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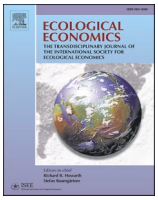

Following the Circular Economy in European rural municipalities through the Spanish Urban Agenda

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ABSTRACT

The Circular Economy (CE) is a driver of change and regeneration at a global level, and especially for rural areas. However, there is a missing link regarding the CE in municipalities, i.e. at the macro level encompassing the built environment, which is even more pronounced concerning rural environments as a result of an existing scientific literature primarily focused on large cities. The present paper addresses these issues by means of parallel analysis of two key research axes targeting, on the one hand, the concept of CE tailored to the field of study of the built environment and, on the other hand, the implementation of CE in European rural areas. The former puts forth an adapted definition of CE, while the latter generates a database tool for CE strategies based on benchmark CE and sustainability databases, relying on the case study strategy adopted: the Spanish Urban Agenda. This analysis allows for a broader relevance of findings, as it can be extrapolated to other international official documents, on top of illustrating the CE decision-making process applied to municipalities and its respective strategy selection.

1. Introduction

The Circular Economy (CE) is increasingly positioning itself as a global sustainability axis. Specifically, at the European Union level, the Commission developed a multitude of plans and strategies, such as the "zero waste programme for Europe" (European Commission, 2014a), the communication on resource efficiency opportunities in the building sector (European Commission, 2014b), the "EU Circular Economy Action Plan" (European Commission, 2015), a "monitoring framework for the Circular Economy" (European Commission, 2018), the "European Green Deal" (European Commission, 2019), and the "New Circular Economy Action Plan for a cleaner and more competitive Europe" (European Commission, 2020a). In addition, the European Commission's Directorate-General for Environment (2014) has laid out its vision for 2050: "Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably".

In turn, member countries develop their own CE-boosting roadmaps, as is the case of the Netherlands (Dutch Ministry of Infrastructure and the Environment, 2016), Finland (Sitra Studies 121, 2016), Germany (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2016), Portugal (Portuguese Ministry of Environment, 2017), Italy (Ministry for the Environment, Land and Sea, Ministry of Economic Development, 2017), France (French Ministry of Ecological Transition and Solidarity, 2018), Poland (GOZ, 2020), Ireland (Government of Ireland, 2020), and Spain (Gobierno de España, 2020).

This scenario is compounded by the damage inflicted throughout the COVID-19 pandemic. In light of it, the European Union created the Next Generation EU recovery funds (European Commission, 2024a), which aim to promote "a more sustainable, resilient and fairer Europe" and boost the circular economy (European Commission, 2020b). Similarly, the UN stresses the need to promote a CE with the certainty that "the COVID-19 crisis provides an impetus to accelerate transformative change" (United Nations Environment Programme, 2021).

Moreover, by virtue of a CE approach, this recovery process could reach different scales, encompassing the city scale at the macro level (Kirchherr et al., 2017) (Prieto Sandoval et al., 2018). Cities account for a large part of the world's resource consumption, i.e. 60% of the global domestic material consumption (DMC), as evidenced by the data provided in "The Weight of Cities: Resource requirements of future urbanization" (United Nations Environment Programme, 2018), making it

Abbreviations: AUE, Spanish Urban Agenda (in its Spanish acronym); CE, Circular economy; DD, Descriptive Data; ISUDs, Integrated Sustainable Urban Development Strategies; NUA, New Urban Agenda; SDGs, Sustainable Development Goals; SO, Strategic Objective; UAEU, Urban Agenda for the EU.

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particularly relevant to act upon them. In fact, the CE is now considered a key issue for sustainable urban development in both research and practice (Joensuu et al., 2020), giving rise to the concept of circular cities. Its open concept is still up for debate, although several definitions have been put forward in the literature. Prendeville et al. (2018) indicate that a circular city "is a city that practices CE principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realise its vision of a future-proof city". Others, such as Cavaleiro de Ferreira and Fuso-Nerini (2019), point out that, although the definition of circular city should bear in mind the most significant features of the CE, it should also consider the dynamics of the city and its fundamental structures. Nonetheless, practical implementations of the CE framework transcend this debate by focusing on the reality of the city, and therefore constitute one of the foundations of this research.

Urban clusters or cities meet a minimal threshold of 5000 inhabitants, under which areas are labelled as rural (Vandecasteele et al., 2019). However, the Quito Declaration (General Assembly. United Nations, 2016) determines a scope of action inclusive of cities, towns, villages and overall human settlements of all sizes, and their importance was ratified in the Ljubljana Agreement (Slovenian Presidency of the Council of the European Union, 2021). Recent research findings pointed to only 2.8% of CE strategies being applied to municipalities of under 20,000 inhabitants (Petit-Boix and Leipold, 2018), despite the fact that, in 2015, 28% of the European population actually lived in rural areas (Vandecasteele et al., 2019). Thus, a CE implementation framework would present a great opportunity to generate value in these municipalities (Salvia et al., 2018) as well as for their populations. According to a report by the International Labour Organization (2018), rural workers will be among the most affected by climate change and environmental degradation, but "a transition to agricultural sustainability and a circular economy will result in more and often better jobs". In turn, the European Commission's "A vision for rural areas towards 2040" (European Commission, 2024b) states that "rural areas have a key role to play in the sustainable bio- and circular economy".

In addition, the COVID-19 pandemic brought about a favourable scenario in rural areas, highlighting a higher quality of life compared to overcrowded large cities (Aurambout et al., 2021). This outcome stems from the fear-driven quest for increased security, as happened with previous pandemics, such as the 2014 Ebola one (UN-Habitat, 2020). These issues open the door to start reviewing urban decentralisation on account of the understanding that, in the long term, one of the critical points will lie in "how the future of work and education evolve after extended periods of telework and distance learning" (The World Bank. Urban, Disaster Risk Management, Resilience and Land (GPURL), 2020).

Nevertheless, it has been claimed that trending concepts, such as the CE, experience a diffusion in their meaning (Kirchherr et al., 2017), possibly due to the heterogeneity in approaches and applications within the literature (Prieto Sandoval et al., 2018). In this sense, it would be key that the research sector focuses their efforts on contributing towards a definition consensus (Reike et al., 2018). A brief background was obtained through a database search strategy, comprising two scientific literature databases, ScienceDirect and Web of Science, coupled with a citation snowballing approach (Wohlin, 2014) (Appendix A). The search output stressed the topicality of the subject, as well as its relevance within the field of study, which is reflected in numerous publications dealing with micro-level issues to a greater or lesser extent. The macro and *meso* levels also hold a strong research presence, albeit to a lesser degree, so much so that only Korhonen et al. (2018b), Laumann and Tambo (2018) and Reike et al. (2018) address, in general or other domain-specific papers, the field of the built environment at all three levels. Even though a greater number of papers targeting this field of study take this consideration into account, this is not true for all of them. Moreover, specific research contemplating the CE's macro level from a city or urban planning standpoint was developed by Geldermans (2016) and Mhatre et al. (2021). Conversely, little research has been dedicated to capturing CE strategies in smaller settlements, although recent research such as that of Joensuu et al. (2020) suggested that databases that capture city practices could encourage the built environment to move towards a CE framework.

As far as the built environment is concerned, the multilevel nature of the CE is composed of: i. a macro level, previously mentioned and comprehending the remaining levels, which refers to the city or urban planning scales; ii. followed by a *meso* level, concerning the building scale; iii. a micro level, in which construction features are developed (Pomponi and Moncaster, 2017). In this way, to determine how the CE can impact said levels, it is necessary to analyse certain architectural schools of thought. According to Rowley et al. (2012) each person has a varying view of sustainability, mainly influenced by their professional experience (Turcu, 2013). Considering the recommendation made by Kirchherr et al. (2017) on the need for scope-tailored definitions of the CE, this study examines the latter in relation to urban planning, building and construction and an adapted definition is preliminarily proposed.

In light of the above, the overarching aim of this paper is to provide clarity on circularity in rural municipalities, developing a compendium of the European strategies reported in online CE and sustainability databases. This work extends the approach followed by previous authors such as Petit-Boix and Leipold (2018) and Prendeville et al. (2018) to small municipalities while providing up-to-date data. The major driving force behind this work is to facilitate the identification of urban strategies for each specific context in a global fashion and, thus, bridge the gap in communication as well as establish a broad vision on this topic (Joensuu et al., 2020).

According to Joensuu et al. (2020), complementing the databases of city-based CE strategies with appropriate evaluation methods is warranted. However, the existing CE models and frameworks in the literature are case-specific and conceptual, and cannot be extrapolated to the city scale (Prendeville et al., 2018). Common CE tools, such as life cycle analysis (LCA), material flow analysis (MFA) and the ReSOLVE framework, were deemed unsuitable for studying the circularity of a city, Cavaleiro de Ferreira and Fuso-Nerini (2019) argue that "they are generally too specific or too broad, since they were not developed specifically for circular cities". For this reason, the literature analysed discloses other methods of tackling the CE analysis in urban settings, e.g. categorisation (Petit-Boix and Leipold, 2018), the adaptation of tools such as ReSOLVE (Prendeville et al., 2018) or the creation of a specific indicator-based framework (Cavaleiro de Ferreira and Fuso-Nerini, 2019).

