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What are the key dimensions that CE emphasizes on? A systematic analysis of circular economy definitions

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Abstract
Today, the concept of the circular economy (CE) has different meanings for various scholars. There are numerous definitions that focus on highlighting different aspects and principles of CE. However, there has been little effort made regarding the focus of CE definitions on various environmental aspects, such as waste management, wastewater treatment, biodiversity, carbon emissions and climate change. To clarify this complex environment, this paper examines the research endeavors surrounding the CE by analyzing 136 descriptions sourced from various entities and researchers. In particular, a more thorough investigation of CE is warranted to explore the possible ways of adopting its principles. To achieve this, Microsoft Excel and Leximancer™ software are employed to thematically and content-wise analyze the descriptions. The results reveal that "waste" and "recycling" are central concepts in CE descriptions, which align with the goals set forth in Union legislative acts, the "Roadmap for a Resource-Efficient Europe," and the European Green Deal aimed at increasing recycling rates and eliminating waste.

Keywords Circular economy · Definitions · Quantitative analysis · Content analysis · Leximancer

1 Introduction

The current state of the global economy is characterized by a rapid increase in consumerism, which appears to be unsustainable. Mainstream economic thinking promotes a linear economy that leads to a continuous and gradual degradation of ecosystems. In order to prevent environmental degradation and preserve natural resources for future generations, CE is suggested as a promising and appropriate tool to achieve sustainability goals (Broman and Robèrt 2017). Consequently, existing literature requires a more thorough investigation and consideration of CE from both the side of consumers (Allwood et al. 2011; Ghisellini et al. 2016) and the side of producers (Bakker et al. 2014; Su et al. 2013).

Current literature suggests that the CE concept does not have a universally accepted definition among scholars and practitioners. Many definitions highlight various principles of CE, such as reduce, refuse, reuse, redesign, recycle, and remanufacture. Today, the wide range of content associated with the CE concept can lead to understanding problems for scholars. Many scholars have collected various definitions that focus on different aspects of CE. In the seminal paper by Kirchherr et al. (2017), 114 different definitions of CE are identified. The authors point out that before 2012, most CE definitions primarily emphasized the principle of recycling, while after 2012, there was greater emphasis on reusing and reducing. In the period after 2012, they also found that CE definitions emphasized the well-known "3Rs," which include the principles of reuse, recycle, and reduce.

Similarly, Nobre and Tavares (2017) analyzed 70 CE definitions and identified that most definitions primarily

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emphasize reuse, then recycling, and finally extending the lifespan of products. Of particular importance, they identified an equal balance of definitions between the three main categories in which CE is located, that is, at the micro, meso, and macro level. The important study of Korhonen et al. (2018) shows that some of the existing definitions are based on the CE definition set by the Ellen MacArthur Foundation. By utilizing content analysis techniques, Homrich et al. (2018) analyzed 35 CE definitions and identified that the most common terms in CE definitions are "resource" and "productivity." Other definitions utilized terms such as "waste," "energy," and "equipment." Most of the definitions analyzed by Homrich et al. (2018) emphasize reducing inputs by consuming fewer natural resources and materials and reducing outputs by eliminating pollutants.

The majority of existing CE definitions aim to cover all sectors, levels, and environmental aspects (Nobre and Tavares 2017; Geissdoerfer et al. 2017; Nikolaou et al. 2021; Saidani et al. 2018). However, some definitions focus on specific levels, aspects, or business sectors, which is another significant weakness in the current analysis of CE literature. Moreover, there is little mention of the environmental aspects, such as climate change, waste, wastewater, biodiversity and carbon emissions (Xie et al. 2023) that each definition (particularly) or CE (in general) could address. This focus only on the principles of CE has led to confusion among scholars, who conclude that the concept only pertains to solid waste management and that CE already existed in the context of the three '3Rs' (reuse, recycle, reduce) in this field. However, CE is a tool for water and wastewater treatment, climate change mitigation, elimination of biodiversity loss, renewable energy creation, and reducing natural resource consumption.

