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From Waste to Commons: Digital Pathways for Circularity and Community Resilience in Sintra

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Abstract

This paper investigates how evaluating and applying circular economy (CE) principles at the municipal level can spark regenerative practices through community collaboration and the smart use of digital technologies. Focusing on Sintra, Portugal, it explores how leveraging local data and digital platforms can empower community involvement, support resource mapping, and foster accountability among public and private sectors. The analysis considers both the benefits and challenges found at the crossroads of ecological transition, territorial fairness, and participatory technology. Ultimately, CE is viewed as more than a method for saving resources. It is a foundation for local resilience and the sustainable management of shared assets.

Keywords: *Circular Economy; Transitions to Sustainability; Sustainability; Community Engagement; Local Resilience.*

Introduction

The climate emergency currently facing humanity is one of the greatest and most urgent challenges to be resolved and is due to a combination of social factors, notably our linear neoliberal economic model, associated with the weakening of global institutions and democracy (Raworth, 2017). The changes needed to reverse the environmental imbalances associated with climate change are so profound that we may be facing a new wave of profound socio-technical changes, in a process dubbed Transitions to Sustainability (Schot & Kanger, 2018). The goal of sustainability should not be limited to the environment; it should also be social, with changes in society simultaneously occupying the means and the end of this process. Thus, the discipline of Transitions to Sustainability seeks to address environmental challenges, starting with the climate emergency, while transforming society, thereby making it the main agent of positive change in the Biosphere (Loorbach et al., 2017). Among the necessary social improvements, the following stand out: maintaining or advancing democratic institutions and human rights, achieving global peace, and greater and better access to health care, education, food, and decent work, among other goals, mainly reflected in the UN's sustainable development goals (Liverman, 2018). In the theoretical field, research is divided into two main lines of thought, weak and strong sustainability, with distinctions regarding the extent of social changes necessary to achieve sustainability and their consequences on the economy and access to material goods (Neumayer, 2025).

It is within this context of the need for changes in the socioeconomic model that the CE is inserted, a new rational approach to the production model, centered on the logistics chains of consumed products, characterized by the transformation of these into circular chains, instead

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of the traditional linear ones, that is, with the reduction or even elimination of the release of waste into the environment (Kirchherr et al., 2023). These profound changes to the economic model are only possible with the use of new information technologies, such as IoT, big data analysis, or communicating the 10Rs to populations, and new public and private organizational models, with the goal of optimizing each node of the logistics chains (Bocken et al., 2021).

The complexity of the relationships between the economy, society, and the environment requires a multidisciplinary approach at the intersection of ecology, sociology, political science, and economics (Ostrom, 2009). It is at this intersection between different fields of knowledge and the difficulty in systematizing complex human systems that socio-ecological systems emerge, based on Ostrom's work and incorporating concepts from institutional theory. Another observation made by the author is the need to divide these systems into smaller parts—such as subsystems or lower analytical levels—to facilitate understanding of the relationships between the different elements. In these smaller spaces, it is possible to analyze territorial resilience in detail, including community cohesion and population well-being. This work is part of this complex systematic view of territories and human societies, seeking to analyze value chains on a geographical scale and their relationship with resilience and sustainability, through a case study at the municipal level.

These objectives translate into the central research question of this work: How can circular economy practices contribute to local resilience and sustainability at the municipal level? Separated into several sub-questions: SRQ1: How resilient is the municipality of Sintra, and how does it compare to the national average? SRQ2: Which local organizations contribute to advancing CE principles in Sintra? SRQ3: What technologies are used locally to promote circularity? SRQ4: How do these elements of the CE interact in Sintra's socio-ecological system? SRQ5: What are the impacts of CE on territorial resilience and community participation?

Through a series of successive sub-research questions, this study adopts a descriptive case study approach to examine the implementation of circular economy principles in the municipality of Sintra. The methodology is based on a qualitative descriptive case study analysis of the Municipality of Sintra, employing a set of circularity and territorial resilience indicators.

Theoretical Background

The first dimension relevant to this study is the governance of different organizations within socio-ecological systems. Ostrom addresses this issue, particularly in Governing the Commons, distinguishing four models: public, private, community, and polycentric (Ostrom, 2015). Throughout work, the author supports the idea that communities can be self-governed, and that there is not only a public or private model. It also defined eight principles for effective resource governance: well-defined boundaries; congruence between ownership, provision rules, and local conditions; collective choices; monitoring; sanctions; conflict resolution mechanisms; right to self-organization; layered governance. The principle of layered organization supports the territorial lens used in this study; the municipal level and internal organization models can be used to classify internal organizations within municipalities. To systematize, understand, and predict the behavior of complex adaptive systems representative of a given geographical area, Ostrom's work addressed this issue from an institutionalist perspective, including rules of governance, to clearly establish the relationship between human systems and ecological

systems (McGinnis & Ostrom, 2014). It establishes as key central elements: social, economic, and political figurations; resource units; the resource system; the governance system; users; interactions and outputs; and relationships with the ecosystem (Ostrom, 2009). This work also defined a set of secondary elements for each subgroup.

