations. They appear as a means to address environmental challenges while fostering economic growth, and to respond to the increasing demand for environmentally friendly products and services, driven by both consumer preferences and regulatory pressures (Harris & Albrecht, 2015). Green clusters refer to the geographical concentration of firms, institutions, and organizations that are focused on environmentally sustainable practices, technologies, and innovations. They promote green growth, driving sustainability efforts, and fostering innovation in sectors such as renewable energy, eco-friendly products, and environmental services.

Green clusters share several key characteristics that distinguish them from traditional industrial clusters. First, they are typically composed of firms and institutions focused on sectors such as renewable energy, green manufacturing, waste management, and environmental consulting. They are also supported by public policies that encourage green innovation through subsidies, tax incentives, and research grants. The presence of local governments, universities, and non-governmental organizations (NGOs) that promote sustainability appears also as a crucial feature. Another important driver is the availability of funding and investment. Many green clusters are supported by venture capital firms, business angels, and government programs that provide financial resources for companies developing clean technologies. Green clusters are supposed to play a critical role in reducing the ecological footprint of industries and regions: the firms adopt sustainable practices that reduce energy consumption, waste, and emissions. Moreover, their collaborative nature allows for the diffusion of green technologies and practices across industries, enhancing the environmental impact of local economies.

This approach has given rise to many experiments and allowed the setting of different clusters at the local level (Belfanti & Alberti, 2022). It is the case of the GreenTech Cluster, centered in the city of Aarhus, which focuses on areas such as wind energy, bioenergy, and energy storage technologies and has created numerous green jobs, contributing to Denmark's transition to a low-carbon economy. Or of the Germany's Eco-Innovation Cluster, located in the state of North Rhine-Westphalia, which brings together firms, government agencies, and research institutions that focus on reducing environmental impact through technological innovations (Kiese, 2019). In this case, one of the key areas of innovation is green construction; the companies have developed energy-efficient building materials, renewable heating solutions, and smart grid technologies to reduce the carbon footprint of the construction industry. Let's also cite the example of the Cleantech Clusters in the United States, particularly in Silicon Valley, which has embraced clean technology by fostering a vibrant ecosystem of cleantech startups, venture capital funding, and research institutions. This green cluster is home to companies specializing in renewable energy, energy storage, energy efficiency, water management, and waste-to-energy technologies. Even if it is barely mentioned in the literature, in all these situations, the success of green clusters depends on the strength of public policies that promote green innovation. Without supportive

[6] Google Scholar: Green clusters, 5,7 M citations; Industrial symbiosis: 95,000; Eco-industrial parks: 5,000.

policies, such as incentives for renewable energy production or funding for R&D, green clusters may struggle to grow and thrive (OECD, 2011).

Despite their potential benefits, the literature identifies severe challenges in the development of green clusters. One key challenge in clusters analysis is the difficulty of coordinating efforts among diverse stakeholders, including firms, research institutions, and policymakers. With green clusters, a few other problems appear. The high costs of developing and scaling green technologies remain a major challenge; financial support from government programs, venture capital, or private investment is crucial, but such funds may be insufficient or difficult to access, particularly in regions with weaker financial infrastructure or less developed green policies (Gibbs & O'Neill, 2014). Green clusters are also often heavily dependent on government policies, subsidies, and incentives to promote innovation and sustainability. However, changes in policy priorities or the reduction of government support can destabilize them and, the momentum of green technology development can slow down. Their success also depends on the availability of a skilled workforce, but many regions face challenges in developing the necessary skills for green industries on the local labor market (e.g., expertise in renewable energy, environmental engineering, or sustainable business practices). Another limitation is the risk of greenwashing, where companies or organizations within green clusters claim to be environmentally friendly without actually implementing significant sustainable practices. This can undermine the credibility of green clusters and their long-term viability. Furthermore, local governments in non-clustered regions may struggle to replicate the success of established green clusters due to differences in infrastructure, resources, or political will (Martínez-del-Río & Céspedes-Lorente, 2014).