To address this research gap, this paper proposes an index to analyze 136 research articles published in the last 20 years, aiming to identify the main aspects and terms that definitions are focused on. Despite the conceptual richness of CE approaches, there is a clear research gap in understanding the linkages and relationships between key concepts, as the literature rarely discusses suitable methodologies to explore how these concepts relate to each other. Simultaneously, this study aims to bridge the gaps between academics, scholars, theorists, and practitioners, as the diversity characterizing CE makes it challenging to define and delimit targets conceptually. The proposed framework involves both thematic and content analysis. It is based on the notion that CE is not solely theoretical but also instrumental in various actions across different sectors. In terms of methodology, the Leximancer software is used to analyze the conceptual content of CE definitions for the first time. The findings suggest that significant attention is devoted to "waste management" and "recycling" as key strategies that can facilitate the EU's circular transition. The substantial amount of waste generated poses a threat to modern economies and societies due to the high costs of waste management and its impact on the environment. Therefore, the concepts of "environment", "economy", "waste", "4R principles", "materials", and "energy" are of paramount importance in CE descriptions.

The remainder of the paper is organized as follows. The second section describes devotes the theoretical underpinnings and current methods that accompany the CE conceptual approach. The suggested methodology is described in third section, while the fourth section presents the results. The following section discusses while Sect. 6 gives concluding thoughts and outlines policy implications and suggestions for further research.

2 Mapping the CE concept

The concept of CE has gained significant attention in recent years, with scholars responding to development pressures, economic concerns, and energy deficits (Allwood et al. 2011; Hara et al. 2011; Li et al. 2010; Union 2014). CE aims to maximize resource efficiency by highlighting that unsustainable consumption and production patterns have exceeded the environment's boundaries (Naustdalslid 2014). The Oslo symposium in 1994 established the dimensions of CE, which involve using goods and services that meet basic needs to improve the quality of life and minimize the overexploitation of natural resources throughout their life cycle. From the outset, the circular approach has been viewed as an excellent opportunity to promote economic growth and sustainable resource management. In the past two decades, numerous efforts have focused on reviewing the CE concept (Ghisellini et al. 2016; Kirchherr et al. 2017; Nikolaou et al. 2021) with Moraga et al. (2019) investigating CE indicators and Kirchherr et al. (2017) analyzing 114 definitions to identify 17 dimensions of CE.

2.1 Socio-economic domain

Theoretical discussions on the expected benefits of implementing circular initiatives focus particularly on the spillover effects associated with CE methods (Ghisellini et al. 2016; Stahel 2016; Stahel and Clift 2016). The literature shows that these benefits are not limited to consumers and businesses adopting and implementing circular methods, but also spread throughout the entire economy (Allwood et al. 2011). At the consumer level, the adoption of circular initiatives appears to have a significant impact on reducing property costs, as highlighted by Singh and Ordoñez (2016). Such initiatives could be further enhanced through changes in property ownership, such as product leasing systems. Ghisellini et al. (2016) argue that the CE approach is rooted in the context of neoclassical economics. For instance, the discourse surrounding CE is also characterized by a reevaluation of ownership status through management systems that involve leasing products to consumers-administrators who, in turn, hold exclusive rights to the service. Yan and Wu (2011) argue that circular initiatives reflect a mode of economic growth that aims to enhance economic value by harnessing the additional value-creation potential of materials and products, social value by strengthening social cohesion, and environmental value by promoting the resilience of natural resources and transitioning to sustainable energy use. Singh and Ordoñez (2016) focus on the benefits of material savings by emphasizing that CE adopts a biomimetic approach that proposes innovative ways of transforming the linear consumption and production system into a circular one, contributing to economic viability through material savings. Saidani et al. (2018) highlight the issue of price volatility, stating that the circular model is capable of enhancing both competitiveness and sustainability. Specifically, the circular model could alleviate manufacturers' dependence on raw materials by effectively addressing sharp price fluctuations (Kiser and Prager 2016). It is worth noting that waste absorption, material supply, and utilization are identified as the three main environmental pillars.

Several studies have explored the potential trade-offs between the need to conserve, renew, and restore ecosystems and the economic pressures faced by businesses (Bocken et al. 2016; Fang et al. 2007; Park et al. 2010). Examples of this include service-product systems (Ghisellini et al. 2016; Bocken et al. 2017; Castellani et al. 2015), industrial symbiosis (Jiao and Boons 2014; Lehtoranta et al. 2011; Wen and Meng 2015; Yang and Feng 2008) and eco-industrial parks (Bai et al. 2014; Wang et al. 2010). Murray et al. (2017) shed light on the social pillar of sustainability, while Van Buren et al. (2016) suggest that CE can stimulate the creation of new economic activities and jobs. Wijkman and Skånberg (2016) emphasize that a circular transition is essential to remain within planetary boundaries. According to Yong (2007), Yuan et al. (2006) and Zhu et al. (2012), the CE mission is to balance the material flows between the socioeconomic system and the ecosystem and comply with ecological criteria necessary for achieving economic development (Zhang et al. 2009; Zhijun and Nailing 2007).

