



# Integration of the circular economy paradigm under the just and safe operating space narrative: Twelve operational principles based on circularity, sustainability and resilience

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## ABSTRACT

The goal of this research is to theoretically integrate the CE paradigm within the environmental sustainability framework. Based on the shortcomings detected in the circular economy literature, we followed a three steps procedure. Firstly, we conducted a narrative literature review that underlies the need of understanding the circular economy as a resilient, sustainable and circular economy, and we identified twelve principles to operationalize the circular economy under the environmental sustainability paradigm. Secondly, we created a database containing information on twenty-six strategies of circular economy. Thirdly, we analyzed the data to assess how the principles explored in phase 1 are being considered by the current circular economy strategies. Results revealed a high variability of approaches performed by the governments to reach the circular economy. Moreover, strategies grouped into the resilience domain are barely incorporated into circular economy strategies, and hence some circular economy strategies reveal shortcomings in their capacity to generate real changes. Further research is needed to perform a more holistic analysis based on complex adaptive system thinking, which would allow connecting more essential elements to enhance a socially fair development that preserves the environment.

## 1. Introduction

Despite circular economy (CE) has gained momentum in the political, business, and scientific fields, its theoretical framework and role under the sustainable development paradigm is still under discussion (Prieto-Sandoval et al., 2018; Schögl et al., 2020). The usefulness of CE to advance towards sustainable development is widely accepted (Geissdoerfer et al., 2017; Schroeder et al., 2019), but it is also known that CE could become counterproductive in the long term due to limitations of the concept in its current form (Korhonen et al., 2018a; Millar et al., 2019), i.e., adopting closing-the-loop production patterns with a strong focus on increasing resource efficiency (Ghisellini et al., 2016; Alhawari et al., 2021).

Indeed, the CE paradigm has been previously argued to include a broader scope of strategies that covers a holistic transformation of

business (de Jesus et al., 2018), substituting inputs and increasing the share of renewable and recycled resources (Sousa-Zomer et al., 2018), minimizing or eliminating the use of hazardous substances (Chen et al., 2020; Silvestri et al., 2021), digitalizing businesses (Antikainen et al., 2018), implanting industry 4.0 plans (de Sousa Jabbour et al., 2018; Awan et al., 2021), using big data to enable sustainable production and consumption (Jabbour et al., 2019), and adopting other production-consumption patterns shifting from the current business-as-usual model to CE, such as the product-service (Camilleri, 2019; Tukker, 2015) and collaborative (Ghisellini et al., 2016) systems.

CE was born as a response to an unsustainable linear production-consumption system (Geng and Doberstein, 2008). It can be understood, therefore, as an umbrella concept that addresses the way humanity produces and consumes goods and services (Merli et al., 2018; Schögl et al., 2020), and it can be assumed that, regardless of its

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multiple roots and boosters, the main objective of CE is to adjust the production-consumption system to the requirements of environmental sustainability (Suárez-Eiroa et al., 2019). Nevertheless, despite its promising outcomes, such as the expected urban sustainability transition (Fratini et al., 2019), the sustainable production and consumption (Awan, 2020), or the achievement of the sustainable development goals (Schroeder et al., 2019), the large number of avenues to reach CE hinders a consensus about its framing and scope (Korhonen et al., 2018b). This results in the development of CE strategies in an uncoordinated manner in the different implementation levels (Pomponi and Moncaster, 2017; Winans et al., 2017) and territories (McDowall et al., 2017), and hence the performance of the different social actors remain unconnected (Corona et al., 2019). Furthermore, resilience has been considered as a prerequisite for sustainability and, consequently, the transformation of those systems threatening planetary resilience should be explored (Folke et al., 2010). In this context, Biggs et al. (2015) proposed a framework to improve the resilience of socio-ecological systems in order to live together with a natural system with biophysical limits. Nevertheless, to our knowledge, resilience thinking and CE have not been formally integrated yet.

Based on the above, we consider that the framing of CE as a sustainable production-consumption system has not been addressed sufficiently, and that integration of resilience thinking within the circular economy paradigm is clearly needed. Subsequently, the goal of this research is to theoretically integrate the CE paradigm within the environmental sustainability framework. Our research was guided by two research questions:

- How can the circular economy be framed to reach a production-consumption system compatible with environmental sustainability?

- What operational principles enable circular economy under the environmental sustainability paradigm?

To answer these questions, we firstly conducted a narrative literature review that underlies the need of understanding circular economy as resilient and sustainable. We identified twelve principles to operationalize the circular economy under the environmental sustainability paradigm (Section 3.1). Secondly, we created a database containing information on twenty-six strategies of circular economy, and we analyzed the data to assess how the principles explored in Section 3.1 are being considered by the current circular economy strategies (Section 3.2). Moreover, Section 4 discuss the typologies of strategies detected and presents the limitations of the data analysis, and Section 5 presents the main contributions and implications of this paper.

## 2. Research method

This investigation has been organized into three main phases (Fig. 1): i) a literature review to derive the theoretical framework and the principles to operationalize CE under the environmental sustainability paradigm; ii) the creation of a database with information about the content of the different CE strategies; and iii) data analysis to assess how the principles explored in phase 1 are being currently considered by CE strategies.

### 2.1. Theoretical framework

We performed a narrative literature review to investigate the main elements included within the CE umbrella under the environmental sustainability paradigm. A narrative literature review is less rigorous

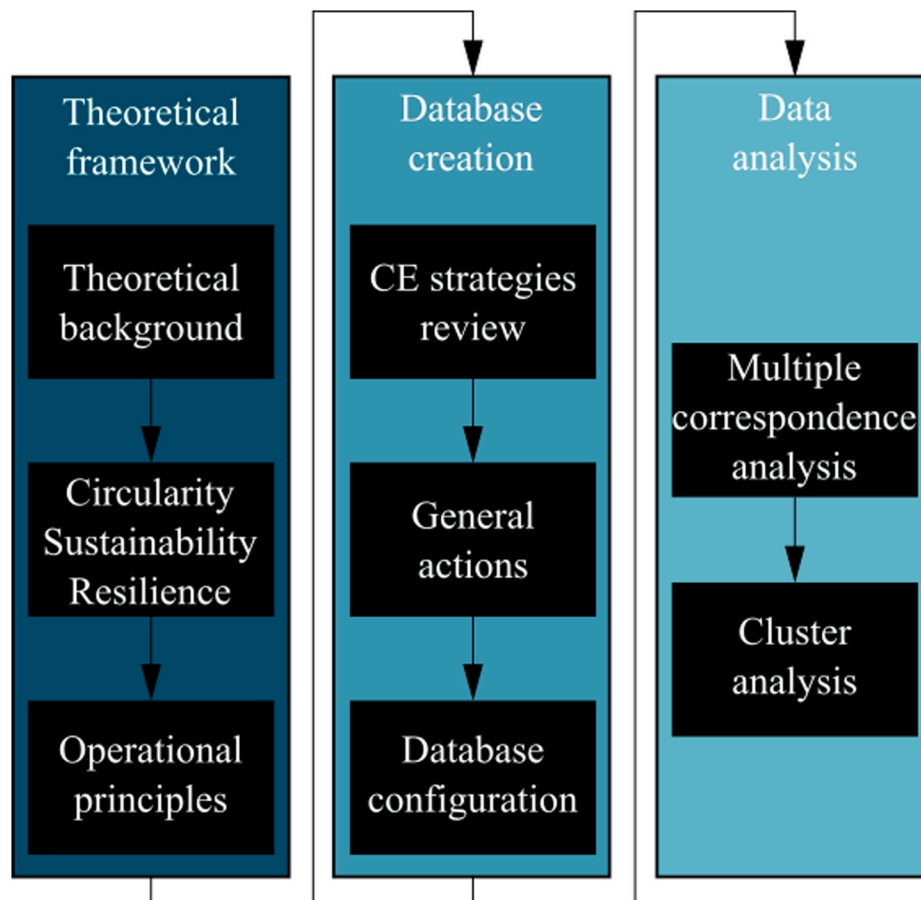


Fig. 1. Diagram depicting the methodological process followed in this research.