Finally, the experiences of green clusters thus consist above all of a reinterpretation of the cluster's methodology, in which some elements of good environmental or sustainability practices are injected; the very principles of the CE are never really present in this approach, in particular in terms of saving natural resources, extending the life of products or recycling outputs or wastes. These choices, on which the green cluster movement is based, are opposed to the ones of a generation of alternative local systems, which propose to reflect on an often-pragmatic approach to analyze and to promote the way to organize relationships based on the principles of the CE at the local level. These numerous and various studies, which are often based on examples or concrete experiments carried out at the local level, takes on different names, like industrial symbioses, eco-industrial parks, or industrial eco-systems… But they have in common the particularity of belonging to Industrial Ecology (Frosch & Galopoulos, 1989, Ayres & Ayres, 2002). This filed of research, defined as « the study of systemic relationships between society, the economy, and the natural environment… focuses on the use of technology to reduce environmental impacts and reconcile human development with environmental stewardship while recognizing the importance of socioeconomic factors in achieving these goals" (International Society for Industrial ecology, 2025).

3.2. Industrial symbioses and eco-industrial parks: operationalization of resource flows at the local level

In his foundational paper, Chertow (2000) explores the concept of industrial symbiosis (IS) as a key component of Industrial Ecology, emphasizing the exchange of materials, energy, water, and by-products among industries to enhance resource efficiency and reduce environmental impact. Chertow defines industrial symbioses as systems of geographically proximate firms engaging in mutually beneficial resource exchanges, and classifies them into three levels. Through waste exchange programs, where firms seek partners for by-product utilization. By self-organized networks, where companies naturally develop symbiotic relationships. And via planned eco-industrial parks, designed to foster resource-sharing from inception. He emphasizes the collaborative strategies among industries to enhance environmental and economic performance, and highlights the economic and environmental benefits of IS, including cost reduction, pollution prevention, and energy efficiency. Despite the fact that barriers such as trust issues, logistical constraints, and regulatory challenges can hinder widespread adoption, Chertow concludes that policy support, economic incentives, and better understanding of IS dynamics are crucial for scaling up IS.

In fact, as noticed by Neves et al. (2020), IS do not necessarily require geographical proximity between participants, and the different components in charge of the process can take place over distances much greater than the limits of a territory, as shown by the experiments led in Tianjin, China (Yu et al., 2014b) or Choctaw, USA (Zhang et al., 2013) for example. However, most authors agree that the spatial dimension is important and that it allows for much more efficient circular processes. This is the reason why many experiments take place at the local level and why the examples chosen in the presentations of case studies are always based on a territorial approach. The authors then highlight the interest of having reduced transport costs, and also emphasize the more economical nature of the consumption of resources, as well as the advantages presented by the possibility of face-to-face exchanges between the participants. It is therefore quite natural that the model most often used in the analysis of industrial symbioses is that of eco-industrial parks, with the iconic example of Kalundborg, in Denmark.

As described by Jacobsen (2006), the Kalundborg system is based on the collaboration between companies belonging from various sectors (energy production, oil refining, chemical manufacturing, plasterboard producer, agriculture, etc.), and working together in a defined small geographical space to exchange and to spare resources. The various material flows among the companies are based on water, solid waste or energy exchanges. For example, thermal waste from a power plant is used to heat a fish farm, and organic waste from the fish farm is then used as fertilizer on neighboring farms… Very early, Ehrenfeld and Gertler (1997) highlighted the historical evolution of Kalundborg's industry, in which interdependent relationships among different companies developed over time. These links often stem from industrial decisions and collaborative practices that go back several decades and have shaped current practices and influenced the choices of companies in the region, which is reminiscent of the path dependency phenomena observed in many industrial districts. In the same line, scholar also observes, in this system, the importance of relations of cooperation and sometimes of trust between the different participants (Ashton & Bain, 2012).