2.2 Socio-environmental domain

CE is an efficient strategy that aims to extend the life cycle of products through shared functions and the exploitation of natural cycles to conserve energy while promoting the prudent use of critical raw materials. Baxter et al. (2017) and Niero et al. (2017) shed light on the implementation challenges associated with the circular potential embodied in material flows. Bocken et al. (2016) state in this regard, that CE aims to exploit natural cycles to conserve energy while linking with the prudent use of critical raw materials. Charonis (2012) considers CE as a restorative and regenerative system while European Commission (2014) defines CE as a model capable of transforming production chains and consumption patterns. EUKN (2015) perceives companies as driving forces in achieving circular transition. Chertow and Ehrenfeld (2012) held the notion that an industrial ecosystem is considered circular when a resource has a respective closed flow which is also supported by many studies (Jiao and Boons 2014; Jones et al. 2013; Mathews and Tan 2011; Zink and Geyer 2017).

Several researchers have examined the integration of CE into an industrial system (Hobson 2016; Hultman and Corvellec 2012; Iung and Levrat 2014) where material flows circulate at a high rate without entering the biosphere (WRF 2012). The importance of a closed-loop system is underlined by Geng and Doberstein (2008), Geng et al. (2012, 2013) and Goldberg (2017). In this sense, the adoption of cleaner production patterns is of paramount importance (Conticelli and Tondelli 2014; Geng et al. 2009; Linder et al. 2017; UNEP 2011). Iron and steel industries are considered as pilots to foster the development of cleaner technologies (Wang et al. 2013). Dajian (2008) sheds light on the exchange value of CE while Den Hollander et al. (2017) argue that the term "waste" does not exist in a CE model. On the contrary, Preston (2012) considers waste as an input to another process. This idea is also reflected in the studies of Liu and Bai (2014) and Veleva et al. (2015). Extending this reasoning, Haas et al. (2015) and Hislop and Hill (2011) underline the need to waste elimination which is subject of intensive examination in the studies of Richa et al. (2017), Winkler (2011) and Wu et al. (2014).

On the other hand, waste management systems for achieving a circular transition are addressed by Sakai et al. (2011), while Schroeder et al. (2019) note that eco-design practices need to be implemented alongside recycling actions (Sihvonen and Ritola 2015; Skene 2018; Song et al. 2015; Tisserant et al. 2017). CE is also seen as a system where growth is decoupled from resource consumption (Dupont-Inglis 2015; EMF 2012, 2013, 2014, 2016; Liu et al. 2009; Mendoza et al. 2017; Yabar et al. 2009), promoting sustainable development (Ma et al. 2014; Ness and Xing 2017). Moreau et al. (2017) emphasize the importance of intensifying use, while Murray et al. (2017) unveil the beneficial effects of CE on human well-being. CE is also seen as a key driver to alleviate pressure on natural resources due to the expected increase in the world's population (OECD 2016). Pingjing et al. (2013) categorize material flows into biological and technical nutrients, while Reh (2013) shows that the more liquid, solid, and gaseous resources are used, the more solid residues, offgas, and wastewater have to be treated.

3 Research methodology

This section describes the suggested research framework for this study (Fig. 1). The framework consists of five basic steps. The first step involves developing research questions through a review of the current literature. Specifically, a dataset of relevant literature about CE definitions is analyzed to identify research gaps and potential research questions for the study. To answer our research questions, 203 articles that mention the term "Circular Economy" are examined along with the keywords presented in Table 1. The dataset is filtered to include only peer-reviewed journals, resulting in a dataset of 136 research articles and studies that have been published in the last 20 years. The next step involves developing measurement systems to quantify relevant information. This step uses Microsoft Excel and Leximancer analysis techniques. After the data analysis process, the research questions are addressed, and future trends are identified and discussed.