than a systematic review, but it serves “a vital scientific function” (Baumeister and Leary, 1997), being essential “for linking together studies on different topics, either for purposes of reinterpretation or demonstrating interconnections” (Schroeder et al., 2019). During the literature review process, we dealt with the challenging task of finding the equilibrium between relevance and comprehensiveness. Firstly, we employed different combinations of the following keywords in the Web of Science and Scopus platforms: *circular economy*, *planetary boundaries*, *resilience*, *sustainability*, and *sustainable development*. By applying the snowball technique, we dug deeper into the available literature. Fig. 2 summarizes the main steps conducted during the literature review process.

Firstly, we integrated the literature concerning the production-consumption system into the just and safe operating space for humanity narrative (Raworth, 2017a). Afterwards, we exposed the need of integrating circularity, environmental sustainability (henceforth, just sustainability), and the resilience domains to build a CE framework that allows the transformation of the production-consumption system to meet the requirements of environmental sustainability. Consequently, we defined twelve operational principles that allow us to connect the theoretical objectives of the resilient, sustainable and circular economy to practical actions. A total of 103 scientific papers were reviewed, of which more than 83% correspond to the period 2010–2021, and ca. 46% belong to the period 2017–2019. The main source was the Journal of Cleaner Production, with 24 articles consulted, followed by Resource, Conservation, and Recycling, with 8 articles.

## 2.2. Database creation

### 2.2.1. Review of circular economy strategies

A total of twenty-six CE strategies were reviewed (Table 1). We searched CE strategies written in Spanish or English through Google and Firefox browsers. Although not all the existing CE strategies were analyzed, the sample covers CE strategies from different continents, territorial levels, and years of development. We have just selected CE strategies, and hence specific actions within the CE paradigm were excluded. For instance, the government of New York has banned the use of expanded polystyrene, but it has not presented any CE strategy (Government of New York, 2020).

Fig. 3 presents the geographical distribution of the CE strategies reviewed and the territorial levels they cover. Most of the strategies reviewed come from Europe, but strategies from Australia, America (Canada, Mexico, and South America), and China were also considered. The strategies reviewed cover three different territorial levels: fifteen national strategies, ten subnational strategies (states within a country, provinces, regions, and cities), and one supra-national strategy (the

**Table 1**

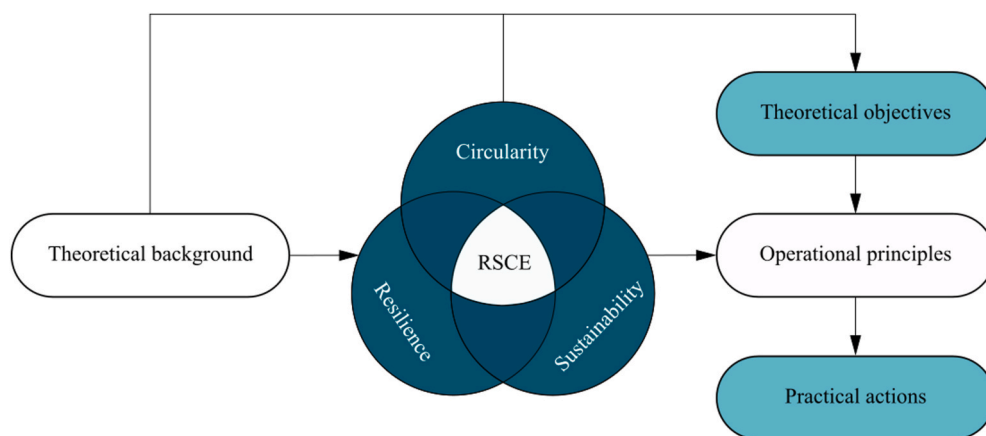
Metadata of CE strategies reviewed in this research.

Territory	Territorial level	Code	Reference
Argentina	National	ARG	Gobierno de Argentina (2019)
Mexico City	Sub-National (City)	C.D. Mx.	Gobierno regional de Ciudad de Mexico (2019)
Basque Country	Sub-national (Region)	PV	Gobierno del País Vasco (2019)
China	National	CN	CCICED (2008)
Colombia	National	CO	Gobierno de Colombia, (2019)
Germany	National	DE	The German Government (2016)
Denmark	National	DK	The Danish Government (2018)
European Union	Supra-national	EU	EC (2020)
Extremadura	Sub-national (Region)	Ext	Gobierno de Extremadura (2017)
Finland	National	FI	Finnish Government (2016)
France	National	FR	French Government (2019)
Galicia	Sub-national (Region)	Gal	Gobierno de Galicia (2019)
Greece	National	GR	Greek Government (2018)
Italy	National	IT	Italian Government (2018)
London	Sub-national (City)	LDN	Government of London (2016)
Maribor	Sub-national (City)	Ma	Government of Maribor (2019)
The Netherlands	National	NL	Dutch Government (2019)
New South Wales	Sub-national (State)	NSW	Government of New South Wales (2019)
Ontario	Sub-national (Province)	ON	Government of Ontario (2017)
Portugal	National	PT	Portuguese Government (2017)
Scotland	National	SCT	Scottish Government (2016)
Slovenia	National	SI	Slovenian Government (2019)
Spain	National	ES	Gobierno de España (2020)
Toronto	Sub-national (City)	TO	Government of Toronto (2020)
Uruguay	National	UY	Gobierno de Uruguay (2019)
Victoria	Sub-national (State)	Vi	Government of Victoria (2019)

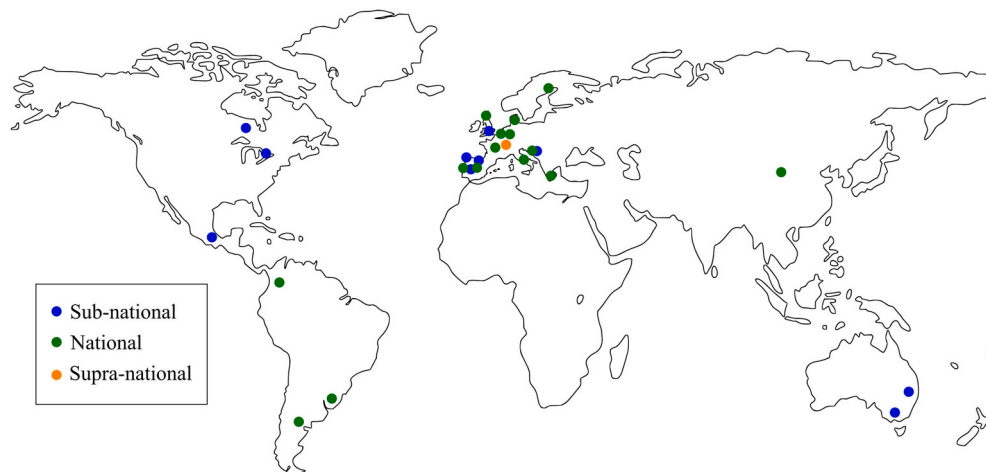
European Union). Regarding the year of elaboration, the Chinese CE strategy was approved in 2008, and the rest during the last five years: four from 2016, three from 2017, four from 2018, eleven from 2019, to 3 from 2020.