In 2004, following a socio-ecological approach, Walker defined resilience as the ability of a system to maintain balance when subjected to external disturbances through its reorganization, particularly in the areas of functions, structures, identity, and relationships (Walker et al., 2004). A more social perspective on the concept of resilience was presented by Berkes & Ross in 2013, as the set of forces or characteristics important for the self-organization and agency of a community, drawing up a list of the main factors: people–place connections; values and beliefs; knowledge; skills and learning; social networks; engaged governance (involving collaborative institutions); a diverse and innovative economy; community infrastructure; leadership; and a positive outlook, including readiness to accept change. The greater a socio-ecological system's resilience, the better for the community.

As for territorial justice, which is essential for understanding the relationship between distant territories, in 2007 Zuindeau defined this concept as the equitable exchange of resources through the transfer of sustainability, placing it in this broader context, including time, representing current concerns as intra-generational dilemmas and concerns about future consequences as intergenerational. In this work, the exchange of material resources always corresponds to the exchange of sustainability between territories, including externalities such as pollution along value chains, consequences of global risks, and addresses possible spatial trade-offs (Zuindeau, 2007). Subsequently, Soja (2009) defines it as a fair sharing of public resources and services to achieve minimum acceptable living conditions, comparing their distribution in different spatial areas and using spatial rearrangements to assess unfair disadvantages (Soja, 2009).

The CE presents itself as a solution in line with weak sustainability, incorporating economic decoupling as the result of its implementation, i.e., the separation between economic growth and the extraction of non-renewable raw materials, allowing society to continue to prosper in material terms while continuing to grow economically in a new paradigm (Kirchherr et al., 2023). The starting point for this approach aligns with the observation that there are physical limits to raw materials and space in the Earth system and seeks to change value chains through a set of practices to make them sustainable, i.e., reducing or eliminating waste production. However, despite considering a smooth transition of society to a more sustainable model to be possible, the implementation of fully sustainable logistics chains remains dependent on enormous social transformations, particularly in the behavior of individuals, in the forms of governance of public and private organizations, and in democracy itself (Loorbach et al., 2017). For this study, the CE needs to be defined as a model for organizing the management of social ecosystems based on value chains, with the nodes of these chains defined as the basic unit of the model (Bocken et al., 2021). The CE does not have the primary objective of preserving or regenerating ecosystems, but it does have an indirect positive impact on environmental and social sustainability by reducing the release of pollutants into the environment. In 2023, Kirchherr et al. quantitatively analyzed 221 definitions and concluded that there is no consensus and that it is unlikely to be reached. Like the definition of CE, its implementation is the subject of much debate across

various disciplines within the scientific community, and there is currently no clear, single path to achieving sustainability in logistics chains. One of the models for implementing the CE in urban areas was proposed by Sánchez Levoso et al. in 2020 and consists of four steps: analysis of the context, selection of the implementation scope, identification of circular economic opportunities, and roadmap for implementation.

The need to regenerate territories in the three dimensions of sustainability requires multidisciplinary approaches, such as the regenerative lens, presented by Buckton in 2023. In this conceptual framework, the regeneration of socio-ecological systems is defined as the balanced maintenance of human and ecological cycles, or the positive reinforcement of well-being, co-evolving and renewing themselves rather than degenerating. This author also identifies five critical factors for regenerative dynamics: global perspective of ecology, mutualism, diversity, agency, and reflection (Buckton et al., 2023).

In the socio-technical dimension, the sustainability of logistics chains is only possible through the use and development of new Information Technology tools (Dubey et al., 2020). Despite the clear benefits, these technologies raise numerous technical and ethical challenges, including their responsible use in society, hindering their diffusion by clashing with current legislation (Qadri et al., 2025) and potentially harming users' health (Docherty & Biega, 2022). Authors such as Docherty & Biega report on the responsible use of technologies for user well-being, characterizing the implications of this tool not only from a behavioral perspective, but also from a socio-technical approach, including social, political, environmental, or policy consequences. Others go further and include the consequences for social sustainability when addressing relationships with democracy and governance (Qadri et al., 2025) or digital citizenship (Gooding & Phillips, 2025).

Regarding public policies promoting circularity, quantitative objectives were established for waste reduction and recirculation through European targets set out in the 2008 EU Waste Framework Directive. This directive enshrined circular economy principles in Community law by establishing a waste hierarchy, confirming the "polluter pays" principle, introducing the concept of extended producer responsibility, defining targets for waste recycling and recovery, and mandating waste management plans and waste prevention programs (EP & CEU, 2008). In 2018, municipal recycling targets for 2025, 2030, and 2035 were revised, requiring the recycling rate to reach at least 55%, 60%, and 65% of generated waste, respectively (EP & CEU, 2018). With the directive's revision, food waste reduction targets were introduced: a 10% reduction for waste from production and manufacturing, and a 30% per capita reduction for food waste from retail, restaurants, distribution services, and households (EP & CEU, 2025). In terms of practical implementation, action plans were defined at various levels, such as the European Circular Economy Action Plan at the EU level and national Action Plans for the Circular Economy (PAEC). The European action plan aims to equip the European Union with appropriate tools and establish an agenda to achieve the European Green Deal through the efficient use of natural resources, with the goals of reducing the environmental footprint, making the economy more competitive, achieving carbon neutrality, and initiating the regeneration of terrestrial ecosystems (European Commission, 2020). The roadmap is based on seven pillars: product sustainability, key value chains, waste reduction, a multilevel approach (People, cities, and regions), cross-cutting measures, global leadership, and monitoring. In