3.1 Research questions development

Several methodological approaches have been developed to investigate the CE concept. Kirchherr et al. (2017) conducted a systematic analysis of 114 CE definitions, while Lieder and Rashid (2016) provided an overview of CE using the term "circular economy" for the period from 1950 to 2015. Ghisellini et al. (2016) analyzed the existing literature at micro, meso, and macro level using content analysis techniques. Moreau et al. (2017) investigated energy flows and material stocks in relation to CE, while Prieto-Sandoval et al. (2018) employed a systematic literature review to identify eco-innovations. Blomsma and Brennan (2017) used narrative reviews to show how CE can serve as a conceptual umbrella. Nikolaou et al. (2021) employed bibliometric techniques, typology, and narrative literature review to explore

Table 1 CE dimensions

Dimension (*i*)	Variables of interest (*j*)
Environmental	"Resource scarcity", "Energy", "Energy Flow" (Industrial Metabolism), "Conservation", "Efficiency", "Resource Depletion", "Life Cycle", "Resource Productivity" "Environmental Impact", "Environmental Sustainability", "Environmental degradation", "Cleaner Production", "Zero Waste", "Waste management", "Waste", "Landfill", "System effectiveness", "Emissions" (Industrial Metabolism), "Pollution"
Economic	"Economic Development", "Industrial Economy", "Growth", "Cost", "Economic Sustainability", "Competitive economy", "Competitiveness"

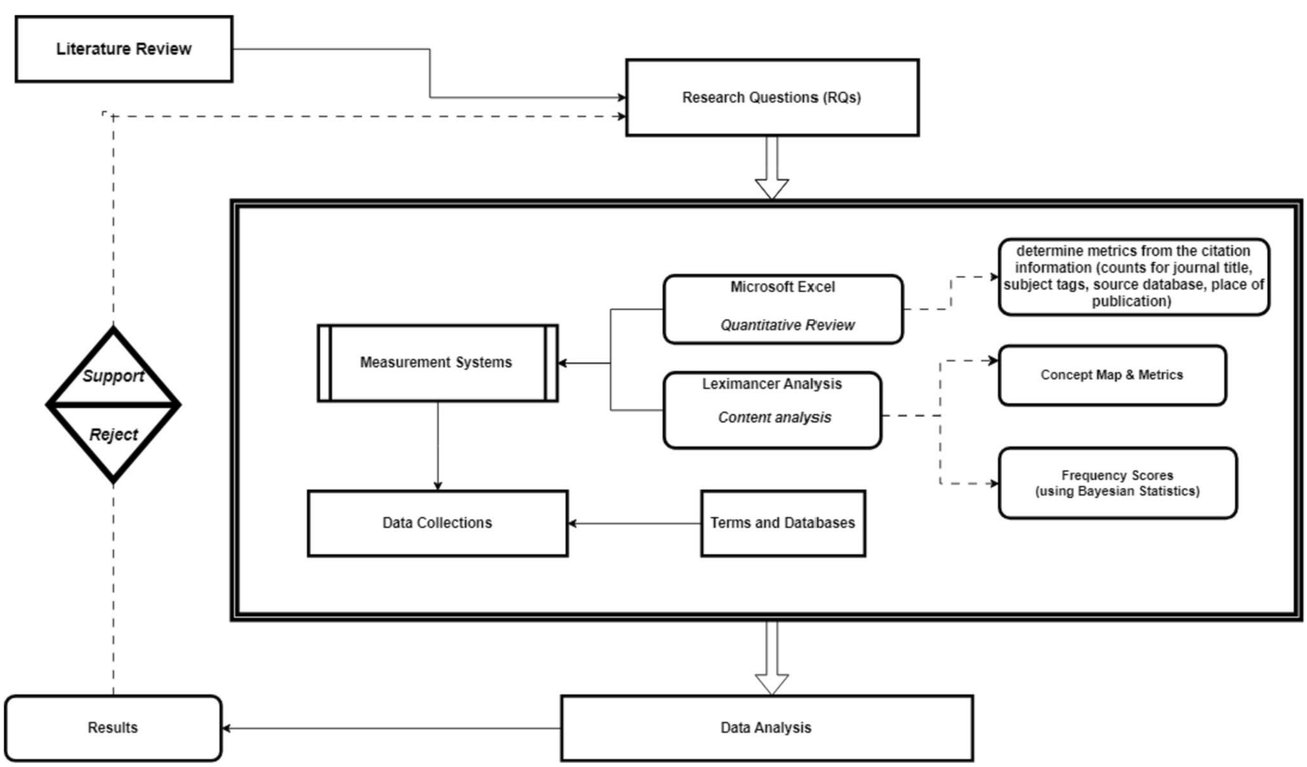

Fig. 1 Research framework

the relationship between CE and sustainability. Geissdoerfer et al. (2017) conducted bibliometric analysis and snowballing techniques to investigate the similarities, differences, and relationships among CE descriptions. Homrich et al. (2018) analyzed 35 CE definitions through a combination of bibliometrics, semantic, and content analysis in a systematic literature review. Using social network and content analysis, Nobre and Tavares (2017) examined 70 definitions. Through a comprehensive approach, Korhonen et al. (2018) attempted to investigate CE in the light of the socioeconomic and environmental domains. To the best of our knowledge, there is still a gap in the literature for creating a CE concept index that incorporates the relationships and links between key concepts, calculates relative co-occurrence frequencies, and develops a two-dimensional CE concept map. Such a map could enrich scholars' and practitioners' understanding of CE by representing possible developmental pathways.