### 2.2.2. Selection of general actions

The selection of the most suitable general actions is based on the CE strategies review, as well as on the literature review performed in step 1. The selected general actions were grouped into the twelve operational principles obtained during the theoretical framework analysis step. For



**Fig. 2.** Narrative literature review process. The results can be grouped into three main steps: the theoretical background, the conceptualization of the resilient, sustainable and circular economy (RSCE), and the selection of twelve operational principles.



**Fig. 3.** Location of CE strategies reviewed coloured based on the territorial level they refer to. Selected strategies include one supra-national strategy (Europe), fifteen national strategies (Argentina, China, Colombia, Germany, Denmark, Finland, France, Greece, Italy, The Netherlands, Portugal, Scotland, Slovenia, Spain, and Uruguay), and ten sub-national strategies (Basque Country, Extremadura, Galicia, London, Maribor, Mexico City, New South Wales, Ontario, Toronto, and Victoria).

instance, the principle of *closing the system* includes general actions such as *recycling* or *collecting wastes separately*. Each general action covers different specific actions. For instance, the general action of *recycling* may include specific actions such as recycling a higher percentage of plastic waste or improving recycling techniques focused on the building sector.

The list of general actions aims at covering most of the actions included in the different CE strategies. To achieve this list, an iterative process was performed. The final list of general actions is not intended to be definitive, neither exhaustive, but it can be used as a first guess to analyze the potential of the different CE strategies to address environmental sustainability. The list of general actions included in each principle should not be used to represent the principles they belong to, since they are just a simplified sample of their content. The main outcomes of the selection of general actions are presented in Section 3.2, and a detailed list of general actions can be consulted in the Supplementary File.

### 2.2.3. Database configuration

We first built a qualitative database where rows included the general actions selected and columns referred to the CE strategies reviewed. Gaps were filled with a “Yes” or a “No” based on whether the CE strategy covers the studied general action or not. After completing the initial qualitative database, it was transformed into a quantitative database. For this purpose, the percentage of general actions covered by each principle was calculated. For instance, if a given CE strategy obtained “Yes” in four out of five general actions within a principle, the principle was labelled with a 0.8.

A general action could be labelled with a “Yes” as a result of the existence of different specific actions. As a consequence, two strategies with large differences in the number of specific actions within a given general action would both be labelled with a “Yes”. Sometimes, a “Yes” depended on the use of the right word. For instance, the Greek CE strategy promotes *reusing empty buildings*, and it could be or not referred implicitly to the repurposing of buildings for different functionalities they were initially designed. In this case, the Greek CE strategy gets a “No” in the general action *Repurposing* since it was necessary to explicitly refer to the action.

The action of a CE strategy must fit exactly with the general action proposed in order to get a “Yes”. For instance, the French government mobilizes a considerable number of resources to recover packages and also promotes the use of recyclable packages. Therefore, the French CE strategy got a “Yes” in the general actions *Reverse logistics* and *Using compostable/biodegradable/recycled resources/materials*. However, they

got a “No” in the general action *Smart packaging*, since it refers to reduce the complexity of packages, use alternative sustainable packaging, or reuse packaging.

If a strategy includes a general action into its objectives, but it is not integrated into the action plan, the CE strategy got a “No” for that particular general action. For instance, the CE strategy of New South Wales (Australia) recognized the need for thinking of innovative new ways to repurpose old materials at the international level. However, its CE strategy does not cover the general action *Repurposing* within its action plan, and hence it was labelled with a “No” in this general action.

We acknowledge that all the above-mentioned methodological limitations should affect the results of the analysis carried out in this study. Consequently, they should be taken into consideration in the interpretation of the results. A detailed explanation of the condition to get a “Yes” in the different general actions is shown in the Supplementary File.

### 2.3. Data analysis

Data analysis was expected to reveal the main structural patterns among the CE strategies studied. To this aim, a multiple correspondence analysis (MCA) and hierarchical cluster analysis (HCA) was processed using the R Statistical package. Then, the detected similarities and differences were used to discuss the potential of current CE strategies to address environmental sustainability.

MCA is a dimension reduction technique that allowed extracting the main patterns of variability of the reviewed CE strategies. The percentage of general actions including within each principle covered by each CE strategy acted as the input data for the analysis.

HCA was processed from the similarities or distances among CE strategies according to the principles addressed, by using the Euclidean distance. The Expectation-Maximization algorithm was used to select the most suitable number of classes.

## 3. Results

### 3.1. Theoretical framework

#### 3.1.1. Theoretical background

The social-ecological system (SES) analyzes the interrelationship between the natural system and the social system (Pastor, 2018), which, in turn, rely on a specific mix of ecosystem services (Virapongse et al., 2016). A high enough environmental pressure can endanger the foundations of such systems (Rocha et al., 2018), both at the global (Stoknes and Rockström, 2018) and local (Verburg et al., 2016) scales. The



planetary boundaries (PBs) framework (Rockström et al., 2009; Steffen et al., 2015) is the departing point of our narrative. It seeks to define the safe operating space for human activities within the planet; a concept that was extended to include the social needs covered by human activities, what further derived in the definition of the safe and just operating space for humanity (Raworth, 2017a).

We assume that the production-consumption system refers to the physical exchanges between the natural and the social system, and hence to the flows of energy and matter between both systems, a direct consequence of the way that goods and services are produced and consumed (Korhonen et al., 2018a). When analyzing the production-consumption system, efforts are channeled to the understanding of how the social system can be compatible with a finite natural system, thus emerging the idea of an empty or full world (Daly, 2007) or the ecological footprint approach (Wackernagel and Yount, 1998).

This conception of the production-consumption system is far from a holistic analysis of sustainable development, as it excludes economic, social, and environmental elements. For instance, inflation or interest rate might be important to assess the performance of a given economy, but they are not directly related to the analysis of material and energy flows between the natural and the social system. A similar situation exists with the maintenance of ecosystem services related to cultural needs or social objectives such as ending hunger or ensuring access to clean water for everybody. Although they are certainly relevant to society, they are not directly implied in the production-consumption process.

We are aware that interdependent relationships do exist among all these and other elements such as employment, educational access, poverty, etc. In this study, we advance towards a holistic analysis by integrating the resilience domain under the CE umbrella, and hence the related social and governance processes. We further discuss the necessity to address such elements by applying complex adaptive system thinking to the analysis. To this aim, we reviewed the elements included to date, throughout the scientific literature that addresses CE under the environmental sustainability paradigm, and searched for elements belonging to the resilience thinking domain connected to the CE framework.

### 3.1.2. Conceptualizing the resilient, sustainable, and circular economy

We depart from the assumption that the production-consumption system is the mechanism that controls materials and energy flows between the natural and the social system. This mechanism operates to enhance a fair development that preserves the environment (Raworth, 2017a). From this perspective, the key question is: how could be configured a production-consumption system compatible with the safe and just operating space?