Portugal, the adoption of a Circular Economy action plan began in 2017 with Council of Ministers Resolution No. 190-A/2017 and the publication of the first roadmap in 2023. This legislation sought to equip the State with instruments to increase circularity at various levels, such as specific economic sectors and territorial entities like municipalities (APA & DGAE, 2023; Presidency of the Council of Ministers, 2017). In 2026, the development of a new roadmap—PAEC 2030—was approved, coordinated by the Portuguese Environment Agency, the Directorate-General for Economic Activities, and the Office for Planning, Policy and General Administration (Presidency of the Council of Ministers, 2026).

This exploratory study analyzed the municipality of Sintra as a territorially delimited system due to its diverse physical and social characteristics, allowing for comparison to other areas of the national territory, like the analytical generalization methodology (Yin, 2018). The municipality of Sintra is in the northwesternmost part of the Lisbon metropolitan area, with densely populated urban areas in the south, representative of the metropolitan urban periphery, and less populated rural areas in the rest of the municipality (Fig. 1).

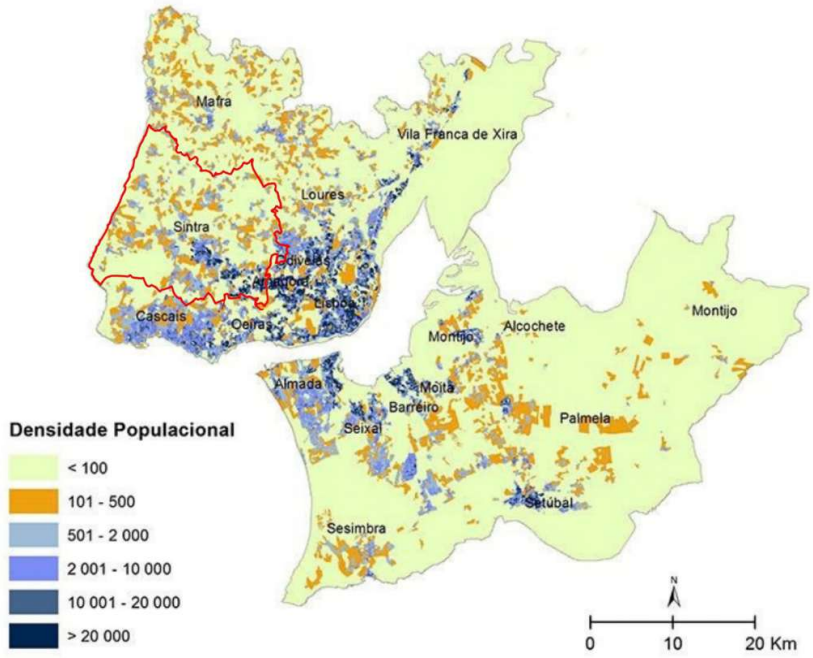

Fig.1 Population density in the Lisbon metropolitan area, with Sintra outlined in red (Source: (Morgado, 2017).

It also features a natural park, an extensive coastline on a national scale, and areas dedicated to primary economic activities in rural areas (Fig. 2).

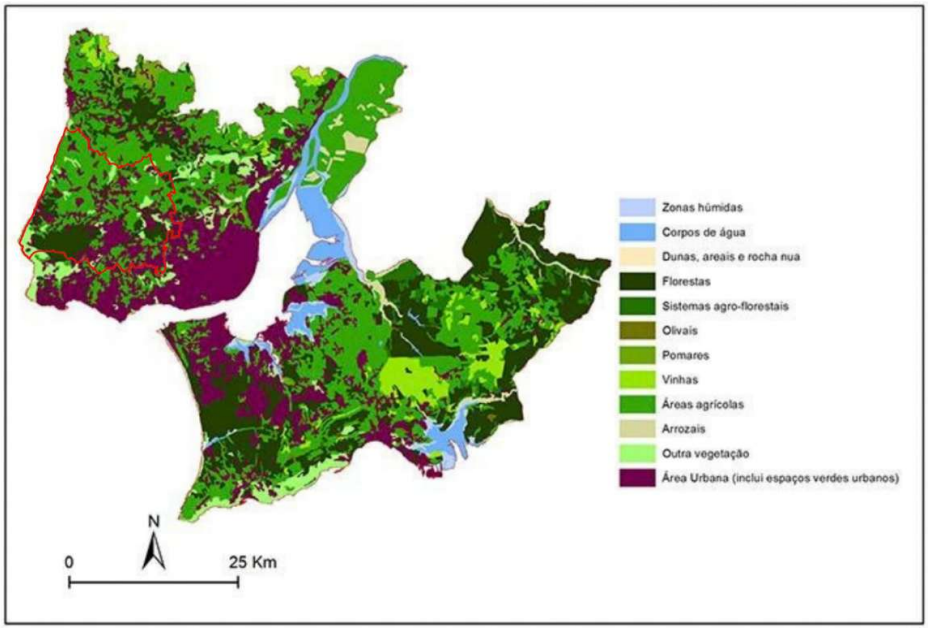

Fig.2 Land-use patterns in the Lisbon metropolitan area, with Sintra outlined in red

(Source: (Morgado, 2017).