Specifically, the present study aims to investigate CE descriptions through the use of thematic and content analysis techniques. This study will delineate the linkages within the CE by answering the following research questions:

RQ_1: "Which subject tags are highlighted and are most relevant to the environmental and economic dimensions of CE?".
RQ_2: "Which are the key concepts most frequently discussed and how they are related to each other?".
RQ_3: "Which are the optimum strategies that can foster the EU's circular transition?".
RQ_4: How do academics and practitioners incorporate CE principles in the descriptions through co-occurrence frequencies?".

3.2 Measurement systems

To address these questions, we analyze the CE definitions in relation to the targets outlined in Union legislative acts, such as the "Roadmap for a Resource-Efficient Europe," and the European Green Deal, which aim to increase recycling rates and eliminate waste. To calculate the frequency of subject tags, especially the CE objectives (economic and environmental), we utilize the Microsoft Excel software. Additionally, we employ text mining software called Leximancer (Chen and Bouvain 2009) to extract concepts using resulting weighted term classifiers.

3.2.1 Quantitative analysis

The Microsoft Excel software is used to estimate the counts for the subject tags, specifically for the CE objectives (economic and environmental). The percentage of occurrence of each dimension (environmental, economic) is estimated to delineate the CE mission through the frequency of occurrence of each dimension. The mapping of the dimensions and variables of interest is presented in Table 1.

The relative rating of dimension i (environmental, economic) is calculated according to the total incidence of variable interest j belonging to dimension i from the following relation (1):

$$DSi = \sum_{j=1}^{\chi} F\ Defji \quad (1)$$

where, DSi = The dimension rating i., $FDefji$ = The incidence of variable interest j belonging to dimension i., x = The total number of dimension variables of interest i.

3.2.2 Content analysis

In the next step, we employ text mining software called Leximancer, which is a relatively new method for transforming lexical co-occurrence information from natural language into semantic patterns in an unsupervised manner. The software uses two stages of semantic and relational extraction of emerging information, with a different algorithm for each stage. The algorithms are statistical but incorporate nonlinear dynamics and machine learning. The aim is to outline possible ways of adopting CE principles and to delineate the relationships that emerge among variables. Specifically, Leximancer performs automatic content analysis by searching and extracting thesaurus-based concepts from the text data. These concepts are then coded into the text using the thesaurus as a classifier. To generate a concept map, the resulting asymmetric concept co-occurrence information is used. In essence, Leximancer is a method for transforming lexical co-occurrence information from natural language into semantic patterns.

To generate a list of important lexical terms based on their word frequency and co-occurrence usage, a unified body of text was examined. These terms were then used to seed a bootstrapping thesaurus builder, which learned a set of classifiers from the text by iteratively extending the seed word definitions. The resulting weighted term classifiers were used to extract the concepts, creating a concept index for the text and a concept co-occurrence matrix. From this matrix, the relative co-occurrence frequencies of the concepts were calculated, producing an asymmetric co-occurrence matrix. An emergent clustering algorithm was then used to generate a two-dimensional concept map. To display more general parent concepts at higher levels, the connectedness of each concept was used to generate a third hierarchical dimension. This two-step process was used to compare the results from academic sources.

3.3 Data collection

Following the systematic research process outlined by Sullivan et al. (2018), we assembled a dataset of relevant literature. To answer our research questions, we conducted a keyword investigation (depicted in bold) and considered some indicative definitions as an example (Table 2). The publication database was filtered using the Scopus database, and the investigation was based on major journals publishing in this field, such as the Journal of Industrial Ecology, Journal of Cleaner Production, Resources, Conservation and Recycling, and Sustainability Science. Specifically, we examined 203 articles that mentioned the term "Circular Economy," along with the keywords identified below in bold, which are principal contributors to the transition towards a CE.