In this regard, the EU points to the Urban Agenda as the strategic framework for cities (European Commission, 2014c). In line with this, the Urban Agenda for the EU (UAEU) was approved in 2016 on the basis of the Pact of Amsterdam (Netherlands EU Presidency, 2016), which in turn contributed to the fulfilment of the New Urban Agenda (NUA) approved in the same year by means of the Quito Declaration (General Assembly. United Nations, 2016).

Spain is one of the few European countries, together with Finland and the Czech Republic, that has published progress reports on the implementation of the NUA (United Nations Human Settlements Programme, 2024). Furthermore, it promoted urban sustainability with Next Generation EU recovery funds (European Commission, 2014a) through the elaboration of Local Action Plan Pilot Projects of the Spanish Urban Agenda (AUE, using the Spanish acronym) (BOE, 2021). The AUE suggests cities to be key elements in achieving CE and calls for action to "Make a sustainable management of resources and favour the circular economy" (Gobierno de España. Mitma, 2019). In this sense, this research proposes an analysis that transcends the theoretical aspect of the CE and simultaneously promotes its implementation and growth

in the built environment, through a decision-making tool from the AUE: Descriptive Data (DD)[1] (Gobierno de España. Mitma, 2021). The present assessment relates the DD with the compendium of strategies gathered, favouring the choice of appropriate CE strategies. In this way, this analysis could constitute an example of facilitating the consultation of CE implementation strategies in municipalities with less than 5000 inhabitants.

It is important to note that authors such as Avdiushchenko and Zając (2019) warn that, although there are relevant actors in the context of CE such as China, their conditions cannot be equated to those of Europe, and therefore their experience cannot be directly transposed into this environment. For instance, the European population is less concentrated and more polycentric (European Union. Regional Policy, 2011). For this reason, this research focuses primarily on the European context and its respective strategies.

Although the scope of this study is framed within the AUE, it could be extrapolated to the remaining European countries, given that the latter relates the DD with all the SDGs (Sustainable Development Goals) -including SDG 11 "Sustainable cities and communities" and SDG 12 "Responsible consumption and production"-, the NUA, the UAEU, and the Integrated Sustainable Urban Development Strategies (ISUDs) (Appendix B). These, in turn, entail a link with urban sustainability strategies in the rest of Europe, as could be the case of Finland with its "Sustainable City programme" (Ministry of the Environment, Finland, 2021) or the Czech Republic with its "Implementation Plan for the New Urban Agenda" (Ministry of Regional Development, Czech Republic, 2021). In this way, municipalities in the rest of European countries could use this study as a reference for decision-making, taking into account data from their own context and carrying out an applied analysis similar to that developed in section 4.2 of this paper.

To achieve the aforementioned aim, and ensuing this first introductory section, this paper is structured as follows: i. section 2, presenting the methodology developed; ii. section 3, delving into the analysis of the CE in the built environment; iii. Section 4, providing the CE implementation in European rural populations and the discussion; iv. section 5, reflecting the conclusions drawn from this research and including the limitations of the study and recommendations of possible future lines of research.

2. Methodology

The research strategy adopted lies in two converging flow lines, detailed hereafter (Fig. 1). The first one (section 3) provides the necessary analysis to address the CE in urban planning, building and construction from the standpoint of architectural schools of thought (section 3.1). Subsequently, it develops a conceptual framework that gathers the concept of CE in the scientific literature through a search on ScienceDirect and Web of Science (section 3.2.1, Appendix A) and proposes a definition adapted to the different levels of study (section 3.2.2), which is validated by a comparative analysis with the findings from previous schools of thought.

The second axis (section 4) deals with the implementation of the CE in rural European communities. Firstly, a search on CE strategies was undertaken in online reference databases, such as Circular Europe Network (2024), Sustainable Cities Platform (City of Aalborg et al., 2024), Governments Going Circular (De Groene Zaak, 2017) and Circular Cities Declaration (ICLEI Europe, 2024). Subsequently, a specific database tool for municipalities of under 5000 inhabitants was generated (section 4.1). Secondly, an applied analysis was carried out using the case of AUE and the DD as a decision-making tool, and its relationship with the strategies found in the previously elaborated database (section 4.2). Said relationship is tackled in a two-fold manner: i. directly, on the basis of what is indicated by the AUE; ii. indirectly, rooted in the definition of the CE proposed in the present paper (section 3.2.2). In turn, a tool was created by way of which an equivalence system collects the relationship between the DD and the SDGs, the NUA, the UAEU and the ISUDs (period 14–20) based on the AUE objectives with which each CE-related DD is linked, taking into account the information collected by the AUE for each of its objectives (Gobierno de España. Mitma, 2019) (Appendix B).

3. Circular economy: urban planning, building and construction

To further the understanding of the concept of CE, this section lays out an analysis of its origins and link to architecture (section 3.1.) as well as the establishment of the conceptual framework (section 3.2.1.), including the proposal of a definition adapted to the field of study (section 3.2.2.).

3.1. Background on the circular economy: architectural schools of thought

While some authors, such as Iung and Levrat (2014), argue that the concept of the CE builds on that of industrial metabolism and the industrial ecology of the 1990s and its optimisation, at the same time, various developing schools of thought (Fundación COTEC para la Innovación, 2017) start to refine this concept, adding different nuances. Based on the literature review (Ellen MacArthur Foundation, 2024; Van Dijk et al., 2014; Ghisellini et al., 2016; Geissdoerfer et al., 2017; Pomponi and Moncaster, 2017; Laumann and Tambo, 2018), the authors pinpointed a set of schools of thought in the architecture sector: Shearing Layers, Cradle to Cradle and Looped Economy / Performance Economy. Their main features are developed in the following sections.

3.1.1. Shearing layers

Duffy and Brand's work on the Shearing Layers theory (Pomponi and Moncaster, 2017) was brought to fruition in the publication "How Buildings Learn: What Happens After They Are Built", developed by Brand (1994) and adopting the term first coined by Duffy (1990) (Monge Pascual, 2016). This theory establishes that buildings have their own metabolism, dependent on a series of layers that are modified throughout the building's life cycle. These shearing layers are divided into: site, structure, skin, services, spatial distribution and furniture, ordered according to their expected durability. They organise the building so that it could have a long life span, as a way to ensure a maximum use of resources and energy both during construction and use. In like manner, this layer structure is kept at the urban scale, allowing for a framework to be established about the evolution of the city (Sattrup and Strømann-andersen, 2011).

3.1.2. Cradle to Cradle

The term Cradle to Cradle was coined in the late 1970s by Stahel (Ellen MacArthur Foundation, 2024), only to flourish later on, with "Cradle to Cradle - Remaking The Way We Make Things" being published in 2002 (McDonough and Braungart, 2002). This school of thought arises from the idea that resources should be kept within the cycle for as long as possible, and that this is achievable without any significant quality decrease. It establishes three basic principles: waste equals resource, as happens in nature where an element's waste nourishes another, and hence waste does not actually exist; renewable energies, as an integrated part of products or services; and diversity, with context-specific products and services tailored to the diversity of places and cultures (Van Dijk et al., 2014).

3.1.3. Looped economy / performance economy

In 1977, Reday and Stahel presented a report for the European Commission entitled "The potential for substituting manpower for

[1] The Descriptive Data (DD) are quantifiable, updated annually and officially provided by the Ministerio de Fomento (Spain). They are relevant to this research because they can be used to measure progress towards circularity.

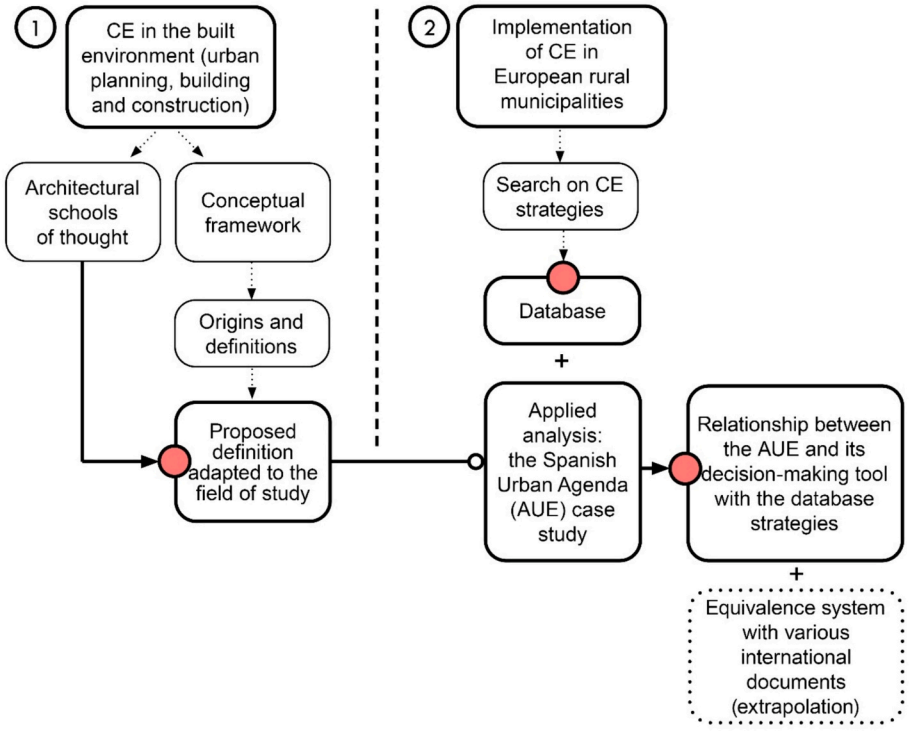

Fig. 1. Flowchart of the proposed methodology. Own elaboration.

energy", describing their vision of a Looped Economy. Yet, it was not until 2006 that this initial concept was updated and expanded from Looped Economy to Performance Economy in the publication "The performance economy" (Stahel, 2006; Van Dijk et al., 2014). This school of thought aims at optimising products starting at the design stage to increase their durability and adaptability, allowing the remanufacturing of worn parts, as well as recycling and waste prevention. It advocates for a service-based business model, rather than one centred on sales, to promote product optimisation and quality (Van Dijk et al., 2014) (Ellen MacArthur Foundation, 2013).