It is in this area that the extraction and production of aggregates take place, among which marble stands out. The municipality's economic activity is predominantly tertiary, with the manufacturing sector having a greater weight than the national average (Fig. 3).

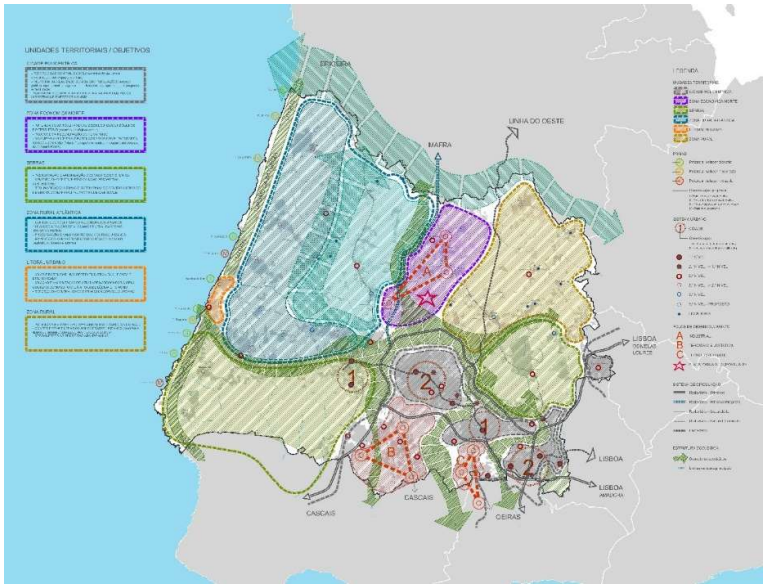

Fig.3 Sintra's territorial development model (Source: Câmara Municipal

de Sintra (CMS) & DM-APG, 2015).

The economic drivers are in the southern part of the municipality, coinciding with the most densely populated urban areas. This area of the municipality concentrates historical industrial centers of high economic importance, notably in the pharmaceutical, tobacco, and machinery

and industrial parts production industries. In terms of built public infrastructure, the municipality is served by a university campus, a vast network of public schools, a hospital, health centers, various sports facilities, performance venues, urban and forest parks, and bathing areas (Terezo, 2014). Regarding road and rail infrastructure, it features a railway line and a Complementary Route (IC19) equivalent to a toll-free motorway connecting to the rest of the metropolitan area, two motorways, and several national roads (Fig. 3). The municipality's urban fabric developed around the two main historical axes connecting to Lisbon: the IC19 and the Sintra railway line. The business sector is equally diverse, with the presence of local, national, and international companies. Demographically, we verified that it is a municipality with a relatively young population, with population growth above the national average, even during the period of economic crisis (2011-2015) (Statistics Portugal (INE), 2025).

Methodology

This exploratory and conceptual work is part of a doctoral research project on transitions to sustainability and represents one of the first steps in a broader study based on a case study with a geographical focus on the municipality of Sintra, aimed at finding solutions to achieve sustainability in logistics chains. This article begins by defining key concepts and identifying indicators, organizations and technologies relevant to assessing local resilience. Based on bibliographic research on the process of assessing and implementing the CE, a process combining the critical view of this work is presented. The next step is to construct a conceptual framework, based on a systematic socio-ecological approach, representing a sustainable logistics chain with a geographical perspective and identifying the nodes where information technologies and community organization are essential. Based on the selected indicators, this study proposes a qualitative, exploratory analysis of the municipality of Sintra's territorial resilience, using conceptual frameworks that link resilience to the use of information technology for assessment and implementation. Finally, the conclusions, the answer to the research question, and the future perspectives will be presented.

Case study context

The focus of this work is the municipality of Sintra, situated on the edge of the Lisbon metropolitan area and the westernmost point of mainland Europe. It is divided between a densely populated urban zone, connected to the center by two main roads and an urban railway line, and a large rural area surrounding it, including the Sintra-Cascais Natural Park. Its historic center, Vila de Sintra, is located at the crossroads of these three regions and is a well-known tourist destination.

The indicators presented were chosen taking into account the definition of socio-ecological resilience (OCDE, 2018), in order to link the situation of the municipalities with community and local resilience, as proposed in the works of Berkes & Ross (2013), Hansen (2023) or OCDE (2018). The area, total population, and population density allow us to situate and compare the size of the municipality. Population growth and variation can indicate future municipal demographic behavior, while the unemployment rate allows us to assess the connection between people and the labor market, forming part of the territory's economic resilience (OCDE, 2018). The number of associations, in turn, is associated with various concepts of resilience by

Berkes & Ross, such as social networks or engaged governance (Berkes & Ross, 2013). The economic indicators were chosen to support the portrayal of the territory presented in the contextualization of the work, the ideas conveyed by the accessed municipal documents, the concepts presented by Berkes & Ross, 2013, and to allow a description of the municipality's economic situation in light of economic resilience supported by the OECD (2018).