3.4 Data analysis

The present analysis is based on an indexing of 136 research articles and studies published in the last 20 years. Initially, in 2005, CE was described as a recycling economy, in which resources would be transformed into products and then fully recycled through appropriate material transformation (Birat 2015; Thomas and Birat 2013; Xin et al. 2014). At the same time, it was also approached in the context of waste management and processing, as it was noted that resources and goods could not be effectively utilized without reducing unnecessary demand (Stahel 2013). Prior to 2006, there was a tendency to change both the conceptual view and the dimensions of CE based on the researcher's optical focusing and theoretical starting point, since it was not an independent research field. Consequently, CE research questions were identified simultaneously in declarations of ecological, environmental, and industrial ecology, mainly referring to the mapping of new, more effective methods to minimize and recycle waste, as well as to improve management systems of natural resources.

However, since 2006, CE has gained its own identity and independence from the research fields it previously drew its theoretical ideas from. Academic research has started to view CE as an autonomous concept that incorporates the "4R principles" and potential benefits promised by its principles, both at the micro-level for individual businesses, consumers, and industries, and at the macro level for communities, cities, and countries. Thus, CE has often been used as a general term encompassing any initiative of reduction, reuse, recycling, and recovery involved in the production and consumption processes (Ghisellini et al. 2016). However, the CE literature available during the preparation phase of the study does not adequately address crucial issues such as climate change, water and air quality protection, and concerns related to well-being.

4 Results

The results, obtained using the Microsoft Excel software, indicate that the concept of "waste" holds a principal position in CE descriptions, followed by "energy," "efficiency" and "cleaner production" (see Fig. 2). This reflects the growing global concern about the level of waste generation across countries and regions. In order to signal the transition to a society of "zero waste" and an economy where the costs of "waste management" can be minimized, the linear way of life must be reshaped. Specifically, the results show that the "efficient" utilization of "resources" and "energy" does not offer high added value unless it is accompanied by the adoption of "cleaner production" patterns and actions to reduce unnecessary demand (RQ_1).

An analysis of the results pertaining to the economic dimension reveals that the term "growth" is frequently referenced in comparison to other definitions, followed by "economic development", "industrial economy", and "cost" (Fig. 3). Consequently, CE embodies a strategic approach that emphasizes "growth" and fosters "economic development" while simultaneously integrating various methods for generating value and ensuring sustainability by reorganizing the existing "industrial economy". Furthermore, this approach enhances the "competitiveness" and sustainability of businesses, thus resulting in significant "cost" savings (RQ_1).

The prominent themes that surface from the Leximancer analysis are "environment", "economy", "waste", and "recycling" (Fig. 4). This suggests that CE is primarily viewed from the perspective of waste management, emphasizing that efficient resource and product usage alone is insufficient without a corresponding reduction in unnecessary demand (Stahel 2016). Originally, CE was characterized as a recycling economy, in which resources are transformed into products and subsequently recycled in their entirety through appropriate material transformation (Yap 2005) *(RQ_2)*.

As indicated by the thematic analysis conducted using the analyst synopsis (Table 3), CE is fundamentally characterized by environmental and economic challenges, highlighting the imperative of securing and substituting critical raw materials and recovering finite stocks from waste streams. Additionally, CE advocates for the use of recyclable materials and underscores the significance of extending the lifespan of products through circular design. These insights are apparent in the text blocks corresponding to the definitions of CE.

The role of waste management and recycling (RQ_3) is highlighted and closely intertwined with the CE concept when examining the emerged relationships. It should be noted that, like most algorithms, there are parameters that need to be set and the choices made are expected to

Table 2 Literature review keywords investigation according to the following definitions