3.2. Conceptual framework

To determine the CE's conceptual framework in the three domains of the built environment, a number of explicit definitions of CE are identified through the searches carried out in ScienceDirect and Web of Science for the brief background presented in Appendix A (section 3.2.1). Based on these definitions and taking into account the schools of thought analysed in section 3.1, a CE definition adapted to the field of study is proposed in section 3.2.2.

3.2.1. Compilation of definitions

Among the dozen definitions examined[2] (Geng and Doberstein, 2008; Ellen MacArthur Foundation, 2015; Gregson et al., 2015; Haas et al., 2015; Ghisellini et al., 2016; Sauvé et al., 2016; Geissdoerfer et al., 2017; Kirchherr et al., 2017; Murray et al., 2017; Korhonen et al., 2018a; Prieto Sandoval et al., 2018; Suárez-Eiroa et al., 2019) (Appendix C), only those contributed by Kirchherr et al., 2017, Prieto Sandoval et al. (2018) and Suárez-Eiroa et al. (2019) explicitly mention the applicability of the concept in the realm of the built environment and incorporate its multilevel dimension (see Table 1, column referring to "levels"). Despite the fact that in putting forth their CE definition, Suárez-Eiroa et al. (2019) took the research of Kirchherr et al. (2017) and Prieto Sandoval et al. (2018) into consideration and pondered the shortcomings in the area pointed out by Pomponi and Moncaster (2017), the need to produce a definition adapted to each field provides the rationale for selecting the definitions from all three authors (Kirchherr et al. (2017), Prieto Sandoval et al. (2018) and Suárez-Eiroa et al. (2019)) as a starting point for this analysis.

3.2.2. Proposed definition adapted to the field of study

Following the recommendations of Kirchherr et al. (2017), and with the intent of providing a CE definition that would allow for its cumulative development, a critical and quantitative analysis of all three selected definitions, already used in the scientific literature, was performed. To this end, a simplified adaptation of the analysis carried out by Calisto Friant et al. (2021) was made to the scope of this paper. In addition, a classification by clustering was adopted according to the following criteria: system type, objectives pursued by the CE, implementation requirements and levels of application; the total number of the keywords or aspects selected was also counted (Table 1).

Building on the above analysis, the basis for a definition was established through the accumulation of similarities. For the system type, an economic system was chosen due to its wide scope including distribution, and not only production and consumption as proposed by Suárez-Eiroa et al. (2019). Objective-wise, and seeking the widest possible scope of the concept, the term sustainable development was added along with more specific issues identified by Prieto Sandoval et al. (2018) and Suárez-Eiroa et al. (2019). It includes both energy and material loops (Prieto Sandoval et al., 2018) and the extraction of resources and generation of waste and emissions (Suárez-Eiroa et al., 2019). The implementation section entails the proposals of all authors as they were deemed complementary. Specifically, only part of Kirchherr et al.'s

[2] All definitions belong to the research collected in the brief background of Appendix A (see Figure A1), with the exception of two, which were obtained from this background using the snowball technique, but excluded for the following reasons. Regarding the first one, the definition provided by Geng and Doberstein (2008) is included in other studies on CE definitions (Ghisellini et al., 2016; Sauvé et al., 2016; Geissdoerfer et al., 2017; Prieto Sandoval et al., 2018), but the field of study - China - cannot be compared to those in Europe, as indicated by Avdiushchenko and Zając (2019). With respect to the second, the definition provided by the Ellen MacArthur Foundation (2015) appears in all the studies on CE definitions reflected here, but it is not a scientific article.

Table 1
Critical and quantitative analysis of selected definitions.

Selected definitions		Categorisation*				Total keywords/ aspects selected count
References	Definition	System type	Objectives	Implementation	Levels**	
Kirchherr et al. (2017)	"An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/ distribution and consumption processes. It operates at the micro level (products, companies, consumers), *meso* level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers."	**"economic system"**	"with the aim to accomplish **sustainable development**, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations"	"reducing, alternatively reusing, recycling and recovering materials in production/ distribution and consumption processes […] It is enabled by **novel business models** and **responsible consumers"**	micro level: "products, companies, consumers" meso level: "eco-industrial parks" macro level: "city, region, nation and beyond"	4
Prieto Sandoval et al. (2018)	"An economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), *meso* (economic agents integrated in symbiosis) and macro (city, regions and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces and consumes."	**"economic system"**	"aims to prevent the depletion of resources, **close energy and materials loops**, and facilitate **sustainable development**"	"requires **cyclical and regenerative environmental innovations** in the **way society legislates, produces and consumes**"	micro level: "enterprises and consumers" meso level: "economic agents integrated in symbiosis" macro level: "city, regions and governments"	5
Suárez-Eiroa et al. (2019)	"Circular economy is a regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with capacity to be implemented at any scale."	"regenerative production-consumption system"	"aims **to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries**"	"through **closing the system, reducing its size and maintaining the resource's value as long as possible within the system**, **mainly leaning on design and education**"	**any level** ("design")	4

* Keywords or aspects selected for the proposed definition are marked in bold.
** The explicit mention of the field of study is underlined.

definition (2017) was considered, i.e. the support of new business models and responsible consumers, since its remainder is more precisely detailed in (Suárez-Eiroa et al., 2019): "reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes".

Likewise, in Table 1, the discourses captured in the different definitions reflect a holistic vision of CE, with keywords or aspects selected from at least 3 of the 4 categories of each of them. In quantitative terms, the contribution of each of them to the proposed definition is similar (4 or 5 keywords or selected aspects). However, these contributions generate differentiated nuances from a global vision that calls it "economic system" to novel aspects such as "mainly leaning on design and education". In this way, this quantitative vision places the proposed definition in line with more holistic thinking, with the aim that CE is not reduced to "end-of-pipe solutions and actually bring about tangible socio-ecological change" (Calisto Friant et al., 2021). The focus is commonly limited to "end-of-pipe factors" and this holistic perspective is necessary to achieve CE and reach the transition, including design as part of an integrated strategy (Hartley et al., 2020).

Based on the most recent publications on CE, the concept of circular disruption is incorporated into this field "as a possible focal point for scholars" to reflect on radical changes to achieve a more sustainable model in the short term (Kirchherr et al., 2023). In this sense, the private sector is particularly important "as a key catalyst for society-wide CE transition" (Straub et al., 2023), especially start-ups, which have "a higher capacity to adopt more disruptive circular business models"

(Henry et al., 2020). Therefore, this issue was also incorporated into the definition proposed through the "novel business models" based on the work of Kirchherr et al. (2017).

In addition, this foundational work to achieve an adapted CE definition was contrasted with the theories developed in the architecture field (section 3.1.), observing that it gathers the following characteristics:

- it touches on the basic resource issues shared by the different theories, e.g. achieving an extended lifetime for the best use of resources and energy invested (Shearing Layers), the need to keep resources within the cycle as long as possible (Cradle to Cradle) and increasing the durability and adaptability of products (Looped Economy - "to close energy and materials loops" (Prieto Sandoval et al., 2018), "to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries" (Suárez-Eiroa et al., 2019);
- it has the flexibility to accommodate the modification of the different layers (Shearing Layers) or the search for greater adaptability (Looped Economy - "cyclical and regenerative environmental innovations" (Prieto Sandoval et al., 2018));
- it includes design as a key point (Looped Economy - "mainly leaning on design" (Suárez-Eiroa et al., 2019)), essential to the development of buildings' metabolism (Shearing Layers).

Although the preliminary definition obtained (Table 1) included the commitment to new business models, it was extended to indicate that these can also be service-based to fully reflect the Looped Economy proposal. By the same token, and to expressly point out the suitability of this definition regarding the built environment and adequately serve as a guide for future research, the specific scales of the field of study indicated by Pomponi and Moncaster (2017) were added: the macro, meso and micro scales.

Finally, the following definition of CE is advanced based on Kirchherr et al. (2017), Prieto Sandoval et al. (2018) and Suárez-Eiroa et al. (2019) for the built environment:

Circular Economy is an economic system whose aim is to close energy and material loops while maintaining extraction rates of resources and generation rates of waste and emissions under suitable values for planetary boundaries, with the ultimate goal of achieving sustainable development. It must be implemented through novel business models, also based on services, and responsible consumers, with cyclical and regenerative environmental innovations in the way society legislates, produces and consumes, closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education. It can be implemented at any level: macro level (city or urban planning), meso level (building) and micro level (construction).

4. Implementing the circular economy in European rural villages

This section presents the search findings on CE strategies in small European settlements in database form (section 4.1). Said strategies were subsequently examined, taking Spain as a case study, to determine their correlation with the AUE's DD (section 4.2).