Korhonen et al. (2018b) pointed to CE as an essentially contested concept, i.e., a concern widely recognized but, at the same time, addressed by different avenues, all of them probably valid, and all of them considered as the right path by their authors (Gallie, 1956). In practice, regardless of this epistemic condition, many scholars approached CE as an umbrella concept to address the environmental sustainability of the production-consumption system, and hence as a toolbox that integrates a wide range of strategies from diverse scientific fields (Merli et al., 2018; Schögl et al., 2020). The toolbox-assigned objectives range from “decoupling of environmental pressures from economic growth” (Ghisellini et al., 2016) to “maximize ecosystem functioning and human well-being” (Murray et al., 2017). Here, we assume that CE aims at adjusting flows between the social and the natural system to fit environmental sustainability. This stance is supported by epistemological statements, as outlined hereafter.

Circularity refers to the way resources move within the system through closed-loop patterns (Linder et al., 2017), which is connected to the idea of eco-efficiency and results in most of the indicators proposed in the CE literature (Moraga et al., 2019). Initially, the idea of circularity was associated with the 3R-tradition of “reducing, reusing, and

recycling” (CCICED, 2008). Progressively, CE incorporated actions oriented towards recovering, repurposing, remanufacturing, repairing, rethinking, etc. (Reike et al., 2018). Circularity can develop into significant rebound effects (Korhonen et al., 2018a) when it is focused on eco-efficiency, the output created relative to the harm caused, since increasing eco-efficiency can lead to increasing resource use (Figge et al., 2014). These negative effects would confront the own existence of CE since it was born as a response to the environmental unsustainable linear production-consumption system (Bonciu, 2014; Murray et al., 2017). Since circularity can coexist within an unsustainable production-consumption system (Pauliuk, 2018), CE necessarily incorporates the notion of environmental sustainability. The inclusion of the principle “reducing” supports this idea, since “reducing” leads to multiple strategies beyond the circularity within the production-consumption system. In this connection, the Ellen MacArthur Foundation (2013) states that addressing the limits of the linear production-consumption system requires transcending circularity, which should not exist alone within the CE framework.

This narrative is also supported by a large fraction of scholars. For instance, Niero and Kalbar (2019) proposed “coupling material circularity indicators and life cycle-based indicators” to assess CE, Genovesi et al. (2017) claim the need of including “more relevant environmental indicators” to compare the performance of linear and circular systems, and Elia et al. (2017) suggested “reducing inputs and use of natural resources” and “reducing emission levels” as requirements to be measured within the CE framework. From a most conceptual stage, Hobson and Lynch (2016) outlined the inability of a circularity-based CE “to address many deeply embedded challenges around issues of consumption and the consumer”, Kirchherr et al. (2017) and Murray et al. (2017) claimed that CE aims “to accomplish sustainable development”, and Corona et al. (2019) perceived CE “as a sustainable economic system”. This CE framework led us to the conception of a sustainable and circular economy (SCE), as described in Suárez-Eiroa et al. (2019).

One of the main complex features of social-ecological systems, resilience, has been considered as a prerequisite for sustainability (Biggs et al., 2012, 2015, 2015). Resilience can be addressed from different perspectives according to the scope of application. From the social-ecological system perspective, it can be described as the ability of the system to adapt and positively transform itself as a response to a perturbation (Folke et al., 2010; Walker et al., 2004). The condition “positively” refers to a new, more suitable, and more sustainable system structure (Masnavi et al., 2019). In our narrative, resilience addresses the structural elements dealing with changes, and it gives an idea about the ability to change toward more circular and sustainable systems.

To our knowledge, the most formal integrations of resilience thinking and CE to date were performed by Fabbicatti and Biancamano (2019), who proposed a policy framework to manage urban landscapes by integrating the concepts of circularity, productivity and resilience, and by Fan et al. (2019), who connected several scattered ideas to face waste, energy, water, and pollution challenges into a smart, resilient, sustainable and circular economy.

Despite the lack of a formal and explicit integration of CE and resilience, the CE umbrella has progressively incorporated different elements from the resilience-thinking paradigm. These are the missing elements referred to by Korhonen et al. (2018b) when claiming that “the values, societal structures, cultures, underlying world-views and the paradigmatic potential of CE remain largely unexplored”, and by Schroeder et al. (2019) when stating that “more multistakeholder partnerships are required” to advance CE practices and business models. Resilience also becomes a key concern for Pla-Julián and Guevara (2019) when reproducing the need to deepen “interconnections and interdependences within the biophysical and social worlds” when using CE to promote environmental sustainability. Resilience thinking also partially integrates the narrative regarding the governance and social issues of CE systems (i.e., Chertow and Ehrenfeld, 2012; Walker et al., 2021).

In this research, we propose a formal integration of resilience thinking within the CE umbrella, since it can be considered as a prerequisite to advance towards the implementation of CE within our narrative. We therefore assume that CE practices do not support environmental sustainability when governance or social processes are excluded from the analysis. Thus, CE might be integrated, at least, by three principal components: circularity, sustainability, and resilience. It is worth highlighting that, as a direct consequence of this integration, social elements should be necessarily involved within the CE framework, even when it is only understood as the mechanism that controls flows between the natural and the social system, thus leading to the proposal of a resilient, sustainable and circular economy (RSCE) to boost a CE compatible with a fair development that preserves the environment. Based on the definitions proposed in Folke et al. (2010) and Suárez-Eiroa et al. (2019), RSCE could be defined as a production-consumption system that aims at adjusting resource inputs and waste and emissions outputs to suitable values for environmental sustainability, and which is able to adapt and transform positively in the face of perturbations.

### 3.1.3. Operational principles for a resilient, sustainable, and circular economy

Operational principles for a resilient, sustainable and circular economy are now derived from the theoretical objectives to adjust flows between the natural and the social system to suitable values for environmental sustainability, as described above. This exercise is based on two previous investigations. Suárez-Eiroa et al. (2019) critically analyzed CE when it is only focused on circularity, and described a sustainable CE (SCE) based on seven operational principles to connect the theoretical objectives of SCE to practical actions. Similarly, Biggs et al. (2015) proposed seven principles to build a resilient social-ecological system, understanding resilience as the “ability to live with change, and develop with it”, and aiming at “ensuring an adequate and reliable flow of essential ecosystem services to meet the needs”. Thus, none of the operational principles proposed here are new in essence.

Although the operational principles have been divided into the three domains (Fig. 4), all of them are directly or indirectly interconnected. Thus, for instance, enhancing circularity generally implies improving resilience, since the socio-economic system becomes more independent from critical ecosystem services such as mineral or water provision. Similarly, maintaining ecosystem’s diversity and redundancy will result in a more sustainable natural system due to the higher ability to absorb perturbations. Therefore, there is an inherent difficulty to handle the

three concepts separately.

The three principles linked to the sustainability domain, drawn from Suárez-Eiroa et al. (2019), are: i) *adjust the inputs to the socioeconomic system*, e.g. moving from fossil fuels to renewable energy systems, ii) *adjust the outputs from the socioeconomic system*, e.g. minimizing waste generation, and iii) *reduce the general needs for resources*. The two principles deriving from the circularity domain are: i) *close the system*, e.g. recycling or preparation for re-using, and ii) *maintain the value of the resources within the system as maximum as possible*, e.g. repairing or donating under-used goods.

The seven principles under the resilience domain, readjusted from those proposed by Biggs et al. (2015), aim at incorporating the ability for change. The *Foster complex adaptive systems thinking* and *encourage learning* principle are integrated into the principle *Educate for RSCE*. Education for an RSCE includes at least the understanding of complex adaptive systems (Biggs et al., 2012), the improvement of knowledge and skills to booster the transition of businesses (de los Rios and Charnley, 2017) in areas such as the product design, the product, planning and control, and the logistics and supply chains (de Sousa Jabbour et al., 2019), as well as the acquisition of pro-sustainable habits and values (Portes, 2006; Singh and Giacosa, 2019). It has been shown that autonomous individuals foster social resilience (Welzel et al., 2003). But for this to promote sustainability, autonomous individuals need to integrate values related to equity and social and environmental harmony (Schwartz, 2010, 2015).