Authors	Description
Zhu et al. (2011, p. 405)	"Due to ***resource scarcity*** and ***environmental degradation***, a new development concept emphasizing environmental concerns, called the circular economy (CE), has been enacted in legislation in China. This environmental management concept can be implemented at three levels, namely, region, industrial zone, and individual enterprise, with the objective of boosting *economic development* while lessening environmental and resource challenges"
Zhu et al. (2010, p. 1325)	"These principles include eco-systemic self-sustaining properties which require recycling of essential materials and ***energy***"
Yan & Wu (2011, p. 1–5)	"The circular economy is such kind of economic mode which takes the efficient and circular use of resources as its core, the *"3R" (reduce, reuse and recycle)* as its principles, is characteristic with closed-loop material cycle and cascade of ***energy use***, and runs according to the way of natural material circulate and the ***energy flow***"
Velte et al. (2018, p. 775)	"The circular economy is a framework that sets into a relationship different ways of ***value creation and conservation***, e.g., through reuse, refurbishment, remanufacturing or recycling"
Birat (2015, p. 1)	"The rationale is that ***growth*** has been based in the past on wasting raw materials and resources ("the linear model") and that a more resource-wary approach would benefit Europe by reducing the ***depletion of natural resources*****,** whether they are rare or not, and the dependency of the Region on raw development of a circular economy, based on ***recycling*****,** ***reuse, reduction – even elimination – of waste*** (all recyclable waste (plastics, metals, glass, paper, cardboard, biodegradable waste) barred from ***landfilling*** by 2025 and all *landfill* stopped by 2030) and lean-eco design. This is similar to speaking of industrial and urban ecology, of ***urban metabolism*** and of exploiting urban or industrial mines"
Ness & Xing (2017, p. 572 ff.)	"The CE, though, seeks to have no net *impact on the environment*, by restoring any damage done in resource acquisition while *minimizing* ***waste generated*** during the production and ***life cycle*** of products. Moreover, it has been claimed that CE approaches will generate jobs and improve *competitiveness*, while fostering ***energy savings*** and reducing ***GHG emissions***"
OECD (2011, p. 20)	"Improving ***resource productivity*** through sustainable materials management requires integrated ***life cycle*** based policies for waste, materials and products"
Park et al. (2010, p.1496)	"The CE concept has been actively promoted by Chinese government policy makers as a way to improve ***resource productivity***, boost eco-efficiency, and strengthen ***environmental sustainability***"
Fang et al. (2007, p. 316)	"At the micro-level, the CE will ensure that byproducts are identified in individual enterprises and used effectively either internally through ***cleaner production*** (CP) or externally by other industries"
Mirabella et al. (2014, p. 29)	"Moreover, industrial ecology concepts such as cradle to cradle and circular economy have been considered leading principle for eco-innovation, aiming at ***"zero waste" society*** and economy where wastes are used as raw material for new products and applications"
Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015, p. 23)	"This definition rests on three principles: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows. Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles. Foster *system effectiveness* by revealing and designing out negative externalities such as water, air, soil, and noise ***pollution***; climate change; toxins; congestion; and negative health effects related to resource use"
FCCA (2020, p 55)	"A circular economy is moving from the linear ***industrial economy*** of "take-make-consume and dispose" to an industrial economy of "reusing, repairing, refurbishing and recycling" resources"
Geng et al. (2010, p. 5278)	"Such a closing of the loop results into higher conservation of natural resources and ***lower disposal and production costs"***
Singh and Ordoñez (2016, p. 342–353)	"CE is an economic strategy that suggests innovative ways to transform the current predominantly linear system of consumption into a circular one, while achieving ***economic sustainability*** with much needed material savings"
European Commission (2015, 614 final)	"The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a ***sustainable, low carbon, resource efficient and competitive economy"***