Table 1. Presentation of some geographical, demographic, economic and associative indicators of the municipality of Sintra. (CMS, 2014; INE, 2026). a) Average per municipalities.

Indicator	Municipality of Sintra	National average	Source
Area	319,23 km²	299,4 km² (a)	INE
Population	395 528 hab	34902,7 hab (a)	INE, 2024
Population density	1.208,1 hab/km²	116,6 hab/km²	INE, 2024
Population variation (2014-2019)	+2,7%	- 0,19%	(INE, 2023)
Young people (below 15years)	14,2%	12,7%	INE, 2024
Unemployment rate	5%	6,3%	INE, 2025 IEFP 2025
Cultural and recreational associations	80	n.a.	CMS, 2014
Sports clubs / sport associations	47	n.a.	CMS, 2014
Economic activities as % of local GDP:			INE, 2024
Extractive Industry	0,1%	0,4%	
Agriculture, forestry and fishing	0,6%	2,3%	
Consulting and scientific activities	4%	7,5%	
Education	1,3%	1,1%	
Health and social support activities	3,2%	3,6%	
Artistic, entertainment, sports, and recreational activities	1,8%	1,6%	
Transformative industry	26,4%	19,1%	

Then, based on the framework presented by these authors in the same article, examples were identified for each of the ten relevant factors and presented in Table 2. A justification is provided for each example given regarding the cited local resilience factors.

Table 2. Local examples of factors that promote resilience (source: Berkes & Ross, 2013)

Factors	Example	Justification
People–place connections	Sintra urban railway line	The Sintra Line is widely used to identify the place of origin of inhabitants within the Sintra urban area (Guerreiro, 2019).
Knowledge	ISCTE – IUL Sintra campus	Since 2022, the Iscte – Instituto Universitário de Lisboa, a public university institution, has operated a campus in Sintra (ISCTE, 2026).
Skills and learning	Secondary schools: Stuart Carvalhais, Recuperação do Património de Sintra or Santa Maria	Sintra Municipality School Cluster, including an example of a school offering vocational training dedicated to heritage restoration (CMS, 2020).

Social networks	Sintra Social Network, Sintra Business Association, QSintra, Volunteer Network	Formal networks of contact between organizations and associations in the municipality were selected (*Aesintra | Associação Empresarial de Sintra*, s.d.; *ASSOCIAÇÃO QSINTRA – QSintra*, s.d.; *Rede Social*, s.d.; *SintraVoluntária*, s.d.).
Engaged governance (involving collaborative institutions)	Ser Alternativa, Os Patarecos – IPSS, SOLAMI, volunteer firefighters	Examples of private social solidarity institutions present in the municipality (*Os Patarecos - Associação Particular de Solidariedade Social*, s.d.; *Ser Alternativa – Associação de Apoio Social | Desenvolvimento harmonioso, físico e espiritual*, s.d.; *Solami*, s.d.).
A diverse and innovative economy	Pharmaceutical and parts manufacturing industry	Based in Sintra (*Escritórios & Contactos | Glintt Global*, s.d.; *Visão geral | Hikma*, s.d.). Innovation in these sectors (OECD, 2025; World Economic Forum, 2023).
Community infrastructure	Citizen Space, Youth Center, Recreational Centers, Olga Cadaval Center, Sintra Museum of Arts	Municipal infrastructure (*Espaço Cidadão de Sintra*, s.d.; *Museus Municipais*, s.d.; *Rede de Centros Lúdicos*, s.d.).
Leadership	Sintra's City Council	The municipal council is the main territorial executive body in Portugal (A.R., 2013).
Values and beliefs	Multiculturalism, Portuguese and Afro-descendant suburban culture	Strong Luso-African presence (Berry, 2011; Putnam, 2007; *Sintra Social*, s.d.).
Positive outlook, including readiness to accept change	Cultural intermediation programs	(Ager & Strang, 2008; Carmen et al., 2022; *Equipas municipais de mediação intercultural*, s.d.; *Sintra Social*, s.d.).

Several organizations and initiatives have been identified as playing a significant role in promoting the CE in the municipality (such as those referred to by Ghisellini et al., 2016; Kirchherr et al., 2023). Each of these entities contributes to advancing CE principles through education, practical initiatives, and public engagement.

- **House of CE**: This organization, supported by CMS, serves as a cornerstone for the dissemination of CE concepts and practices within the community. It provides resources, hosts events, and facilitates dialogue around sustainable economic models.
- **Water and Waste Museum**: Closely linked to the CE, the museum is actively involved in initiatives that encourage the adoption of good practices and raise awareness among citizens about the importance of resource efficiency and waste reduction.
- **Repair Café**: This community-driven initiative offers a space for individuals to learn how to repair various items, thereby extending their lifespan and reducing waste. The repair café is an example of practical, hands-on engagement with CE principles.
- **Development Associations**: Several local development associations are actively engaged in the promotion and implementation of CE actions. These organizations often lead projects, workshops, and campaigns that encourage sustainable practices at the community level.