We included *Design for RSCE* as a principle for building resilience under the RSCE framework, since there is a consensus about the importance of design and innovation for circularity and sustainability (Kalmykova et al., 2018), two components related to the possibility of change, and hence assumed here to be associated with the resilience thinking paradigm. In this regard, the design should be understood as a driving process toward RSCE beyond a simple optimization of the production process (Toxopeus et al., 2015).

*Maintain diversity and redundancy* relates to the capacity of the system to provide alternative options to deal with changes and perturbations. It is mainly focused on the ecological system, as diversity and redundancy are essential to maintain the provision of ecosystem services (Biggs et al., 2015). It can be also translated into the social dimension through practical strategies such as those based on the diversification of resources according to their availability in the natural environment, e.g., using different sources for producing renewable energies (Korhonen and Snäkin, 2015). To promote RSCE, increasing diversity and redundancy should be carried out under the terms of circularity and sustainability, e.

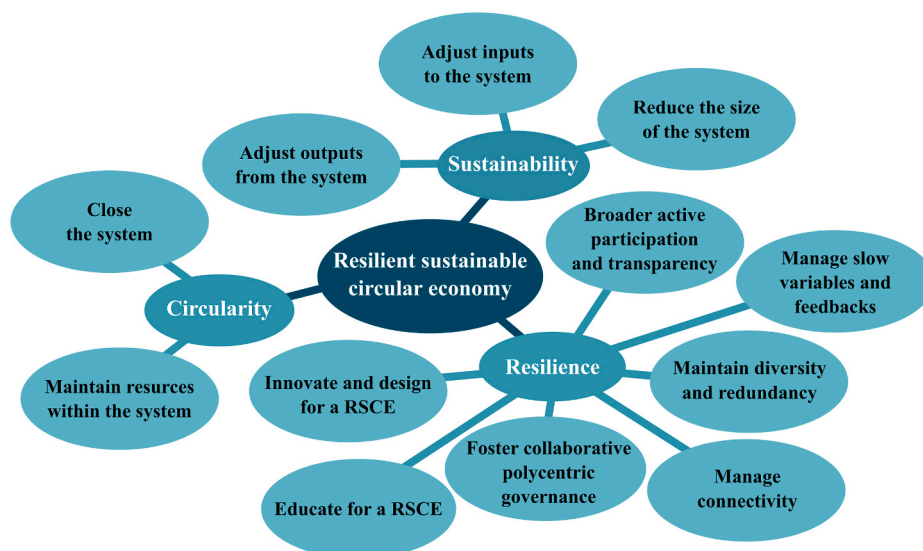


Fig. 4. Operational principles for a resilient, sustainable, and circular economy. Sustainability refers here to the analysis of the production-consumption system as a black box within the natural system, addressing inputs, outputs, and the size of the production-consumption system. Circularity makes reference to the maintenance of resources within the systems once they have been introduced addressing close-loop production-consumption patterns. Resilience represents the ability of the system to change, addressing elements that enhance and boost CE under the environmental sustainability paradigm.

g., using different renewable or recycled materials instead of new cement within the building sector (Leising et al., 2018).

Connectivity refers to “the structure and strength with which resources, species or social actors disperse, migrate or interact across patches, habitats or social domains”, and it is highly context-dependent (Biggs et al., 2015). Therefore, *Manage connectivity* relates to different policy agendas according to each context. For instance, a territory that depends on external resources to a great extent may be vulnerable (Brozzi et al., 2015), and the exploitation of endogenous resources could enhance resilience (Vecchio et al., 2020), but a poorly connected system could be also affected, for example, by the scarcity of local resources (Biggs et al., 2015). In this context, collaborative local economies are usually connected to more resilient economic systems (Hobson and Lynch, 2016), by reducing disconnection and inequality (Leach, 2013).

*Manage slow variables and feedbacks* and long-term thinking are crucial for circularity and sustainability (Korhonen and Snäkin, 2015). Firstly, there is a need for managing complex feedbacks produced between the natural and the social system, both in time and space. Secondly, the distribution of power and the values that hold societies are considered deep variables that determine the way institutions operate over a specific social structure (Portes, 2006). These deep variables evolve slowly, but they can produce changes at short temporal scales (Biggs et al., 2015). In general, it is considered that every kind of unequal distribution of power, such as gender inequality (Harrison, 2006), economic inequality (Wilkinson and Pickett, 2010, 2019), or inequality to access to quality education (Adler et al., 2015; Hanushek and Woessmann, 2007), become barriers in the process toward more sustainable societies. Moreover, there is a consensus that values and social norms can act as barriers to change, hence maintaining the status quo (Caballero and Soto-Oñate, 2015). It is generally accepted that those who hold the power generally aim at keeping it (Bush, 1987), but it is not an exception that important social groups may accept this unequal distribution of power, and hence impede changes (Biggs et al., 2015). Culture acts as a decisive variable during the sustainable and circular consumption decision-making process (Santamaria et al., 2016). In this regard, commons are presented as a powerful tool to face the sustainable challenge ahead (Kallis et al., 2012; Sekulova et al., 2013) and, consequently, the values related to the new collaborative economy paradigm are essential for RSCE (Ghisellini et al., 2016).

*Foster collaborative polycentric governance* refers to political processes in which multiple authorities interact, both vertically (e.g. national and regional governments) and horizontally (e.g. different actors from a territory and common management) (Ostrom, 2010). However, polycentric governance is difficult to implement due to multiple factors, e.g. coordination (Ostrom, 2009), overlapping (Berkes, 2006), gaps in management responsibilities (Robards et al., 2011), etc. The term collaborative refers to institutional alliances (Galaz et al., 2012), which are essential for sustainable development (Brozzi et al., 2015; Galaz et al., 2011), e.g. inter-municipal alliances foster resilience since the partners can benefit from each other (Korhonen and Snäkin, 2015), and inter-firm collaborations and common management can result in enormous benefits for CE implementation (Awan, 2020; Jabbour et al., 2020) and the development of sustainable technologies (Kishna et al., 2017). In this concern, the creation of new formal rules to manage commons can be determinant during CE implementation (Fischer and Pascucci, 2017).

*Broader active participation and transparency* legitimate decision-making processes, being therefore, essential for polycentric governance (Biggs et al., 2015; Portes, 2006). Communication channels are needed for active participation (Brondizio et al., 2009), but they can also be a risk for sustainability under some conditions, such as the lack of transparency or the existence of non-pro-sustainability values and social norms (Satake et al., 2007). Nowadays fake news spread faster than true news by social media, also reaching a higher percentage of the population (Lazer et al., 2018; Vosoughi et al., 2018). Thus, for an active participation process to be successful, it is necessary to, at least, limit corruption, foster transparency, and extending pro-sustainable values

and social norms (Biggs et al., 2015). The benefits of transparent relationships between firms and suppliers have been previously studied (Jabbour et al., 2020), and it has also been proposed as a central element to implementing CE in organizations (BSI, 2018).