4.1. Database: circular economy strategies

The strategies search and selection method followed that of previous research (Petit-Boix and Leipold, 2018). Concretely, international online databases on CE strategies in cities (Circular Europe Network, 2024) or on urban sustainability with a specific section on CE strategies in settlements (City of Aalborg et al., 2024), as well as those registered in Governments Going Circular (De Groene Zaak, 2017) or in the Circular Cities Declaration (ICLEI Europe, 2024), were used as reference points. Despite the extensiveness of Petit-Boix and Leipold (2018) research, i.e. covering 210 strategies developed in a total of 83 municipalities, none of the latter has under 5000 inhabitants. Thus, the method followed allowed for the expansion of existing research in conjunction with the clarification of the status of the CE in small towns.

The need for a proper evaluation of CE strategies in cities (Joensuu et al., 2020), together with the growing debate on CE evaluation tools in urban contexts (Fusco Girard and Nocca, 2019) is evident. In view of this, the selection criteria were narrowed down to those driven by or in European settlements and specifically targeting CE as a theoretical sampling strategy (Petit-Boix and Leipold, 2018). The outcome was a set of 17 strategies involving 1127 European municipalities,[3] with the last search taking place in October 2022 (Table 2). However, the Governments Going Circular (De Groene Zaak, 2017) and Circular Cities Declaration (ICLEI Europe, 2024) databases did not contain any records in line with this research.

The analysis of the set of data obtained revealed that France tops the list of countries regarding the highest number of strategies (Fig. 2). Nonetheless, it is in Spain that the CE is implemented in the highest number of towns, followed by the Netherlands and France. In the remaining countries, a single strategy is implemented in a range of one to six municipalities, except for Italy, where two strategies are developed in a total of nine municipalities.

4.2. Applied analysis: the Spanish Urban Agenda case study

This section delves into the link analysis between the DD and the strategies outlined in the previous section (section 4.1) (see Table 3), and finally, a brief discussion of the results obtained is presented. To do so, the link between the DD and the CE is defined on the basis of two issues: the direct relationship indicated by the AUE with its Strategic Objective (SO) 4 on "Sustainable Resource Management and the CE" (Gobierno de España. Mitma, 2019), and the keyword-based relationship of the adapted definition proposed in this paper (section 3.2.2) (see the first three columns of Table 3). In turn, the CE-related DD are tied with the previously mentioned strategies according to the activities and objectives included in the overview (Table 2) (see the last seventeen columns of Table 3 referring to CE strategies). The identification of these links was based on the expert knowledge of the authors of this paper (Avdiushchenko and Zając, 2019). In this sense, the links that cannot be established directly - the DD and the CE link based on the proposed CE definition, and their relationship with the strategies- are obtained taking into account the influence that could occur between some elements and others based on their description.

From Table 3, the following points are noteworthy:

- Out of the 43 DD provided by the AUE, 20 of them relate to the CE: five directly according to the AUE itself, i.e. D.01, D.06, D.08, D.14 and D.33, and the rest from the proposed definition.
- As for the levels of implementation, waste collection strategies do not only involve changes at the micro level but also at the macro level, as they generate infrastructures and proposals for action at the urban

[3] These strategies are obtained from conscious and direct searching of reference databases. Following the methodology applied by Petit-Boix and Leipold (2018), no systematic data collection is carried out, but rather the "inductive approach" is applied, since it "is particularly useful in mapping new domains of research, as it allows the researcher to remain open to new and emerging themes based on the data". For this reason, an overview of all the initiatives available on the designated platforms is provided, selecting the strategies led by municipalities of less than 5000 inhabitants explicitly related to CE. Nevertheless, in the case of the Sustainable Cities Platform database (City of Aalborg et al., n.d.), a differentiation could be used in the content search engine on its website by limiting the results to the path "pursue a shift towards a circular economy", subsequently distinguishing the strategies related to municipalities with less than 5000 inhabitants by searching for information on each of them. Data collection began in February 2019 and has been updated in October 2022. However, the Governments Going Circular platform (De Groene Zaak, 2017) is no longer accessible, and the Circular Europe Network (n.d.) has access problems.

Table 2
Strategies. Key features.

Reference database	Coding	Strategy	Country	No. of municipalities	Inhab. (range)	General description*
Circular Europe Network (n.d.)	S1	Koopera Reusing Centre	Spain	306	18 - 4891	Object collection and reuse scheme (e.g. clothes, books or household appliances), entailing their collection, preparation for reuse and sale in Koopera shops at affordable prices. Government entities partake in this plan together with Caritas.
	S2	Separate collection and treatment of bio-waste in Catalonia	Spain	736	25 - 4960	Municipalities with a separate collection and treatment scheme for bio-waste are entitled to reduced fees.
	S3	Proximity separate collection in Ljubljana	Slovenia	6	241–1631	The public waste management company substitutes the traditional collection system with underground collection points where a card (free of charge for local inhabitants) is required to deposit organic and residual waste, while glass, packaging and paper waste can be deposited without a card.
	S4	Bienvenue a Poubellec'h campaign in Crozon	France	9	335–3385	Educational game aiming at raising awareness among local people about reducing waste, in collaboration between the governmental body, a museum and the Environment and Energy Management Agency (ADEME).
	S5	Eco-island of Krk	Croatia	6	1260–3134	Door-to-door waste collection system to improve collection quality and reuse rate, implemented by participating municipalities.
	S6	Mobile civic amenity sites in Ile-de-France	France	1	1696	Network of waste collection sites in public places, sorting waste from gardening, construction and demolition, textiles, wood, metals, cardboard or bulky waste. The collection sites are always set up in the same location with a frequency agreed with each municipality. This project is a partnership between the municipalities, the Hauts-de-Seine Syndicate for the treatment of household waste, and a private waste management company.
	S7	Improving bulky waste sorting centres performances in Ile-de-France	France	3	1867–4852	Modifications at sorting centres to eliminate part of the contamination and increase the recovery rate of bulky waste. Carried out by private companies and the Paris metropolitan area's syndicate for the treatment of household waste together with member municipalities of the syndicate.
	S8	Integrated waste management in Treviso	Italy	8	1711–4539	Door-to-door waste collection project. This energy-saving household waste collection scheme is carried out by establishing a collection schedule per municipality and per type of waste for more efficient recovery of materials. Each type of waste is associated with a specific container colour which are present in public areas on the collection due date.
	S9	Flexible fee for selective waste collection in Bergen	Norway	2	2436–4140	Flexible waste collection fare model targeting household waste reduction and, in turn, the optimisation of separate collection. Implemented by a waste management company.
	S10	Underground containers for selective collection in Ile-de-France	France	1	2449	Underground container implementation scheme led by the Montmorency Valley Syndicate for the treatment of household waste, the company Eco-Emballages, which promotes the recycling of household packaging, and the participating municipalities.
	S11	Gypsum to gypsum project	Germany France	2 1	2959–4595	Project focused on the production of gypsum boards from recycled gypsum. It aims to increase the recycling rate of gypsum waste, both from production and construction and demolition waste, by producing slabs with a 30% recycled content. Gypsum is also used in agricultural composting.
	S12	Tertre eco-zoning project in Wallonia	Belgium	2	4251–4508	Several working groups engaging in a variety of topics to carry out the eco-zoning of a coal mining area, in order to improve the management and use of material, energy and water, the collaboration with the transport of goods and people, as well as promoting biodiversity. Synergies are established between the regional government, the municipalities, consulting firms and companies, creating economic development and planning actors for several municipalities.
	S13	Packaging waste reduction campaign in Vicenza	Italy	1	4939	A communication campaign is carried out at the municipal level for the reduction of packaging waste, supported by a communication company.
Sustainable Cities Platform (City of Aalborg et al., n.d.)	S14	The Westerkwartier's Regional Development Co-Operative	Netherlands	38	90 - 4460	Regional cooperative Programme creating a regional development agenda with an approach where citizens, businesses, governments, education system and local research institutes generate innovative solutions to local problems. It seeks multi-perspective and multi-sectoral

(*continued on next page*)

Table 2 (*continued*)

Reference database	Coding	Strategy	Country	No. of municipalities	Inhab. (range)	General description*
						solutions, and succeeds in creating new enterprises and business models, as well as engaging the whole community for sustainable solutions and projects.
	S15	Navarius 20.25 Project "Wineries, Culture and Society"	Spain	1	194	Social, cultural, and economic development plan. The following actions are tackled: enhancement of access networks, public WIFI networks, recovery of heritage buildings for tourism and service purposes, tourist routes, creation of green spaces by converting building courtyards into public squares, conservation and improvement of biodiversity, environmental education programmes.
	S16	"Eat Our Own Bread" ("Magunk Kenyerén") Local Economy Development Program	Hungary	1	283	Economic Development Programme elaborated with the active participation of the local administration, population, representatives of cooperatives and organisations and a group of external experts. It aims to recreate and preserve the town's traditional values, take advantage of agricultural opportunities, and use community money to improve the living environment. Programmes are established to promote agriculture, the retrofitting of residential buildings, and the development of services and enterprises.
	S17	Nerbioi-Ibaizabal Supramunicipal Sustainability Office	Spain	5	970–4192	Supramunicipal Sustainability Office operating through a model of cooperation between municipalities to develop a joint Local Agenda 21, which led to the creation of the Supramunicipal Procurement Service, the Supramunicipal Energy Observatory and the Citizens Energy Portal. Its initiatives focus on the development of Agenda 21, waste collection through the collective contracting of selective waste collection services, energy management and the fight against climate change.