Although it is by far the best known and most often studied eco-industrial park, Kalundborg is of course not the single example of industrial symbiosis at the local level (Paquin & Howard-Grenville, 2012; Heeres et al., 2014). Just refer to other cases like the ones of Tianjin Economic-Technological Development Area (China), a leading park focused on CE practices (Shi et al., 2020), Burnside Industrial Park (Canada), a sustainable industrial hub with energy-efficient infrastructure and waste reduction initiatives, or the transformation of the Salaise-Sablons industrial park (France) into an eco-industrial park (Ribeirao et al., 2018) for example. The symbiosis model is widely disseminated at the international level and seems to transcend geographical and institutional barriers, even if the spread of the "label" eco-industrial park leaves doubt about the very characteristics of these systems. But one question remains today: to what extent is it possible to replicate the ideal characteristics of the Kalundborg Symbiosis (Paché, 2024), which are very special in terms of unique local relationships, geographical proximity, technical and economic opportunities, local organization and cultural acceptance? In other words, how is it possible to extend these modalities of apprehension of industrial ecology dimensions, and to design a broader and more comprehensive definition of a system taking into account the different dimensions of sustainability and CE at the local level.

4. An assessment about the integration of sustainable and CE elements in local production systems

The comparison of local production system models reveals a gradual integration of environmental and CE concerns over the past two decades. However, none of the models examined—industrial clusters, green clusters, and industrial symbioses—fully satisfies the conceptual and operational requirements of a territorial circular approach. Each of them contributes to the advancement of sustainable practices, but their scope remains limited in several key dimensions.

4.1. A gradual integration of sustainability dimensions

The model of green clusters incorporates environmental objectives into economic production systems and addresses ecological challenges through technological innovation and regulatory incentives (Harris & Albrecht, 2015; Moss & Ziegler, 2012). These clusters promote eco-innovation and support the diffusion of green technologies, often under the influence of strong public support (OECD, 2011). Despite these advances, their orientation remains largely linear and productivist. Their focus lies on clean production rather than on systemic resource circularity. Most of them overlook the core principles of CE as defined by Geissdoerfer et al. (2017) and Kirchherr et al. (2017), such as resource conservation, waste reintegration, and the extension of product life cycles.

Industrial symbioses and eco-industrial parks, rooted in the tradition of Industrial Ecology (Frosch & Gallopoulos, 1989; Ayres & Ayres, 2002), provide more tangible results in terms of resource exchange and waste valorization at the territorial level. Numerous studies have illustrated how material and energy flows can circulate efficiently among firms located in proximity (Chertow, 2000; Jacobsen, 2006). These initiatives reduce environmental impacts and foster forms of industrial cooperation. However, they often neglect other critical aspects of CE, such as repair, reuse, or the coordination mechanisms required to build trust and sustain long-term collaboration among heterogeneous actors (Ashton & Bain, 2012; Morales et al., 2019). Furthermore, the governance of these systems rarely includes non-industrial stakeholders, such as citizens, NGOs, or third-sector organizations, whose involvement proves essential in addressing social acceptability, conflict prevention, and inclusive governance (de Morais et al., 2021; Niang et al., 2021).

These limitations highlight the need for a more integrated framework. The objective of this section is to assess the capacity of each model to address the fundamental dimensions of the circular economy at the territorial level. The analysis rests on a comparative matrix that contrasts the three models across a set of criteria related to actor coordination, resource circulation, institutional involvement, stakeholder engagement, and spatial embeddedness. This approach allows us a structured identification of both the contributions and the persistent gaps that must be addressed to develop more complete and effective territorial circular systems.