### 3.2. Analysis of CE strategies

Seventy-one general actions to implement RSCE have been identified in this research: 3 general actions in the principle *Adjust inputs to the system*, 4 in *Adjust outputs from the system*, 7 in *Reduce the size of the system*, 10 in *Close the system*, 8 in *Maintain the value of resources within the system as maximum as possible*, 5 in *Educate for RSCE*, 9 for *Design for RSCE*, 3 for *Maintain diversity and redundancy*, 5 in *Manage connectivity*, 6 in *Manage slow variables and feedbacks*, 3 in *Promote polycentric collaborative governance systems*, and 8 in *Broaden active participation and transparency*.

The top 3 general actions appearing in the twenty-six CE strategies are: *reducing waste generation*, *Biowaste as a resource* and *Recycling*. *Reducing waste generation* means that at least one specific action promotes the reduction of waste generation, including also the reduction of plastic use to minimize plastic waste. *Bio-waste as a resource* refers to actions addressing the closing-the-loop of the nutrients' cycle, i.e. bio-economy and composting. *Recycling* includes all specific actions related to the promotion of recycling, downcycling and upcycling. On the contrary, the top 3 general actions barely appearing in the strategies under study are: *Extending all stakeholder responsibility*, *Minimizing inequalities*, and *Free-cost software to measure impacts*. *Extending all stakeholder responsibility* explores the idea of going beyond the producer responsibility to cover all stakeholders, including consumers, and it is only addressed by four CE strategies. *Minimizing inequalities* emphasize the need for reducing every form of inequality to promote the shift towards a sustainable and circular paradigm, and it is just included in the Extremadura CE strategy. *Free-cost software to measure impacts* means that there is at least one action to support companies to measure their environmental performance, but none of the strategies covers this essential need.

The results of the analysis of CE strategies are shown in Fig. 5. Although some general actions were barely explored by the studied CE strategies, all the principles were actually considered.

Table 2 shows the results of the correlation analysis between all the principles considered in this study. Most of the principles are uncorrelated. The principles *educating for RSCE* (P6) and *managing connectivity* (P9) showed the strongest correlation ( $r = 0.85$ ;  $p\text{-value} < 0.0001$ ). The principles of *managing connectivity* (P9) and *broaden active participation and transparency* (P12) ( $r = 0.77$ ;  $p\text{-value} = 0.0002$ ), and *closing the system* (P4) and *designing for RSCE* (P7) ( $r = 0.69$ ;  $p\text{-value} = 0.0058$ ), were also highly correlated.

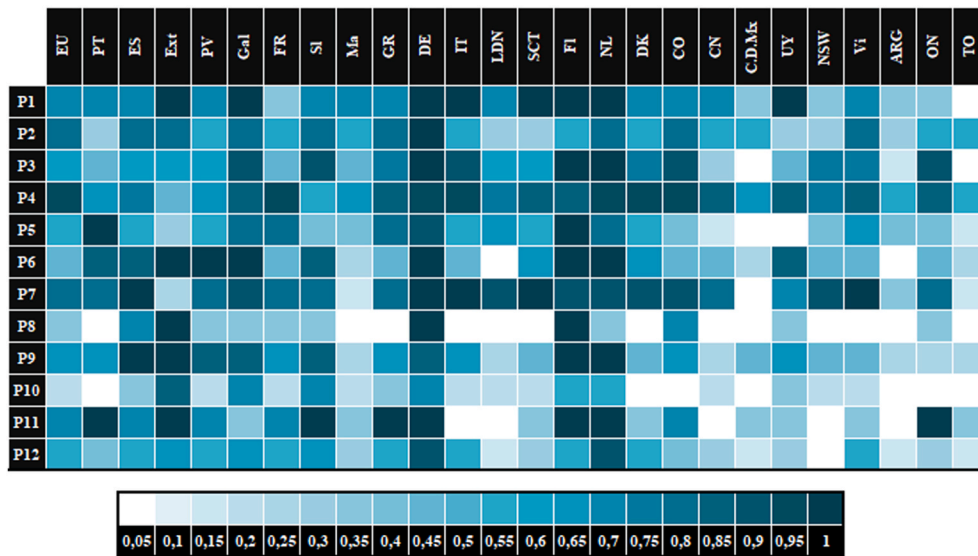
A Multiple Correspondence Analysis (MCA) was performed to identify the main groups of CE strategies (Fig. 6) based on the principles considered. Strategies showing high PC2 values (red dots; upper part of Fig. 6b) correspond to those focused on *closing the system* and *designing for RSCE*, but with low loadings in the resilience principles.

By contrast, strategies scoring low in PC2 (lower part of Fig. 6b) present a high performance in the resilience principles, but low loadings in *closing the system* and *designing for RSCE* principles. Strategies with high loadings in most of the principles are represented in the middle-right part of the plot (green dots). Strategies in the middle-left part of Fig. 6b showed low loadings in most of the principles (blue dots). The rest of the locations correspond to an intermediate position within these groups of strategies.

These four classes also emerged from the hierarchical cluster analysis when cutting at the 1.5-level distance (Fig. 7). This result is consistent with the most suitable number of classes detected by the Expectation-Maximization algorithm.

According to the results of the multivariate analyses, we named the different classes using a color code, as shown in Figs. 6 and 7:





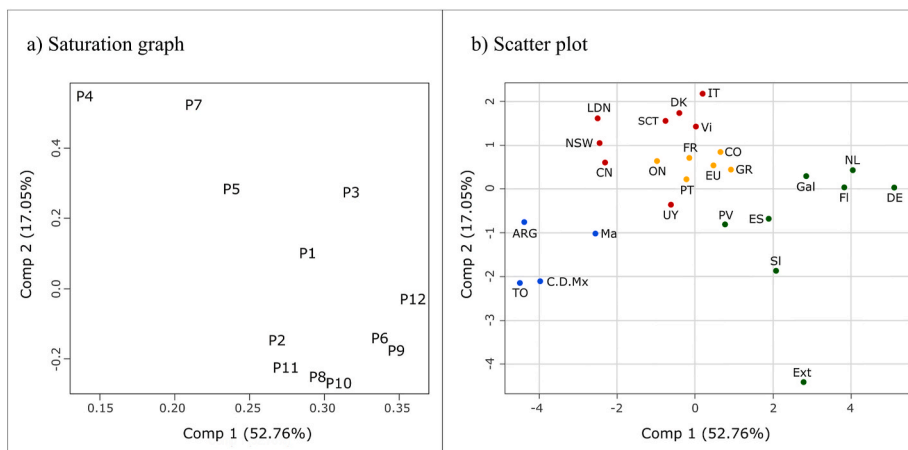
**Fig. 5.** Database containing information about the twelve operational principles addressed by the twenty-six CE strategies. Rows include the twelve operational principles whereas the CE strategies under study are presented in columns. White represents the CE strategy does not address the principle and dark-blue that it addresses the principle entirely. P1: Adjust inputs, P2: Adjust outputs, P3: Reduce the size of the system, P4: Close the system, P5: Maintain within the system, P6: Educate for RSCE, P7: Design for RSCE, P8: Maintain diversity and redundancy, P9: Manage connectivity, P10: Manage slow variables and feedbacks, P11: Foster collaborative polycentric governance, P12: Broader active participation and transparency.

**Table 2**

Correlation analysis among the principles considered under the RSCE framework: Pearson correlation coefficients,  $r$  (lower semi-matrix), and Adjusted  $p$ -values (Holm's method) (upper semi-matrix).