* Description based on the open access information available on the reference websites. The description of some of the strategies was complemented with further information available online.

scale. The micro and macro scales are the most widespread in CE implementation considering these strategies. Yet, actions such as S4 or S13 are exclusively relevant to the micro level as they only deal with training or communication strategies. Regarding the *meso* level, it is covered by four strategies only, two of them specifically concerning building retrofitting (S15 and S16) while the remaining ones establish global strategies (S14 and S17).

- Based on the direct relationship with the CE, only two DD connect to the strategies analysed. As far as the DD 01 on population change is concerned, it relates to all the objectives of the AUE (Gobierno de España. Mitma, 2021). Any action that implements urban sustainability favours this DD, and, therefore, all the strategies examined interface with this DD. Out of the remaining DD with a direct relationship, only D.14, which includes the building age, presents a link with a few strategies based on actions for the retrofitting of existing buildings, as is the case with S11, S14, S15, and S16.

On the other hand, regarding the indirect relationship between the DD and the strategies based on the proposed CE definition, the following are of note. The DD D.02.b, D.02.d, D.03.a, D.03.b., D.26.a and D.27.a on crop production and farming land and employment in the agricultural sector, together with the DD D.26.b, D.26.c, D.26.d, D.27.b, D.27.c, D.27.d, D.28.a, D.28.b and D.28.c on employment in general, match the proposed CE definition in their entirety. Nonetheless, within it, the implementation of "novel business models" with "cyclical and regenerative environmental innovations" stands out; it takes into account the "production and consumption of society", supported by "design and education" and is applicable at all levels. It can be seen that all strategies analysed plug into the unemployment rate DD, i.e. D.28.a on the total percentage of unemployed, D.28.b on the percentage of unemployed between 35 and 44 years of age, and D.28.c on the percentage of female unemployment. In turn, four of the strategies (S11, S14, S16 and S17) relate to all DD on the number of workers and establishments and unemployment rate, and are therefore considered to be complete strategies with respect to employability and the different production sectors. Furthermore, it can be seen that the most promoted sector is the industrial one, as the vast majority of the strategies analysed focus on waste and its treatment, while the agricultural sector has the lowest coverage (S11, S14, S16, S17), and the service sector has an intermediate relevance. The latter is accounted for in strategies implementing dissemination and training tasks (S4, S13, S14, S15) as well as those geared towards services in general (S1, S11, S16, S17). For its part, the agricultural sector is influenced by a larger number of DD, since in addition to those related to the work mentioned above, it is found in DD D.02.b, D.02.d, D.03.a and D.03.b addressing territory and farm surfaces.

It is clear from this analysis that the DD D.06, D.08 and D.33 on population density, housing density and housing stock growth, respectively, do not relate to any of the strategies included in this research. A possible explanation could lie in the fact that the density of this type of municipality is not at the core of the problem. Rather, the low density and quality of spaces and housing is usually a point in their favour. At the same time, there is a large amount of old and/or empty housing, mainly due to depopulation and the lack of generational replacement. To this we may add that strategies are further focused on retrofitting in lieu of expanding the housing stock.

Additionally, the DD are more oriented towards urban features than rural ones and fail to include data on quality of life, or even the use of local materials and bioclimatic strategies typical of heritage architecture in rural environments (Ministerio de Vivienda, 2010). Therefore, even though the DD are the decision-making tool of the AUE and encompass rural municipalities, they do not account for the full spectrum of their specific idiosyncrasies. This consideration may be the underlying reason why only two of the five DD directly related to the CE connect to the strategies analysed.

At the same time the absence of strategies at the *meso* level concerning the built environment is clear, therefore emphasising the need

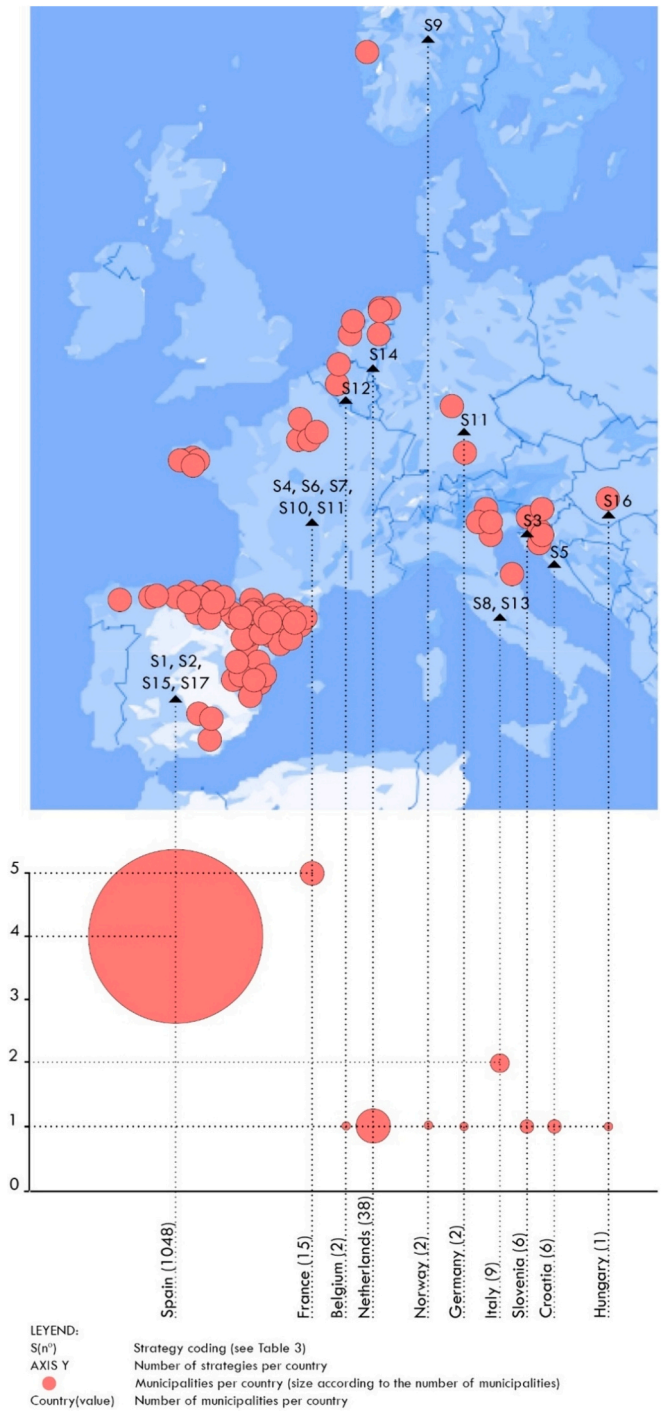

Fig. 2. Distribution of strategies by country. Own elaboration.

and opportunity for future development at this level.

However, the fact that all the strategies are related to the DD of employment (D.26, D.27 and D.28) highlights its importance as a disruptive engine in the circularity of the rural environment, considered as a "socio-technical system which causes the systemic widespread" (Blomsma et al., 2023), key against the depopulation of this context (Recaño, 2017).

5. Conclusions

The significance of the CE at the European level can be observed through its implementation in urban plans, policies and strategies. Yet, the literature review conducted revealed a gap related to rural environments, despite the potential of CE for the latter. Therefore, this paper put forth a tool with a dual purpose: providing a database of existing CE implementation strategies in European rural municipalities and facilitating decision-making, based on the Spanish case study. Apart from the tool developed and its respective analysis, the present research also specifically contributes to the streamlining of the search and selection process of similar and suitable CE strategies after the evaluation of a municipality, with DD as a decision-making tool.

The database obtained, in turn, pointed to the urgency of promoting the CE and its implementation in EU rural municipalities, which was found to be currently scarce with the exception of Spain. Furthermore, according to the research findings, the relevance of providing an adequate definition of the CE in each area is highlighted, since it was detected that even the AUE leaves certain key items such as employment out of account (International Labour Organization, 2018), especially for rural areas (Salvia et al., 2018). Bearing in mind that in the EU many territories are subject to depopulation (Aurambout et al., 2021) and that the Spanish rural emigration mainly originates in the quest of women and young people to improve their employment and educational opportunities (Recaño, 2017), it could be beneficial to generate dynamics towards tying population to these territories. In this sense, the deployment of circular strategies could provoke a transformation towards a more desirable and sustainable model, in the form of the necessary rapid transition conceptualized as circular disruption (Blomsma et al., 2023). Moreover, the strategies analysed reflect the limitations identified in relation to the CE in the scientific literature for urban planning, building and construction. Their development should be encouraged to make the most of the CE in the built environment, as devised by the architects and authors of the schools of thought of Shearing Layers, Cradle to Cradle and Looped Economy / Performance Economy. In this way, questions could be raised such as whether it is necessary to cover all or only some of the scales in order to successfully implement CE in the built environment, or whether schools of thought could continue to evolve to encompass further development in common with the CE, resulting in a CE concept fully adapted to the field of study. At the same time, this research emphasizes the need to promote some questions and key points for rural contexts, such as depopulation and employment understood from circularity. In turn, the specificity of the built environment reflected by architecture schools could also be related to the usual resilience of rural areas, in which resources are usually used in the most efficient way.