- **Clothing Exchange Initiatives**: Both public and private programs facilitate the exchange of clothing, enabling reuse and reducing the demand for new textile production. These initiatives foster a culture of sharing and resourcefulness.
- **Private Companies**: Numerous businesses in the area are dedicated to repairing goods or selling second-hand products. By extending the life cycle of items and promoting reuse, these companies embody the principles of the CE and provide practical options for consumers.

Collectively, these organizations and initiatives demonstrate a strong commitment to fostering the CE in the municipality. Through education, direct action, and the creation of opportunities for reuse and repair, they contribute to a more sustainable and resilient local economy. In terms of public policy, municipal executives have recognized the importance of monitoring and implementing circularity through the creation of economic and legal incentives, as well as mechanisms for participatory public engagement. On this last point, the municipality created a strategic council and has annual participatory budgets of different types (CMS, 2014, 2025). It is also observed that there are several initiatives to promote and raise awareness of good practices among citizens and customers, on the part of public companies and other key organizations of economic circularity (Ghisellini et al., 2016), such as the municipal water distribution company SMAS Sintra (SMAS, 2026) or the waste collection and treatment company Tratolixo (Ambiente Magazine, 2025).

At the municipal level, and with the aim of increasing the sustainability of supply chains, some relevant Information Technologies (IT) were identified (Stock et al., 2018): Real-time indicator visualization, remote monitoring, and mapping platforms. Using these technologies, decision-makers or AI tools can monitor in real-time, including with geolocation, the different actors and key elements of the supply chain, with clear benefits in data generation, knowledge creation, and allowing the optimization of circular supply chains until they achieve sustainability (Fraga-Lamas et al., 2021). While the visualization of the data obtained should be used exclusively by decision-makers, with particular attention to the protection of user data, the mapping of resources is already the responsibility of citizens and may allow for a more precise mapping of the location of resources (Kitchin, 2014), as well as contribute to keeping individuals better informed about circularity solutions (Sauermann et al., 2020).

This resource mapping is a key step in monitoring and implementing the CE and requires the involvement of the entire community, potentially leading to community regeneration through the creation of connected user networks and the strengthening of relationships between users and community organizations (Danielsen et al., 2022). This relationship of assistance in resource mapping by individuals fits within the definition of citizen science and allows for the opening of a two-way communication channel, with users contributing to the increased circularity of materials, but also receiving information on good practices, infrastructures, and organizations that promote the sustainability of supply chains (Sauermann et al., 2020).

Frameworks

Drawing on the definitions of CE assessment and implementation, we began by constructing a summary outline of the existing literature and adapting it to an adaptive, participatory approach. Based on the methodology presented by Sánchez Levoso et al., which includes a fifth step of

monitoring and stakeholder consultation in defining solutions, Fig. 4 was developed to represent a process for evaluating and implementing the CE within a continuous improvement and monitoring framework. The five-step process presented seeks to incorporate best practices in public policy definition, with the participation of different actors (Israel et al., 1998) and inclusion of continuous adaptive models (Folke et al., 2005).

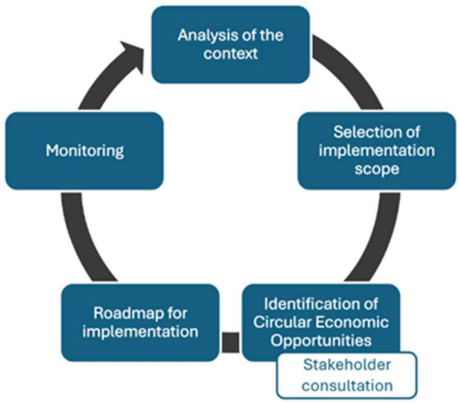

Fig.4: Simplified diagram of the five-step process for implementing community-based policy (Based on Israel et al., 1998 and Sánchez Levoso et al., 2020).

The hybrid supply chain integrates several essential nodes that drive increased sustainability within the municipality. Among these, re-commercialization initiatives play a significant role by enabling the resale and reuse of products, thereby extending their lifecycles. Reverse logistics further supports sustainability by facilitating the return and proper management of products once they reach the end of their useful life. In addition, the establishment of new organizations dedicated to end-of-life product collection—such as waste picker cooperatives—contributes to efficient resource recovery and waste reduction.

Within this supply chain, certain nodes are particularly well-suited for community-based management approaches, and at these points, the participation and oversight of local groups or cooperatives can enhance operational effectiveness and community engagement (Arman & Mark-Herbert, 2021; Rodrigues et al., 2025). To maximize circularity and sustainability, the implementation and responsible use of new information technologies are identified as crucial, since these technologies can streamline processes, improve data collection, and optimize resource flows throughout the supply chain.

The supply chain analysis also incorporates a geographical perspective, clearly delineating the municipality's boundaries. This spatial mapping allows for a targeted assessment of relevant nodes and actors, ensuring that sustainability initiatives are effectively localized and responsive to community needs. The results of this analysis are illustrated in Fig. 5, which represents the hybrid supply chain adapted to the municipal context.