Table 1. Degree of integration of key circular economy and territorial dimensions across three types of local systems

Items	Definitions (What we measure)	Industrial clusters	Green clusters	Industrial symbioses
Interactions between local actors	Actor coordination = density and reciprocity of inter-firm ties; role of intermediaries.	+++	++	+++
Involvement of non-productive local actors	Stakeholder engagement = participation of civil society, NGOs, residents in design and oversight.	0	0	+
Connections beyond the local system	Extra-local linkages = partnerships, value-chain ties, knowledge and finance outside the territory.	+	+	0
Role of local institutions	Institutional involvement = explicit roles of municipalities, agencies, chambers in rule design, support, enforcement.	++	+	+
Green labels	Eco-labelling = presence and depth of certifications, standards and reporting that signal environmental alignment.	0	+++	+
Circulation of waste, energy, water and materials	Resource circulation and local infrastructures = intensity, diversity and stability of material, energy and water loops.	0	+	+++
Territorial resource preservation	Local resource preservation = avoidance of net extraction, closed-loop share within the territory, pressure reduction on local stocks.	0	+	+++
Product life cycle extension	Life-cycle extension = scope of 10R options and their territorial scale.	0	+	+
Geographical proximity	Spatial embeddedness = co-location, transport distances, cross-scale linkages.	+++	+++	+++
Contribution to local employment	Employment contribution = net local jobs and skill upgrading within circular activities.	++	+	+
Governance of circular flows	Steward named; scale fit stated; objectives explicit.	+	++	+++

4.2. Models that need to be improved to take into account all CE relationships

The comparative reading of the elements presented in Table 1 reveals both the specific contributions and the limitations of each model of local production system in relation to CE objectives. The analysis first confirms that industrial clusters and eco-industrial symbioses continue to prioritize internal coordination among firms. Exchanges, mutual adjustment, and forms of productive cooperation remain central in these models, in line with the initial spirit of Marshallian districts and their later reinterpretations (Becattini, 2004; Bellandi & De Propris, 2017). However, relations with broader territorial stakeholders—such as local populations, civil society organizations, or intermediary institutions—are often absent or underdeveloped. Only in the case of industrial symbioses do some examples show the emergence of linkages with actors in agriculture or waste management, often in response to material flow needs rather than from deliberate participatory strategies.

The same pattern appears when examining the role of local institutions. In industrial clusters, local governance structures—such as municipal governments or consular chambers—often play an active role in coordinating actions and supporting inter-firm relations. This is far less evident in green clusters and symbioses, where public institutions mostly act as facilitators of investment or regulators, with little involvement in structuring socio-economic linkages. As for connections with actors located outside the system, the literature provides very few insights. External relations sometimes appear in cluster analyses, especially in discussions about intermediaries or value chains, but they remain largely absent in the industrial symbiosis literature, which tends to focus on spatial self-containment and closed-loop functioning.

Environmental dimensions reveal sharper contrasts across the three models. Green clusters promote eco-certification schemes and environmental labelling, which support clean production and signal alignment with sustainability norms (Martínez-del-Río & Céspedes-Lorente, 2014). Yet, these initiatives often stop at the level of technological modernization or environmental branding, without addressing resource circularity. Conversely, industrial symbioses offer robust illustrations of material and energy exchanges between co-located firms (Chertow, 2000; Jacobsen, 2006), and they clearly support reductions in resource extraction and landfill usage. It is the only model that explicitly presents the need for local infrastructure dedicated to the circulation of different resources. These dynamics result in effective resource savings at the local level, but they rarely include objectives related to repair, reuse, or the extension of product life cycles, which remain peripheral in most implementations. On the spatial dimension, the three models converge around the strategic value of geographical proximity. Proximity facilitates the circulation of material flows, lowers transaction and transport costs, and enables face-to-face interaction, which supports trust and informal coordination mechanisms (Boschma, 2005; Cerceau et al., 2018). This is especially vital in industrial symbioses, where operational efficiency often depends on co-location. The cluster model also emphasizes proximity as a source of knowledge spillovers and local embeddedness.

The issue of labor and employment, although central to the historical cluster approach, receives less attention in the two other models. Industrial districts have traditionally highlighted the importance of localized skills, tacit knowledge, and the co-evolution between workforce competencies and local production systems (Markusen, 1996; Giuliani & Bell, 2005). Workers benefit from proximity not only because of reduced mobility costs, but also due to their familiarity with local production methods and embedded social norms. However, such considerations remain largely absent in the literature on green clusters and symbioses, where employment effects are often discussed in vague or aggregate terms.