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P1	1											
P2	0,2749	1										
P3	0,6056	0,4705	1									
P4	0,34	0,225	0,5284	1								
P5	0,357	0,22	0,5838	0,3657	1							
P6	0,6631	0,4045	0,5471	0,0927	0,3814	1						
P7	0,4552	0,1614	0,7249	0,6886	0,5707	0,3596	1					
P8	0,4374	0,5519	0,4767	0,0703	0,2481	0,652	0,1543	1				
P9	0,6023	0,5422	0,5398	0,0897	0,4208	0,8529	0,3154	0,7362	1			
P10	0,6414	0,5581	0,5047	-0,08	0,2546	0,7084	0,1496	0,6504	0,7329	1		
P11	0,2306	0,5366	0,4494	0,0107	0,4465	0,6093	0,1089	0,6247	0,6381	0,4539	1	
P12	0,6128	0,7752	0,6528	0,3295	0,5423	0,7289	0,4025	0,5733	0,7745	0,6843	0,6401	1

Note: P1: Adjust inputs, P2: Adjust outputs, P3: Reduce the size of the system, P4: Close the system, P5: Maintain within the system, P6: Educate for RSCE, P7: Design for RSCE, P8: Maintain diversity and redundancy, P9: Manage connectivity, P10: Manage slow variables and feedbacks, P11: Foster collaborative polycentric governance, P12: Broader active participation and transparency.



**Fig. 6.** Results of the multiple correspondence analysis performed on the principles considered by the different CE strategies analyzed in this study. a) Correlation of the principles with the two first principal components. b) Loading of the CE strategies on the factorial space defined by the two first principal components. P1: Adjust inputs, P2: Adjust outputs, P3: Reduce the size of the system, P4: Close the system, P5: Maintain within the system, P6: Educate for RSCE, P7: Design for RSCE, P8: Maintain diversity and redundancy, P9: Manage connectivity, P10: Manage slow variables and feedbacks, P11: Foster collaborative polycentric governance, P12: Broader active participation and transparency.

- All-in-all strategies (green class)
- Waste management strategies (blue class)
- Pro-resilience strategies (yellow class)
- Pro-close system strategies (red class)

The *all-in-all strategies* are those with the highest values in most of the principles, particularly in those belonging to the resilience domain. The German, Dutch, and Finnish CE strategies are characteristic of this group. They address 100% of the actions in seven, five, and seven out of the twelve principles, respectively. Close to them, it is located the Galician



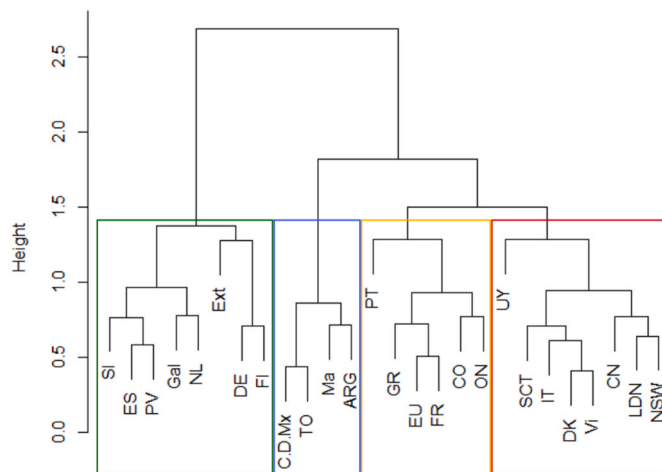


Fig. 7. The four classes of CE strategies resulted from the hierarchical cluster analysis.

CE strategy, which addresses 100% of actions in only two principles, but with general high loadings in most of them. The CE strategies of the Basque Country, Spain, and Slovenia are also included in this class, although they receive lower scores especially in the principles belonging to the sustainability and circularity paradigms. The Extremaduran CE strategy addresses 100% of the actions in four out of seven principles within the resilience domain, but it shows low values in the principles belonging to the sustainability and in the circularity domains.

The *waste management strategies* have the lowest loadings in most of the principles. These strategies present remarkable low values in the principles of reducing the size of the system, maintaining within the system the resources as maximum as possible, educating for RSCE, designing for RSCE, and managing slow variables and feedbacks. However, these strategies showed high loadings in the principle of closing the system.

The *pro-resilience strategies* are located close to the cut-off point between the axes. In general, they have higher loadings than the blue class and medium-high scores in the principles of maintaining the resources within the system, fostering diversity and redundancy, and promoting collaborative polycentric governance.

The *pro-close system strategies* also have higher loadings than the *waste management strategies* in most of the principles, with low scores in the principles belonging to the resilience domain than the yellow class and high values in the principles of closing the system and designing for RSCE.

## 4. Discussion

### 4.1. Typologies of strategies

These results show the high variability of approaches to develop CE strategies around the world. Some strategies are focused just on circularity and barely address the principles of sustainability and resilience. For instance, the CE strategy of Mexico City reached a high score in the *Closing the system* principle (0.6), but less than 0.4 in the rest of the principles. *Closing the system*, and particularly focusing on waste management and recycling, were detected previously as the most common strategies under the CE paradigm throughout the literature (Prieto-Sandoval et al., 2018; Saidani et al., 2019). Other strategies are mainly focused on the sustainability and circularity concepts. For instance, the London CE strategy showed high scores in the principles of sustainability and circularity, but relatively low (0.2) in those related to resilience, except in the case of *Designing for RSCE*. These strategies represent a broader image of CE, including core principles such as reducing, reusing, recycling, and recovery (Kirchher et al., 2017). A considerable number

of strategies present high values for all the principles, including those belonging to resilience. For instance, the German CE strategy scored the lowest value (0.67) in the principle *Managing slow variables and feedbacks*, and the maximum value (1) in seven out of twelve principles. They represent the wider framework to address CE, including elements that go beyond the economic, the environmental, and the technological dimensions, i.e., the social, the governmental, and the behavioral dimensions (Pomponi and Moncaster, 2017).

Despite several CE strategies present positive values in the *Foster collaborative governance systems* principle, they do not propose a way of integrating the objectives among territories. Only the Slovenian CE strategy establishes the basis for integrating the CE goals into the supra and sub-national territorial goals, although it is important to highlight that these targets are not absolute environmental targets; they just cover climate change, plastics and microplastics, and waste generation concerns. In this regard, the Dutch CE strategy is the only one that presents, among its objectives, a reduction of environmental impacts according to the planetary boundary's framework.

### 4.2. Limitations of the classification

Despite the usefulness of the database employed in this study, a series of methodological limitations should be taken into account to adequately interpret our results. Firstly, the fact that a given strategy addresses one action does not directly relate to the quality of the strategy, since the lack of such an action can be motivated by different reasons. For instance, strategies depend on the territory they refer to, e.g., the CE strategy of Extremadura (Gobierno [Gobierno de Extremadura, 2017](#)) does not address the degradation of the coastal degradation, as it is not a maritime region. Secondly, some strategies do not include specific actions in the action plans that are covered by the objectives. The CE strategy of the Basque Country (Gobierno del País [Vasco, 2019](#)) mentions the UE microplastics strategy (EU, 2018/852) and the need to address the microplastics concern, although it does not propose actions on this topic in the action plan. Moreover, the fact that a particular item is not explicitly included in a given strategy does not mean that authorities will not address this issue. For instance, the Spanish CE strategy (Gobierno [Gobierno de España, 2020](#)) does not propose any action to promote biological materials, but the Spanish government presented a bioeconomy strategy that covers this issue (Gobierno [Gobierno de España, 2016](#)). Thirdly, the year of implementation of the CE strategy can be also decisive in the scores obtained. For instance, the absence of actions such as promoting servitization and cooperative consumption systems in the Chinese CE strategy (CCICED, 2008) can be related to the fast development of the CE paradigm during the last decade. Finally, the fact that a CE strategy includes a given action does not mean that it will be successful, as identification of objectives for each action and definition of the adequate tools to reach those objectives is required, as well as the compliance of policies.