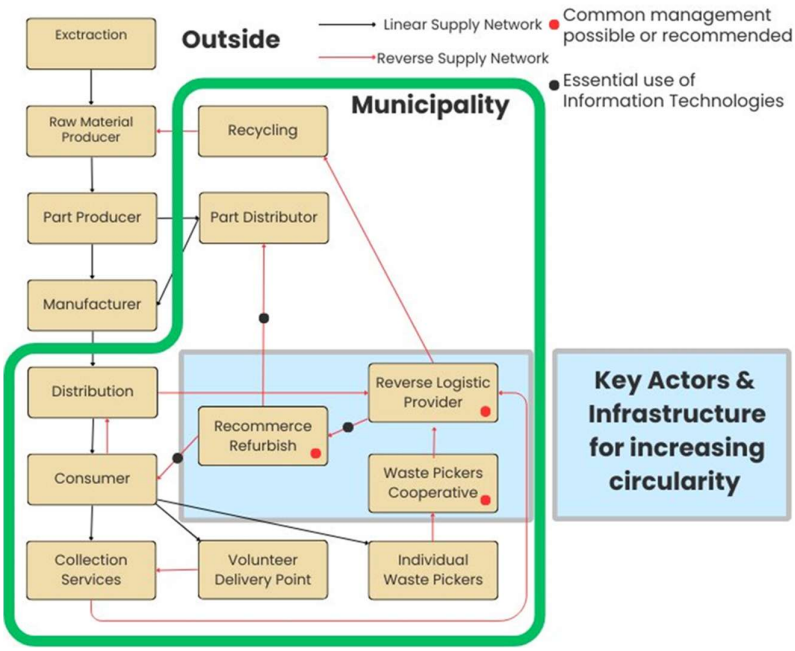

Fig.5: Example of a hybrid SC for a non-renewable product imported with production and processing outside the municipality. Distinction of the municipality's geographical area, with actors partially/totally present to carry out their economic activities, the type of management of each actor, the critical use of information technologies, and the critical actors for the implementation of the CE. (Based on Braz & Marotti De Mello, 2022).

Discussion

An analysis of resilience factors in the municipality (Table 1), compared to the national context, reveals a high proportion of young people, an above-average population growth, and a lower unemployment rates (Lima, 2024). There is also a vibrant cultural and social activity, evident in the number of cultural and sports associations; however, it is not possible to compare this situation with the rest of the national territory because there is no similar data. In economic terms, agriculture and raw material extraction are of little relevance to the local economy, while scientific and educational production stands out positively. This economic data aligns with expectations (Baicker et al., 2010), given that this is an urban municipality. Overall, the selected indicators presented in Table 1 serve as an initial approach to characterizing the sustainability and resilience of the Municipality of Sintra, but they should be supplemented with additional indicators to enhance the analysis and the robustness of the conclusions.

The factors presented to assess local resilience (Table 2) were selected according to the criteria of the Berkes & Ross framework in 2013 because they are representative and emblematic of the municipality of Sintra, in the authors' opinion. For each factor mentioned, there were several possible examples, allowing us to suggest that the municipality has all the prerequisites for long-term resilience. For the survey of community-based organizations with initiatives linked to the promotion of the CE, most examples reported internationally (Quist & Tukker, 2013) are found at the municipal level. Regarding the presence of organizations, activities, or training initiatives dedicated to disseminating good practices in the CE, they are diverse, as stated in the literature, and appear to be relatively uncommon in the literature on Portuguese municipalities.

The choice for the bibliographic basis supporting the construction of the evaluation and implementation process scheme was due to its being an approach in urban systems and environmental management, sharing with this work the character of public policy implementation. The choice of a broader perspective contrasts with most of the literature, which focuses on narrower implementation lenses, such as business models, consumer best practices, or legislation.

The geographic lens applied to the hybrid logistics chain shown in Fig. 5 allows us to visually identify the relevant nodes for implementing the CE in the municipality. This visualization allows us to see the importance of the municipal level for the assessment, regulation, and implementation of recommerce solutions. In fact, this fundamental step in completing the loops is above all a connection of proximity between people and local authorities. Consequently, municipalities may play a key role in implementing circularity in society, as they are public administration bodies present and active at this level.

Using the key actors and infrastructure identified in Fig. 5, this contextualization allowed us to proceed with the systematization of the relationship between assessing and implementing the CE, digitization, and local resilience. The concepts explored throughout this study were cross-referenced, and a summary table (Table 3) was constructed.

Considering the scope required to effectively assess and implement the CE at the municipal level, this is only possible through the use of new digital tools by the entire population (Dubey et al., 2020), in a citizen science approach (Haklay, 2013), where each individual participates in mapping existing resources, receives information on different ways to extend the useful life of products, including where to have them repaired, and ultimately achieve zero waste. This responsible use of technology, considering the definition of avoiding damage to the well-being of populations, promotes local resilience by involving the community and creating new connections between people and organizations (Danielsen et al., 2022).

Tab. 3: Relationship between assessing and implementing CE using technology and local resilience.

	Assess CE	Implement CE
Digitalization	Requires involvement of the population, promote new associations and leads to responsible use of IT.	
Local Resilience	Promotes responsible use of technology.	Reduces the system's connection to the surrounding environment and the transfer of sustainability.
	Enhances community involvement and strengthens social connections.	Raise territory equity. More local power, accountability and agency.