Recent studies suggest that the integration of CE strategies into local production systems could generate significant employment opportunities, especially in the reuse, repair, maintenance, and waste management sectors (Niang et al., 2023). Nevertheless, empirical evidence remains scarce and fragmented. Some contributions in the field of agri-food systems or social economy highlight the importance of workforce requalification, the valorization of manual skills, or the emergence of hybrid forms of employment linked to circular practices (Dorza, 2019; Donner & de Vries, 2021). Others focus on the cultural and social conditions for work acceptance within CE frameworks, pointing to the role of values, trust, and local identities (de Morais et al., 2021). Yet, very few analyses adopt a labor-centered perspective on CE, and the impact of circular strategies on job quality, inclusivity, or wage structures remains largely unaddressed.

5. Towards a broader consideration of local CE relations: the notion of Territorial Circular Ecosystem and its cooperative foundations

We introduce the notion of Territorial Circular Ecosystem (TCE), which allows to go beyond the limits seen previously with other types of local systems. This notion makes it possible both to integrate the dimensions of circularity at the scale of geographical proximities, and to take into account all the stakeholders in the territory involved in circular economy approaches, as well as their relations.

5.1. The question of collaboration and coordination

Ultimately, the central issue concerns the modalities of collaboration at the territorial level. This question lies at the heart of the functioning of local systems engaged in circular economy dynamics. In any sustainable territorial configuration, cooperation rests on three main forms of interaction, each playing a fundamental role in the stability and effectiveness of the system. These forms of cooperation are often interdependent and contribute jointly to the structuring of the local circular ecosystem.

The first involves technical cooperation among productive or innovative actors—primarily firms, production units, and research laboratories. These interactions concern the organisation of material, energy, and waste flows, and support the operational implementation of circular economy processes. The second refers to socio-economic coordination between a broader range of local actors. This includes private firms and farms, but also public authorities such as municipalities, regional agencies, or decentralized state services. These relations include exchanges of information, joint planning efforts, trust-based interactions, and shared frameworks for standards or regulatory compliance. The third dimension involves cooperation with civil society. It includes the participation of local populations, non-governmental organizations, and community groups. Their involvement contributes to the legitimacy of circular initiatives and helps address social acceptance issues. These actors influence technical decisions, raise concerns, and shape collective preferences, which may prevent conflict and reinforce local support.

These three forms of cooperation form interwoven networks that give structure to the local circular ecosystem. Their interconnection creates the systemic nature of the territorial configuration and reflects long-term trajectories marked by institutional arrangements, historical complementarities, and evolving power relations. The durability and coherence of circular practices thus depend on the density, quality, and continuity of these collaborative relationships.

This broad arrangement, which concerns local governance processes, e.g., the establishment of local networks and collaboration protocols between local stakeholders, has been largely neglected in the literature, with the exception of a few pioneering works. Thus, beyond the exchange of energy and material flows and the possible saving of local resources, which are essential, a few authors try to cope with the question of socio-economic relations within eco-industrial parks. For example, Chertow et al. (2008) insist on the fact that many industrial symbiosis exchanges are driven by personal relationships and cooperative mindsets among managers. These findings promote the idea that industrial symbiosis relationships and eco-industrial parks are socially embedded, like other types of agglomeration economies, relying on social connections, mutual familiarity, and shared norms within the local industrial community. On the other hand, both formal and informal institutions can have lasting impacts on firms' behaviors, promoting sustained collaboration and exchange practices, as shown by Morales et al. (2019) study on industrial symbiosis in the Altamira-Tampico industrial corridor, in Mexico.