Future research furthering the following two lines would be warranted: on the one hand, the findings of this research support the need for added research on CE in the field of architecture; on the other hand, the promotion of CE in rural areas could, in the future, lead to an increased number of strategies and information collected in the database tool. Its analysis could also be expanded to other decision-making tools by allowing the comparability of results and the combination of different perspectives. Investigating CE from an architectural point of view could involve exploring the link between schools of thought and strategies such as AUE. Furthermore, understanding the implementation of CE in the built environment, as well as its possible shortcomings, through a dual analysis focused on schools of thought and strategies such as AUE can expand the existing vision of the topic of study. In this way, questions could be raised such as whether it is necessary to cover all or only some of the scales in order to successfully implement CE in the built environment, or whether schools of thought could continue to evolve to encompass further development in common with the CE, resulting in a CE concept fully adapted to the field of study.

Finally, the authors cannot exclude the possibility that potential strategies or municipalities of interest have been missed, since not all strategies provide complete or verifiable data in the databases consulted, which would be required for their study and contrast with the selection criteria. In this sense, the results of this research are inevitably linked to the data availability for each selected strategy, which could

Table 3
Descriptive data (DD) provided by the AUE, relationship with the CE and the strategies obtained.

Descriptive data (DD)*		Relationship with the CE **		Strategies***																
		Direct (SO 4 AUE)	Based on the proposed CE definition	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
		Any level		Level of implementation ****																
				A-I	A-I	A-I	I	A-I	A-I	A-I	A-I	A-I	A-I	I	A-I	I	A-E-I	A-E	E	A-E-I
D.01. Population change 2007-2017 (%)		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
D.02. Territory and habitat diversity	D.02.a. Artificial cover area (%)																			
	D.02.b. Crop area (%)		novel business models / cyclical and regenerative environmental innovations / production and consumption of society / design and education											●			●		●	
	D.02.d. Forest and woodland area (%)																			
D.03. Area of agricultural and forestry holdings	D.03.a. Municipal area used for agriculture and forestry holdings (%)													●			●		●	
	D.03.b. Municipal area used for agriculture and forestry holdings in relation to the city's delimited urban and building land (%)													●			●		●	
D.04. Non-building land area (%)																				
D.05. Green Area (ha per 1,000 inhab)																				
D.06. Urban land population density (inhab./ha)		●																		
D.07. Discontinuous urban land (%)																				
D.08. Housing density (dw/ha)		●																		
D.09. Urban compactness (m^2t/m^2s)																				
D.10. Residential compactness	D.10.a. Built-up area for residential use (m^2t/m^2s)																			
	D.10.b. Built-up area for residential use (%)																			
D.14. Age of the building stock (before 2000 (%))		●												●			●	●	●	
D.17. Mobility and transport infrastructure area	D.17.a. Transport infrastructure area (ha)																			
	D.17.b. Transport infrastructure area (%)																			
D.18. Motorisation index	D.18.a. Vehicles domiciled per 1,000 inhab.																			
	D.18.b. Percentage of passenger cars (%)																			
	D.18.c. Percentage of motorbikes (%)																			
D.22. Population ageing	D.22.a. Population ageing rate (%)																			
	D.22.b. Population senescence rate (%)																			
D.23. Foreign population (%)																				
D.24. Dependency ratio	D.24.a. Total dependency (%)																			
	D.24.b. Child dependency (%)																			
	D.24.c. Senior dependency (%)																			
D.26. Number of workers	D.26.a. In agriculture (%)													●			●		●	●
	D.26.b. In industry (%)			●	●	●		●	●	●	●	●	●	●	●		●		●	●
	D.26.c. In construction (%)													●			●	●	●	●
	D.26.d. In services (%)			●			●							●		●	●	●	●	●
D.27. Number of establishments	D.27.a. In agriculture (%)													●			●		●	●
	D.27.b. In industry (%)			●	●	●		●	●	●	●	●	●	●	●		●		●	●
	D.27.c. In construction (%)													●			●	●	●	●
	D.27.d. In services (%)			●			●							●		●	●	●	●	●
D.28. Unemployment rate	D.28.a. Total unemployed (%)			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	D.28.b. Unemployed 25-44 years (%)			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	D.28.c. Female unemployment (%)			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
D.29. Housing stock (dw/1000 inhab.)																				
D.32. Change in the number of households 2001-2011 (%)																				
D.33. Housing stock growth 2001-2011 (%)		●																		
D.34. Secondary housing (%)																				
D.35. Empty housing (%)																				
D.38. Date of the current urban planning scheme																				

Although the DD provided by the AUE also cover land under transformation in municipalities with specific DD for this purpose, they are not taken into account in this research, so as to limit the evaluation of strategies to the current state of each population. // ** DD related to the CE are marked in blue. // * The coding of the strategies can be found in Table 2. // **** Coding level of implementation: A: macro; E: meso; I: micro.

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taken into account in this research, so as to limit the evaluation of strategies to the current state of each population.
**DD related to the CE are marked in blue.
*** he coding of the strategies can be found in Table 2.
****Coding level of implementation: A: macro; E: meso; I: micro.

have resulted in partial findings.

As an additional point, and in line with previous research by Avdiushchenko and Zając (2019), the authors acknowledge the subjectivity involved in making some associations based on the authors' expert knowledge, and thus, this research is not intended to provide a one-size-fits-all solution.

CRediT authorship contribution statement

Inmaculada Bote Alonso: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Beatriz Montalbán Pozas:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Background

The main purpose of this brief background is to provide an overview of the existing approaches to the topic.[4] The PRISMA method (Stovold et al., 2014) is used to identify relevant scientific literature. The process began in 2019 with the study of highly cited articles on CE in general (Ghisellini et al., 2016; Kirchherr et al., 2017; Reike et al., 2018) and highly cited articles on CE in the built environment (Pomponi and Moncaster, 2017; Petit-Boix and Leipold, 2018; Prendeville et al., 2018; Gravagnuolo et al., 2019). These papers were identified using ScienceDirect and Web of Science. Based on these works, the snowballing technique is applied (Wohlin, 2014). In this way, the base body of literature comprised 985 publications. Afterwards, studies were excluded due to duplications (19), for being documents that were not scientific articles (187), and the selection was based on the title and abstract of the papers (771 studies excluded and 8 studies selected). A new search is carried out in 2021, following the same process as above. Several papers are identified from Science Direct and Web of Science (highly cited articles on CE in general: Suárez-Eiroa et al. (2019), De Jesus et al. (2019), Hartley et al. (2020); highly cited articles on CE in the built environment: Akanbi et al. (2019), Joensuu et al. (2020), Paiho et al. (2020)), and the snowballing technique is then applied (Wohlin, 2014). Subsequently, a base body of literature of 767 publications was obtained. From here, studies were excluded due to duplications (40), or because they were documents that were not scientific articles (105); while based on the title and abstract, 609 studies were excluded and 13 were selected. Additionally, other relevant articles were added later by the authors. Finally, 48 papers were selected for the background (Fig. A1).

The search results obtained are grouped chronologically to identify trends and the relationship between the CE and the field of study divided by levels (macro: city or urban planning; *meso*: building; micro: materials or construction) (Table A1). This relationship was investigated by searching for the keywords in this framework, such as "city" or "cities", "urban", "building", "house", "architecture" or "architectonic", "material" or "construction" and analysing their context. In the search, these keywords are the main search elements, without making combinations. In like manner, the authors proceeded to identify whether the subject of study is mentioned in passing and whether it is addressed from a general standpoint or specific to the field in question.

[4] The purpose of this paper is not to carry out a systematic literature review. The present review is exclusively included in this paper as a brief background to strengthen the research gap, thus avoiding a differentiated section of the systematic reviews. Reporting the assessment of the risk of bias is essential within systematic review processes (Moher et al., 2009). However, other authors use the PRISMA method "for identifying the relevant scientific literature" and do not carry out a systematic review, such as in Giurca and Befort (2023), where specific information on biases was not included. It is important to indicate that in this background there is the possibility of biases, especially considering that this is a research on circularity.