The CE, in turn, increases the local system's resilience by reducing material exchanges with the surrounding environment. Based on Zuindeau's 2007 definition, there is a reduction in the transfer of sustainability across geographical systems, increased equity and resilience between territories, and greater power, accountability, and agency for local populations.

The conceptual frameworks constructed with the concepts addressed throughout this work already provide us with valuable relationships for future work, identifying the nodes of value chains where information technologies are critical, as well as the role of local authorities in implementing the CE or the potential for the development of community organizations. They also allow us to establish the relationship among the CE, responsible resource use, and their impact on local resilience. They could be further improved by increasing the level of detail and serving as a starting point for building a framework for the municipality of Sintra's socio-ecological system from a logistics perspective.

Conclusion

A comparative analysis of the existing indicators presented in Table 1 suggests that the municipality of Sintra may exhibit some characteristics indicative of greater local resilience when compared to the national average, notably its young population, population growth, the presence of cultural and sports associations, and strong manufacturing activity. In addition to these indicators, there are also numerous factors contributing to local resilience (tab.2). In organizational terms, the key players in the municipal CE are mainly social sector associations and public entities, with the local authority playing a leading and important role in its promotion and implementation. The preliminary data from this study —regarding both resilience factors and community-based organizations linked to local best practices — suggest significant potential for sustainable local development and the possibility of standing out positively when compared to the rest of the national territory. Throughout this study, the following were identified as local organizations and events promoting the circular economy: House of CE, Water and Waste Museum, Repair Café, various local development associations, clothing exchange initiatives, and private companies dedicated to circular economy businesses. To achieve sustainability in logistics chains, the most relevant information technologies at this scale are real-time indicator visualization, remote monitoring, and mapping platforms. This type of technological use can be classified as responsible, as it benefits users and society, resulting in sustainability gains for the population and the environment. Through the construction of a framework (Fig. 5), where IT solutions were cross-referenced with the municipal sustainable value chain framework, it was found that their use is essential for optimizing linkages: Part distributor – Recommerce / Refurbish, consumer - Recommerce / Refurbish and Reverse logistic provider - Recommerce / Refurbish. Based on this framework, we can also visualize that the municipal level plays a prominent role in the success of public policies for implementing the CE, due to its proximity to citizens and the characteristics of the services provided to the population. One of the essential factors for local resilience is the connections between citizens, citizen science, and participation in associations and activities they promote (Daniel & Fernandes, 2024). As observed in figure 5, achieving a fully CE model is only possible by mobilizing the whole of society, creating new associations and new organizations, and prioritizing common governance models. New places and new infrastructure are also necessary, contributing to increased social and economic sustainability. By fostering a deeper connection among people, associations, and local authorities, CE promotes greater local resilience and the responsible use of information technologies (Tab. 3). From a systemic point of view, the CE isolates the system, reducing its dependence on the outside world, while increasing its resilience, environmental sustainability, and territorial equity. Finally, locally, democracy also gains accountability, agency, and decision-

making power, leading the CE to act as a catalyst for the regeneration and development of the commons.

Future prospects and next steps for the research - Scaling, Institutionalization and Systemic Transition

This exploratory study represents the first output of a broader investigation into the circular economy from a territorial perspective, focusing on the case study of Sintra. The selected data, discussion, and preliminary conclusions aim to pave the way for the implementation of the ideas presented in this chapter. Based on this initial work, we can begin to outline certain possibilities and considerations, articulated as future avenues for research.

The prospects of municipal circular transition extend beyond local waste management reform. When embedded within participatory governance and supported by responsible digital infrastructures, CE strategies may contribute to broader systemic transformation. One central prospect concern is scaling mechanisms and Scaling Circular Governance. Municipal circular initiatives may evolve through:

- Horizontal scaling: replication across neighboring municipalities through inter-municipal cooperation networks;
- Vertical scaling: integration into regional and national policy frameworks;
- Deep scaling: cultural transformation through changes in norms, values and everyday practices.

If circular governance becomes institutionalized at multiple administrative levels, municipalities may shift from isolated experimentation to coordinated territorial transition.

A second prospect lies in the evolution of digital commons infrastructures and data sovereignty. Instead of relying on proprietary platforms, municipalities may develop open-source, interoperable systems that are collectively governed. Such infrastructures would strengthen data sovereignty, reduce technological dependency and align digitalization with commons governance principles. This trajectory could redefine the role of digital technologies from optimization tools to democratic infrastructures enabling collective stewardship of material flows.

A third prospect concerns the transition from circular efficiency to regenerative territorial models. As local systems become more aware of biocapacity constraints and material interdependencies, CE policies may integrate biodiversity restoration, climate adaptation and social inclusion strategies. In this scenario, municipalities would function as nodes within regenerative regional networks, balancing autonomy with interdependence.

Nevertheless, there are structural constraints and realistic boundaries. Prospects must be assessed realistically. Municipalities operate within globalized supply chains, fiscal constraints and regulatory frameworks that may limit transformative capacity. Without supportive national and European policy alignment, local circular initiatives risk remaining fragmented.

Thus, the long-term prospects of municipal circular transition depend on multi-level governance coherence, stable funding mechanisms, and institutional commitment to participatory design.

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