In two recent papers, Niang et al. (2021, 2022) clearly highlight and analyze this duality between energy and material flows on the one hand, and cooperation links on the other. Based on field surveys conducted on the Cavigny site in Normandy (France), on a local ecosystem specializing in anaerobic digestion issues, they carried out a study in terms of social networks and their evolution over time. Their research made it possible to isolate two main types of networks: a network of material flows, which circulate between companies or local farmers, but also a network of economic exchange relations and cooperation links between local actors. While the two networks have important similarities, they differ on two levels: (i) the place occupied by the actors is different: the role played by waste treatment companies is much more important and central in the network of exchanges of flows and materials, whereas it is the local public authorities and in particular the municipalities that occupy a central place in the network socio-economic exchanges; (ii) a new player appears in this last network: these are the associations for the protection of the environment and the neighborhood, which relay the opinions of the neighboring populations and play an important role in decision-making, whether it is a question of the anaerobic digestion methods used, or the traffic rules of the trucks carrying waste, for example.

5.2. About the notion of Territorial Circular Ecosystem

All of these remarks point to as many shortcomings as new subjects to be addressed. They logically lead to the need for a reformulation of the notion of local production system taking into account the dimensions of sustainability and more particularly of CE, as well as to a broadening of the essential elements of its conceptualization. There is a need for the definition of an analytical device that makes it possible to define and study the characteristics of territorial systems dealing with CE relationships, and furthermore to implement local actions and adapted policies based on this solid ground. That's the reason why we defined the notion of Territorial Circular Ecosystem. According to Bourdin & Torre (2025) "A TCE is a dynamic, interconnected set of economic players, institutions, policies, and practices within a specific territory. It works together to optimize resource flows, reduce waste, and promote regeneration through CE principles. Specifically, it is an integrated and dynamic network of actors (companies, public authorities, research organizations, non-governmental organizations (NGOs), citizens, etc.) and processes (eco-design, recovery, recycling, reuse, etc.) that promote the economic circularity rooted in the territory. This complex structure aims to reduce non-renewable resource consumption, minimize waste production, and promote sustainable product life cycles."

Even if we are at the same infra-regional level as for localized systems of linear production or industrial symbiosis, we refer here to "territorial" and not to "local" systems. The scale is very similar, but we make a distinction with the local (linear) dimension for two reasons: 1) because all local stakeholders are concerned, and not only the actors of production. We refer to the distinction between "local development" and "territorial development", which includes this difference (Torre, 2023); 2) because we are referring to the notion of territory, which is considered as a construct developed by local actors in connection with their common relationships and projects (Sack, 1986).

This distinction is crucial, because the governance modalities of the systems differ greatly depending on whether the flows are organized within small perimeters (eco-industrial parks for example), at the level of metropolitan regions or through larger interregional networks. Geographical scale matters, and governance of circular flows varies with scale, activity, and objectives; it is based on very local or more macro-sectoral interventions depending on the situation. At site level, a named loop steward coordinates contracts, meters, and incident response. At city level, the municipality sets permits, land-use rules, and public procurement criteria that favor reuse and secondary materials. At regional level, agencies set standards for secondary raw materials and support shared infrastructures and corridors. Manufacturing sites focus on quality and supply security; agri-food hubs focus on sanitary rules and seasonality; mixed-use areas focus on acceptance and reverse logistics. Objectives guide choices: ecological regeneration, cost and competitiveness, resilience, and social inclusion.

Territorial Circular Ecosystems may be incomplete, which means that not all the elements are present at the current period. But the objective in the medium term is that the territory has sufficient building components to foster a comprehensive circular approach, enhancing the reduction, reuse, and recycling of materials within the CE framework. Here we take up the elements defined in Bourdin and Torre (2025) (see Figure 1) and accompany them with comments on the components.