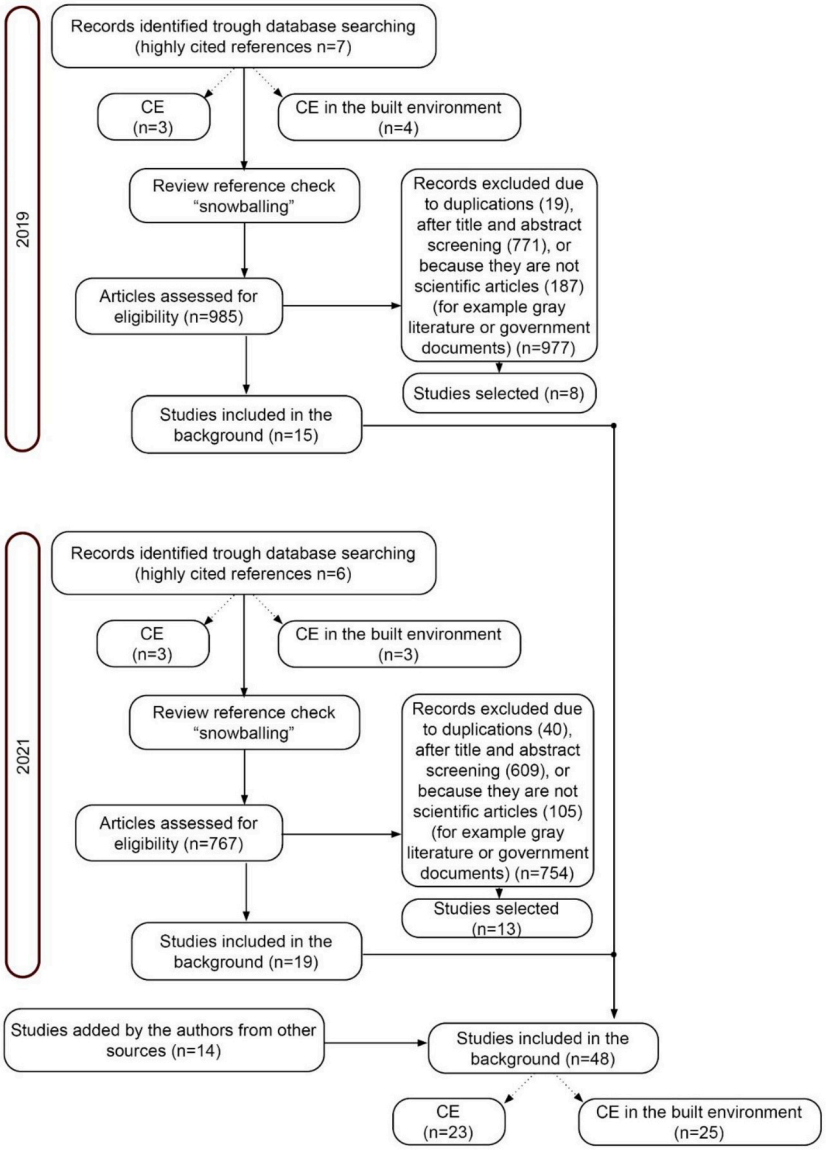

Fig. A1. PRISMA flow diagram of scientific literature selection. Own elaboration.

Table A1
Background.

References	General	Specific	Levels		
			City - Urban planning	Building	Materials -Construction
Van Dijk et al. (2014)		●		●●	●●
Gregson et al. (2015)	●		●		●
Haas et al. (2015)	●			●	●●
Geldermans (2016)		●	●	●●	●●
Ghisellini et al. (2016)	●		●●		●●
Sauvé et al. (2016)	●		●		●
Elia et al. (2017)	●		●		●●
Geissdoerfer et al. (2017)	●				●●
Kirchherr et al. (2017)	●		●●		●●
Murray et al. (2017)	●				●●
Nasir et al. (2017)		●		●	●●
Pomponi and Moncaster (2017)		●	●	●●	●
Akanbi et al. (2018)		●		●	●●
Hossain and Ng (2018)		●	●	●●	●●
Kalmykova et al. (2018)	●		●		●●
Korhonen et al. (2018a)	●				●●

(*continued on next page*)

Table A1 (*continued*)

References	General	Specific	Levels		
			City - Urban planning	Building	Materials -Construction
Korhonen et al. (2018b)	●		●	●	●●
Laumann and Tambo (2018)	●		●	●	●
Leising et al. (2018)		●		●●	●●
Merli et al. (2018)	●		●		●
Petit-Boix and Leipold (2018)		●	●●	●	●
Prendeville et al. (2018)		●	●●	●	●
Prieto Sandoval et al. (2018)	●		●		●
Reike et al. (2018)	●		●	●	●
Akanbi et al. (2019)		●		●●	●●
Akinade and Oyedele (2019)		●		●●	●●
Buyle et al. (2019)		●		●●	●●
Cavaleiro de Ferreira and Fuso-Nerini (2019)		●	●●	●	●
Christis et al. (2019)		●	●●	●	●●
De Jesus et al. (2019)	●				●
Fratini et al. (2019)		●	●●		●●
Fusco Girard and Nocca (2019)		●	●●	●●	●●
Gravagnuolo et al. (2019)		●	●●	●	●
Nußholz et al. (2019)		●		●	●●
Suárez-Eiroa et al. (2019)	●		●		●●
Zeller et al. (2019)		●	●●	●	●●
Hartley et al. (2020)	●		●		●
Henry et al. (2020)	●		●	●	●
Joensuu et al. (2020)		●	●●	●●	●●
Paiho et al. (2020)		●	●●	●	●
Akhimien et al. (2021)		●	●	●●	●
Calisto Friant et al. (2021)	●		●	●	●
Díaz-López et al. (2021)		●	●	●●	●
Malabi Eberhardt et al. (2021)		●		●●	●●
Mhatre et al. (2021)		●	●	●●	●●
Blomsma et al. (2023)	●				●
Kirchherr et al. (2023)	●				
Straub et al. (2023)	●		●	●	●

● The subject of study is mentioned in passing / ●● Focuses on the subject of study or develops it

Appendix B. Guide to links between CE-related DD and international strategies

Table B1
CE-related DD. Relevant information and relationship with international strategies.

Descriptive data (DD)		Definition	Related SO AUE	Relationship with international strategies			
				SDGs	NUA	UAEU (partnership)	ISUDs SO period 14–20
D.01. Population change 2007–2017 (%)		[(Population 2020-Population 2010) / Population 2010] x100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1.2; 1.3; 1.4; 1.5; 1.b; 2.4; 2.c; 3.6; 3.9; 4.2; 4.4; 4.5; 4.7; 4.a; 5.1; 5.2; 5.4; 5.5; 5.a; 5.b; 5.c; 6.1; 6.2; 6.3; 6.4; 6.5; 6.6; 6.b; 7.1; 7.2; 7.3; 7.a; 7.b; 8.1; 8.2; 8.3; 8.4; 8.6; 8.9; 9.1; 9.2; 9.3; 9.5; 10.2; 10.3; 10.4; 10.7; 11.1; 11.2; 11.3; 11.4; 11.5; 11.6; 11.7; 11.a; 11.b; 11.c; 12.2; 12.3; 12.4; 12.5; 12.6; 12.7; 12.8; 12.b; 13.1; 13.2; 13.3; 14.1; 14.2; 14.5; 15.1; 15.2; 15.3; 15.4; 15.5; 15.9; 15.a; 15.b; 16.5; 16.6; 16.7; 16.8; 16.10; 16.b; 17.9; 17.14; 17.16; 17.17; 17.18; 17.19	21; 25; 26; 27; 28; 29; 31; 32; 33; 34; 36; 37; 38; 39; 40; 41; 42; 43; 44; 45; 46; 49; 50; 51; 52; 53; 54; 55; 56; 57; 58; 59; 60; 61; 62; 65; 66; 67; 68; 69; 70; 71; 72; 74; 75; 77; 78; 79; 80; 81; 82; 85; 87; 89; 91; 92; 93; 94; 95; 96; 97; 98; 99; 100; 101; 102; 103; 104; 105; 106; 107; 108; 110; 111; 112; 113; 114; 115; 116; 117; 118; 119; 121; 122; 123; 124; 125; 131; 138; 139; 141; 144; 145; 147; 148; 149; 150; 151; 153; 155; 156; 157; 158; 159; 160	Sustainable land use; Culture/Cultural Heritage; Security in Public Spaces; Inclusion of migrants and refugees; Urban poverty; Circular Economy; Energy transition; Air quality; Climate adaptation; Urban mobility; Jobs and skills; Housing; Digital transition; Public procurement	S.O.2.3.3; S.O.4.5.1; S.O.4.5.3; S.O. 6.3.4; S.O.6.5.2; S.O.9.8.2
D.02. Territory and habitat diversity	D.02.b. Crop area (%)	(Crop area (ha) / Municipal area (ha)) x100	1, 3	1.5; 2.4; 3.9; 6.6; 11.4; 11.5; 11.6; 11.a; 11.b; 13.1; 13.2; 13.3; 14.1; 14.2; 14.5; 15.1; 15.2;	26; 38; 49; 50; 51; 52; 55; 65; 67; 68; 69; 70; 72; 77; 78;	Sustainable land use; Culture/ Cultural Heritage; Energy transition;	S.O.4.5.1; S.O.4.5.3; S.O. 6.3.4; S.O.6.5.2

(*continued on next page*)

Table B1 (*continued*)