## 5. Main contributions and implications

The results obtained in this research provide a valuable contribution to the theory of CE under the environmental sustainability paradigm, proposing twelve principles to connect the theoretical objectives to action plans and testing the proposed framework in a sample of twenty-six current CE strategies.

### 5.1. Main contributions

Being aware of the limitations described above, we believe that this investigation contributes to CE science and policy in several ways. Firstly, it allows the linkage between CE and the just and safe operating space narrative (Raworth, 2017a). It also shows that CE necessarily requires the integration of the resilience, (environmental) sustainability, and circularity domains to operate as a production-consumption system

compatible with environmental sustainability in such space. Resilience thinking and CE had not been previously integrated formally into CE, and this action leads to the connection of a growing literature on governance, social structure or culture related to the CE paradigm (Chertow and Ehrenfeld, 2012; Walker et al., 2021). From the theoretical framework of a resilient, sustainable and circular economy (RSCE), twelve operational principles were defined to connect the theoretical objectives to the practical actions. Most of the principles were extracted and adapted from Biggs et al. (2015) and Suárez-Eiroa et al. (2019), but the definition of these operational principles results in a more comprehensive picture of CE under the environmental sustainability paradigm.

Subsequently, the RSCE theoretical framework was applied to a sample of twenty-six current CE strategies showing that, despite the heterogeneity of the CE strategies analyzed, all the operational principles proposed are addressed by at least one of the CE strategies studied. This outcome supports the importance of these operational principles, as well as the integration of the circularity, sustainability, and resilience domains under the CE umbrella, and reveals that, in general, there is not a clear definition of the scope of CE, especially in relation to the circularity and sustainability domains. Strategies grouped into the resilience domain are barely incorporated into CE strategies, and hence some CE strategies reveal shortcomings in their capacity to generate real changes. Furthermore, the objectives of CE strategies are disconnected from the environmental sustainability requirements, and there is also a lack of integration of CE strategies and action plans among different territorial levels.

## 5.2. Implications for CE science

This research assumed a comprehensive perspective of the production-consumption system, which is considered the mechanism that regulates matter and energy flows between the socio-economical and the natural systems. The fuzzy limits of such a perspective overlap with other disciplines, which, in fact, share the objective of achieving a just and safe space for humanity, e.g., ecological economics, green economics, or even degrowth (D'Amato et al., 2017; Sekulova et al., 2013). Although green economics or ecological economics could be understood as a wider concept than CE (EEA, 2016), in this research we discussed the need for applying a broader scope of CE to include the condition of sustainability and the ability to change related to resilience. This led CE science to transcend the limits of circularity, and move to a more holistic view of the production-consumption system, in particular, and the socioeconomical system, in general.

The societal challenge is how to configure a socio-economic system compatible with the just and safe operating space. This is the integrative idea of Raworth (2017b) when talking about an economic system for the twenty-one century, and also of Pla-Julián and Guevara (2019) when claiming the use of complex adaptative systems thinking in the analysis to enable CE in its way to sustainable development, or Millar et al. (2019) when defended the need for a “unified approach across disciplines to ensure that notions of implementation that adhere to the principles of Sustainable Development are pursued with a similar understanding”. The success to overcome this challenge requires the incorporation of more social (Jabbour et al., 2020; Walker et al., 2021), economic (Ellen MacArthur Foundation, 2020), and environmental elements (Pla-Julián and Guevara, 2019).

An immediate consequence of the results obtained in this research is that more effort is needed to unify the different narratives, such as CE, ecological economics, or degrowth economics, to configure the new socio-economic system, a path that has been already initiated (e.g., Murray et al., 2017; Raworth, 2017b). This leads CE science to further explore holistic transformations of the current business-as-usual model based on the eco-innovation perspective (de Jesus et al., 2018), or on the enormous potential of big data to support the transition towards RSCE (Jabbour et al., 2019).

## 5.3. Implications for policymakers

Our results display a large variety of avenues explored by governments to reach CE. Analytically, this lack of consensus hinders comparisons of different CE strategies and largely impedes monitoring of CE development at a global scale. Although specific actions are highly context-dependent, the proposed operational principles could act as a framework to monitor the development of CE at a given territorial level. In this regard, action plans are recommended to depend on an absolute environmental indicator framework. The calculation of environmental impacts related to the absolute environmental indicator framework should be based on footprint indicators (Elia et al., 2017; Herva et al., 2011), since the responsibility of the different social actors involves direct and indirect impacts on the environment. The fuzzy limits of the proposed resilient, sustainable and circular economy may lead to overlapping of the different policy instruments. A top-down policy process is, therefore, recommended, deriving in new green deals acting as a framework to coherently integrate specific policy strategies.

The application of a broader scope to address CE also implies the consideration of sustainable and resilience elements during the policy generation process. Under the RSCE perspective, governments are requested to provide support for the transformation of the business-as-usual model (Pla-Julián and Guevara, 2019), to guarantee transparency and access to quality public information (Govindan and Hasanagic, 2018), to foster institutional alliances and cooperative policies (Gregson et al., 2015), or to support companies during the transition towards green public and innovation procurement (Milios, 2018). Indeed, governments were identified as essential variables to unlock the transition toward sustainable and circular business models (Tura et al., 2019), assuming their double-role as process supporter and coordinator (Abreu and Ceglia, 2018).

RSCE demands businesses to integrate corporate social responsibility systems. Transparent relationships between companies and their suppliers (Jabbour et al., 2020), and with all their stakeholders (Witjes and Lozano, 2016), inter-firm collaborations and common management (Awan, 2020; Jabbour et al., 2020), and public-private collaborative relationships (Seuring and Gold, 2013), have been pointed out to enhance a sustainable and circular production-consumption process. Businesses generate a symbolic value that intervenes in the development of pro-sustainable values by the civil population (Santamaria et al., 2016), and hence, they have an unavoidable responsibility in the transition towards RSCE.

## 6. Conclusions

In this research, we conducted a review to study the potential of the circular economy to address environmental sustainability. To make CE possible to address environmental sustainability, we firstly proposed the need of understanding CE as a resilient, sustainable and circular economy, and later defined twelve principles to operationalize CE under the environmental sustainability paradigm. Subsequently, this framework was tested in a sample of twenty-six current CE strategies. We found that all the principles are addressed by at least one of the CE strategies, which supports the importance of the operational principles proposed, as well as the integration of the circularity, sustainability, and resilience domains under the CE umbrella.

Our results provide a better understanding of how CE should be framed in order to address environmental sustainability. It has been argued that circularity can coexist with an unsustainable production-consumption system, and hence CE necessarily incorporates the notion of environmental sustainability, which is supported by both epistemological considerations and a large fraction of scholars. Furthermore, since the transition towards CE is not at all guaranteed, the production-consumption system needs to incorporate the ability to adapt and transform positively when it is required, what led us to include the resilience thinking framework under the CE paradigm. Ultimately, social

issues are crucial to enable the expected transition. Further research is needed to perform a more holistic analysis based on complex adaptative system thinking, which would allow connecting more essential elements to enhance a socially fair development that preserves the environment.

### 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.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2021.129071>.

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