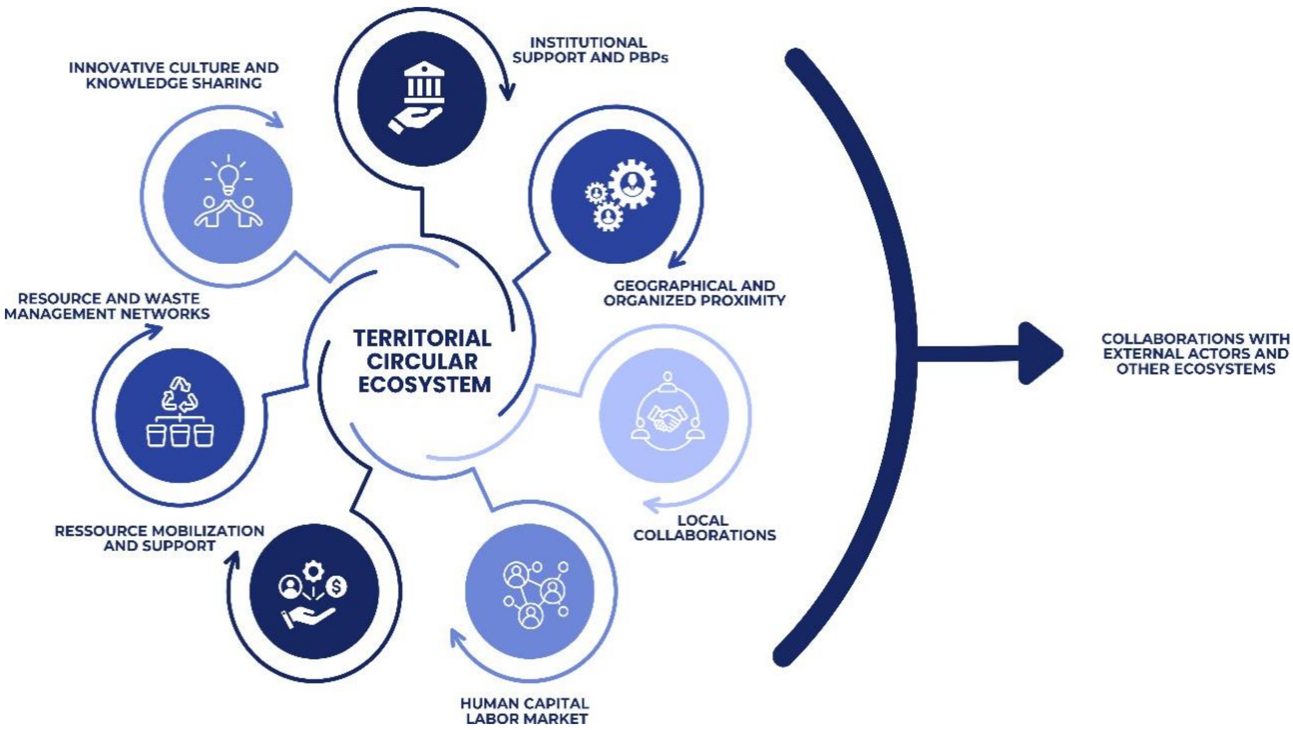

Figure 1. Components of a Territorial Circular Ecosystem (adapted from Bourdin & Torre, 2025)

Geographical and organized proximities are the basis of territorial relations, because they ensure a strong link at the level of collaborations, both for reasons of geographical distance, but also of belonging to the same cultural or production community. It is on this basis that knowledge, know-how and skills are shared in an innovative way. Relations within the system are based on the local labor market, as well as on its management by local firms and organizations. Organized proximity also makes it possible to organize and maintain links with firms or public authorities outside the local system. The dimension of industrial symbiosis is provided by the mobilization of local resources, as well as by the management of flow exchanges and waste recycling, which concerns the three dimensions of the CE (reduce, reuse, recycle). The nature of the dominant activities within a TCE (manufacturing, agri-food or services industry) influences the complexity of loop management, the degree of technological interdependence and the risks of conflict between actors. Ultimately, the entire TCE is steered by local institutions, whether they are local authorities, decentralized State services or consular chambers.

However, two essential dimensions remain insufficiently developed in the literature and call for a clearer integration into the structure of the TCE. The first concerns the connection with external actors and systems. Although organized proximity makes it possible to maintain relations beyond the local perimeter, the framework does not formally include the existence of partnerships, institutional interactions, or economic exchanges that extend outside the territory. These external links represent a strategic resource for local systems. They facilitate access to complementary know-how, financial or technical support, and regulatory innovations that may emerge in other regions. A territorial ecosystem cannot remain entirely autonomous. Its capacity to adapt and evolve often depends on its ability to interact with external entities.