Descriptive data (DD)		Definition	Related SO AUE	Relationship with international strategies			
				SDGs	NUA	UAEU (partnership)	ISUDs SO period 14–20
	D.02.d. Forest and woodland area (%)	(Forest and woodland área (ha) / Municipal area (ha)) x 100		15.3; 15.4; 15.5; 15.9; 15.a; 15.b	79; 80; 95; 96; 101; 124; 125; 144	Air quality; Climate adaptation	
D.03. Area of agricultural and forestry holdings	D.03.a. Municipal area used for agriculture and forestry holdings (%)	(Agriculture and forestry holdings area (ha) / Municipal area (ha)) x100					
	D.03.b. Municipal area used for agriculture and forestry holdings in relation to the city's delimited urban and building land (%)	(Agriculture and forestry holdings area (ha) / Σ (delimited developable land + urban land) (ha)) x100					
D.06. Urban land population density (inhab./ha)		Inhabitants / Area (Consolidated Urban Areas + Consolidated Development Areas)	1, 2, 4, 5, 6, 7, 8, 9	1.2; 1.3; 1.4; 1.b; 2.4; 2.c; 3.6; 4.2; 4.4; 4.5; 4.a; 5.1; 5.2; 5.4; 5.5; 5.a; 5.b; 5.c; 6.1; 6.2; 6.3; 6.4; 6.5; 6.6; 6.b; 7.1; 7.2; 7.3; 7.a; 7.b; 8.1; 8.2; 8.3; 8.4; 8.6; 8.9; 9.1; 9.2; 9.3; 9.5; 10.2; 10.3; 10.4; 10.7; 11.1; 11.2; 11.3; 11.4; 11.6; 11.7; 11.a; 12.2; 12.3; 12.4; 12.5; 12.6; 12.b; 14.1; 14.2; 14.5; 15.1; 15.2; 15.3; 15.4; 15.5; 15.9; 15.a; 15.b	21; 25; 26; 27; 28; 29; 31; 32; 33; 34; 36; 37; 38; 39; 40; 43; 44; 45; 46; 49; 50; 51; 52; 53; 54; 55; 56; 57; 58; 59; 60; 61; 62; 65; 66; 67; 69; 70; 71; 72; 74; 75; 77; 78; 79; 82; 93; 95; 96; 97; 99; 100; 103; 105; 106; 107; 108; 110; 111; 112; 113; 114; 115; 116; 117; 118; 119; 121; 122; 123; 124; 125; 141; 66; 150; 151; 156; 157	Sustainable land use; Culture/ Cultural Heritage; Security in Public Spaces; Inclusion of migrants and refugees; Urban poverty; Circular Economy; Energy transition; Climate adaptation; Urban mobility; Air quality; Jobs and skills; Housing; Digital transition	S.O.2.3.3; S.O.4.5.1; S.O.4.5.3; S.O. 6.3.4; S.O.6.5.2; S.O.9.8.2
D.08. Housing density (dw/ha)		Número de viviendas / Area (Consolidated Urban Areas + Consolidated Development Areas)					
D.14. Age of the building stock (before 2000 (%))		–	2,3,4	1.4; 1.5; 3.9; 4.2; 4.a; 6.1; 6.2; 6.3; 6.4; 6.5; 6.b; 7.1; 7.2; 7.3; 7.a; 7.b; 11.5; 11.6; 11.7; 11.b; 12.2; 12.3; 12.4; 12.5; 13.1; 13.2; 13.3;	21; 34; 36; 37; 39; 44; 50; 51; 53; 54; 55; 65; 67; 68; 69; 71; 74; 75; 77; 78; 79; 80; 82; 93; 95; 97; 100; 101; 119; 121; 122; 123; 144	Security in Public Spaces; Urban poverty; Circular Economy; Energy transition; Air quality; Climate adaptation	S.O.4.5.1; S.O.4.5.3; S.O.6.5.2; S.O.9.8.2
D.26. Number of workers	D.26.a. In agriculture (%)	(Number of affiliates in Social Security in agriculture / Total number of affiliates) x 100	6, 7, 9	1.2; 1.3; 1.b; 2.c; 4.2; 4.4; 4.5; 5.1; 5.2; 5.4; 5.5; 5.a; 5.b; 5.c; 8.1; 8.2; 8.3; 8.4; 8.6; 8.9; 9.2; 9.3; 9.5; 10.2; 10.3; 10.4; 10.7; 11.3; 12.6; 12.b	25; 26; 27; 28; 29; 39; 40; 43; 45; 53; 56; 57; 58; 59; 60; 61; 62; 66; 95; 99; 103; 150; 151; 156; 157	Inclusion of migrants and refugees; Urban poverty; Jobs and skills; Digital transition	S.O.2.3.3: S.O. 6.3.4; S.O.9.8.2
	D.26.b. In industry (%)	(Number of affiliates in Social Security in industry / Total number of affiliates) x 100					
	D.26.c. In construction (%)	(Number of affiliates in Social Security in construction / Total number of affiliates) x 100					
	D.26.d. In services (%)	(Number of affiliates in Social Security in services / Total number of affiliates) x 100					
D.27. Number of establishments	D.27.a. In agriculture (%)	(Number of establishments dedicated to agriculture / Total number of establishments) x 100	7, 9	1.b; 2.c; 5.a; 5.b; 8.1; 8.2; 8.3; 8.4; 8.6; 8.9; 9.2; 9.3; 9.5; 12.6; 12. b	29; 43; 45; 53; 56; 57; 58; 59; 60; 61; 66; 95; 150; 151; 156; 157	Jobs and skills; Digital transition	S.O.2.3.3; S.O. 6.3.4; S.O.9.8.2
	D.27.b. In industry (%)	(Number of establishments dedicated to industry / Total number of establishments) x 100					
	D.27.c. In construction (%)	(Number of establishments dedicated to construction / Total number of establishments) x 100					

(*continued on next page*)

Table B1 (*continued*)

Descriptive data (DD)		Definition	Related SO AUE	Relationship with international strategies			
				SDGs	NUA	UAEU (partnership)	ISUDs SO period 14–20
	D.27.d. In services (%)	(Number of establishments dedicated to services / Total number of establishments) x 100					
D.28. Unemployment rate	D.28.a. Total unemployed (%)	(Number of unemployed inhabitants / Number of inhabitants between 16 and 64 years) x 100	6, 7	1.2; 1.3; 1.b; 2.c; 4.2; 4.4; 4.5; 5.1; 5.2; 5.4; 5.5; 5.a; 5.c; 8.1; 8.2; 8.3; 8.4; 8.6; 8.9; 9.2; 9.3; 10.2; 10.3; 10.4; 10.7; 11.3; 12.6; 12.b	25; 26; 27; 28; 29; 39; 40; 43; 45; 53; 56; 57; 58; 59; 60; 61; 62; 95; 99; 103	Inclusion of migrants and refugees; Urban poverty; Jobs and skills	S.O. 6.3.4; S.O.9.8.2
	D.28.b. Unemployed 25–44 years (%)	(Number of unemployed inhabitants between 25 and 44 years / Total number of unemployed) x 100					
	D.28.c. Female unemployment (%)	(Number of unemployed women / Total number of unemployed) x 100					
D.33. Housing stock growth 2001–2011 (%)		[(Number of housing units 2011-Number of housing units 2001) / Number of housing units 2001] x 100	1, 2, 4, 8	1.4; 2.4; 4.2; 4.a; 6.1; 6.2; 6.3; 6.4; 6.5; 6.6; 6.b; 7.1; 7.2; 7.3; 7.a; 7.b; 11.1; 11.4; 11.6; 11.7; 11.a; 12.2; 12.3; 12.4; 12.5; 14.1; 14.2; 14.5; 15.1; 15.2; 15.3; 15.4; 15.5; 15.9; 15.a; 15.b	21; 26; 31; 32; 33; 34; 36; 37; 38; 39; 44; 46; 49; 50; 51; 52; 53; 54; 55; 65; 67; 69; 70; 71; 72; 74; 75; 77; 78; 79; 82; 93; 95; 96; 97; 100; 105; 106; 107; 108; 110; 111; 112; 119; 121; 122; 123; 124; 125	Sustainable land use; Culture/ Cultural Heritage; Security in Public Spaces; Urban poverty; Circular Economy; Energy transition; Climate adaptation; Housing	S.O.4.5.3; S.O. 6.3.4; S.O.6.5.2; S.O.9.8.2

Note: Coding according to AUE

Appendix C. Explicit EC definitions obtained

To search for the explicit mention of the built environment and its multilevel dimension in the CE definitions obtained (Table C1), an analytical reading of each of them is carried out, taking into account Avdiushchenko and Zając (2019), which avoids using only keywords. For example, although Gregson et al. (2015), Geissdoerfer et al. (2017) and Suárez-Eiroa et al. (2019) use the word "design", the first two only associate it with objects and "waste, emissions and energy" respectively, thus excluding them from the study; unlike the latter, which uses the term from a global perspective at any scale.

Table C1
Explicit EC definitions obtained.

References	Definitions
Geng and Doberstein (2008)	"[…] mean the realization of a closed loop of materials flow in the whole economic system. Different from the traditional linear production model, a circular economy approach encourages the organisation of economic activities with feedback processes which mimic natural ecosystems through a process of 'natural resources → transformation into manufactured products → byproducts of manufacturing used as resources for other industries.'"
Ellen MacArthur Foundation (2015)	"The circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions."
Gregson et al. (2015)	"[…] the circular economy seeks to stretch the economic life of goods and materials by retrieving them from post-production consumer phases. This approach too valorizes closing loops, but does so by imagining object ends in their design and by seeing ends as beginnings for new objects."
Haas et al. (2015)	"The circular economy (CE) is a simple, but convincing, strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows."
Ghisellini et al. (2016)	"By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society. […] CE implies the adoption of cleaner production patterns at company level, an increase of producers and consumers responsibility and awareness, the use of renewable technologies and materials (wherever possible) as well as the adoption of suitable, clear and stable policies and tools."
Sauvé et al. (2016)	"The circular economy aims to decouple prosperity from resource consumption, i.e., how can we consume goods and services and yet not depend on extraction of virgin resources and thus ensure closed loops that will prevent the eventual disposal of consumed goods in land fill sites. Production and consumption also have associated 'contamination transfers' to the environment at each step. In that sense, the circular economy is a movement towards the weak sustainability described earlier. It proposes a system where reuse and recycling provide substitutes to the use of raw virgin materials. By reducing our dependency on such resources, it improves our ability, and the ability of future generations to meet their needs. The circular economy makes sustainability more likely."
Geissdoerfer et al. (2017)	"[…] we define the Circular Economy as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."

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Table C1 (*continued*)

References	Definitions
Kirchherr et al. (2017)	"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), *meso* level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."
Murray et al. (2017)	"The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being."
Korhonen et al. (2018a)	"CE is a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work."
Prieto Sandoval et al. (2018)	"The circular economy is an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces and consumes."
Suárez-Eiroa et al. (2019)	"circular economy is a regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with capacity to be implemented at any scale."

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