The second missing element concerns the involvement of stakeholders beyond firms and public institutions. Civil society organizations, associations for environmental protection, neighborhood groups, and informal collectives often influence local circular economy trajectories. Their interventions may support or oppose specific projects, depending on the perceived fairness, transparency, and territorial impacts of proposed actions. These actors participate in shaping local norms and play a critical role in expressing conflicts or demands. Ignoring their presence weakens the systemic understanding of territorial dynamics and overlooks important mechanisms of legitimacy and negotiation.

6. Conclusion

This article aims to investigate the foundations and properties of the notion of Territorial Circular Ecosystem. The goal was to highlight the interest of this approach and to question its roots in the literature, as well as its operational nature in a perspective of local action or dedicated economic policy. The aim is to determine the main characteristics of this type of systems and to pinpoint their advantages, with a view to analytical reflection, but also to identify general principles for their implementation at the local level. The main objective is to chart the paths towards a localized approach to CE relationships and their inclusion in a systemic framework conducive to the implementation of Circular Economy principles.

We have shown that the roots of TCEs lie in a long tradition of local systems, building on the initial elaborations of the Marshallian districts, to the most recent advances in industrial cluster analysis. It is in this lineage that the approaches in terms of green clusters of industrial symbioses are inscribed, more or less explicitly, which take up the codes of local production systems, with a much greater interest in the environmental and circularity dimensions. We were then able to show that these different approaches, despite their interest, all have shortcomings or limitations that lead to the need to broaden the scope of understanding relationships and to deepen the ecological and environmental dimension, in favor of more sustainable production processes. It is to this objective that the notion of TCE responds, which integrates the systemic dimensions of the relationships between actors, the consideration of the different stakeholders in the territory, the preservation of resources and the implementation of the main dimensions of the CE (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover).

The description of this system should allow us to consider local actions or to determine public policy elements in favor of the implementation of good CE practices. The main lesson is that the systemic dimension is essential and that there is no need to consider initiatives that are totally isolated or disconnected from the main components of a TCE. Of course, it is still relatively rare that all the elements presented above be present at the local level and allow for a complete and general synergy, but, on the other hand, it is necessary for certain bottlenecks to be active to ensure a functioning that does not turn out to be totally disconnected from the local level and without any impact. Otherwise, we will find the "white elephant" phenomenon, well known in local systems, i.e., an initiative that has certain advantages from an ecological or employment point of view, for example, but which does not cause any dragging effect at the local level. In addition to the absence of an economic knock-on effect, which would result in growth being transmitted primarily outside the territory through external leakages, there will be a second effect: environmental benefits will be wasted or at least greatly reduced due to the non-closure of the loop at the local level. For implementation, we recommend a stewardship charter, clear contracts and data rules, and KPIs that track regeneration, cost, resilience, and inclusion across site, city, and region.

Beyond this conceptual proposal, several research directions remain open. First, empirical applications of the TCE framework should be developed and tested in diverse territorial contexts, including fragile or peripheral regions where local coordination capacities vary, and the emphasis could be put on rather neglected topics like organics for food or local agricultural short chains for example. Second, greater attention should be paid to the social and institutional conditions required to activate the full potential of a TCE, particularly in terms of stakeholder governance, social justice, inclusion, just transition and conflict resolution. Third, further work could investigate the articulation between TCEs and multi-scalar policies, in order to clarify the role of regional, national or European institutions in supporting or regulating circular transitions. Ultimately, the TCE concept provides both a diagnostic tool and a strategic compass for territories that seek to embed circular economy principles in local development trajectories. Its operationalization now calls for interdisciplinary contributions, as well as collaboration between researchers, policymakers, and local actors, to ensure a just, resilient, and effective transformation.

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