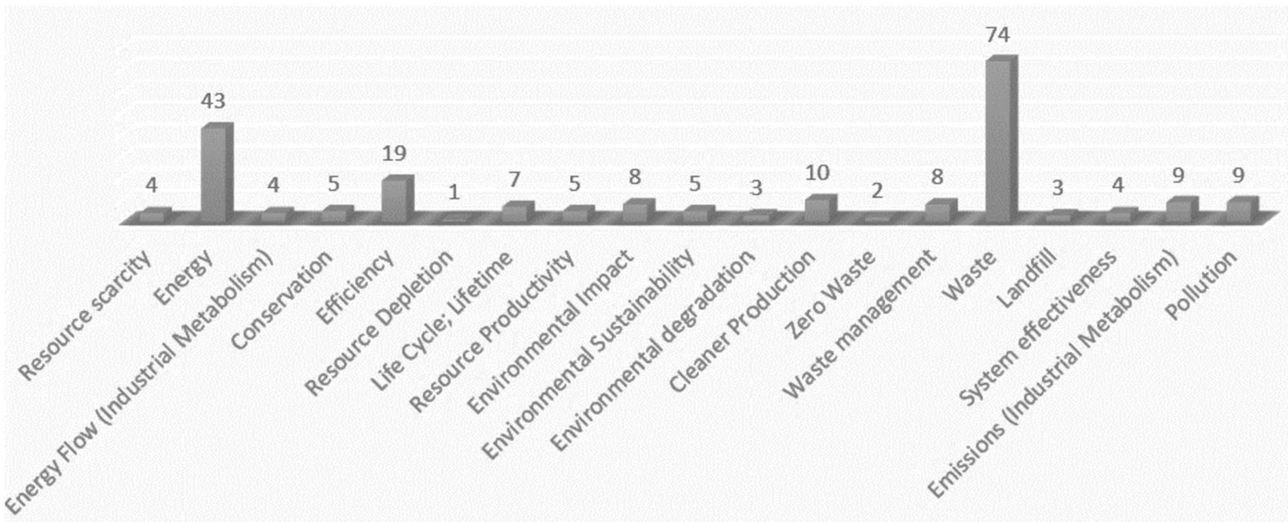

Fig. 2 Environmental dimension of CE

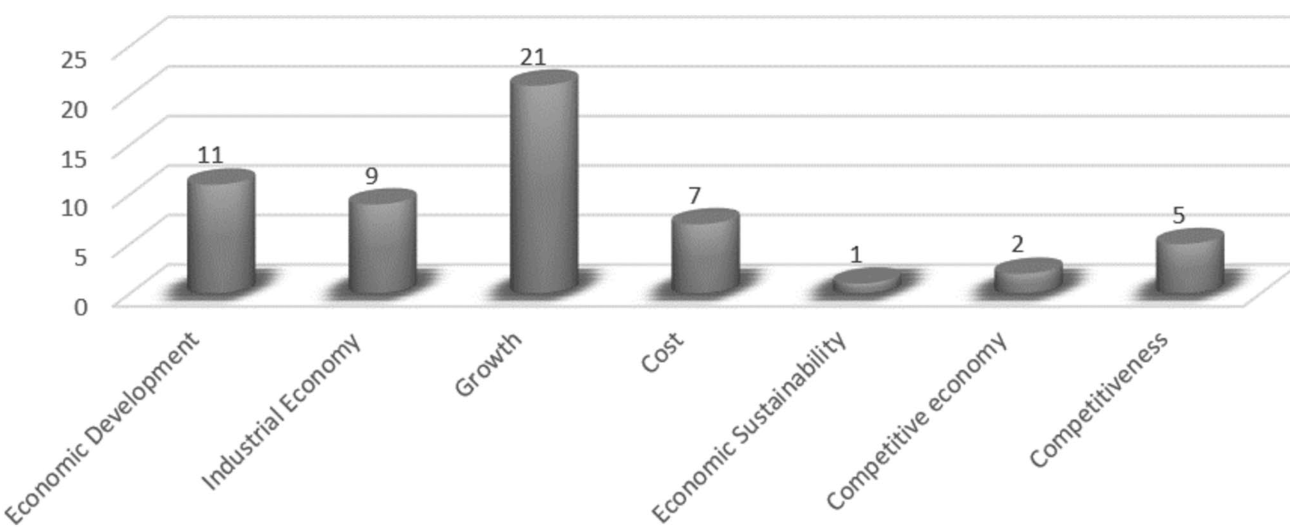

Fig. 3 Economic dimension of CE

Fig. 4 Basic dimension in CE descriptions

Table 3 Results of analysis using analyst synopsis

CE definitions	
Theme	Hits
Economic	190
Waste	178
Materials	161
Recycling	116
Environmental	107
Value	59
CE	46
Design	46
Activities	30
Loops	10

influence the results. Therefore, we designated the terms "waste" and "recycling" as "structural concepts" from the "Required Concepts" list. The outcomes correspond to the text sections that contain the specified "structural concept" and, in this case, the concepts of "waste" and "recycling". The resulting concept map illustrates the network of concepts based on relationships that exclusively include these structural variables within the text. As demonstrated through the co-occurrence approach, waste management is closely associated with the "3R" principles (Fig. 5).

Another significant theme that arises from the analysis of CE is "recycling". It should be emphasized that the achievement of recycling targets can be realized without CE, but the fulfillment of CE targets is not possible without recycling. A closer inspection of this concept reveals that the "Waste" and "Reuse" aspects occupy a central position in the recycling process (as depicted in Fig. 6). This implies that "waste" holds a central position in the recycling process (RQ_2).

In contrast to the narrowly defined recycling of waste, the focus of circular strategies has shifted towards a comprehensive performance-based control throughout the entire lifecycle of materials across all stages of consumption and production. Within the context of CE, "reuse" actions hold the potential for greater impact than conventional recycling, which is marked by limited circularity, quality and value. However, at a global level, the adoption of this approach is still in its early stages and tends to lean towards recycling rather than reuse.

The terminology used to describe the concept of "circular economy" involves merging the words "CE", "circular", and "circular economy" into one term, "circular economy".

Fig. 5 Basic dimensions related to the structural variable "Waste"

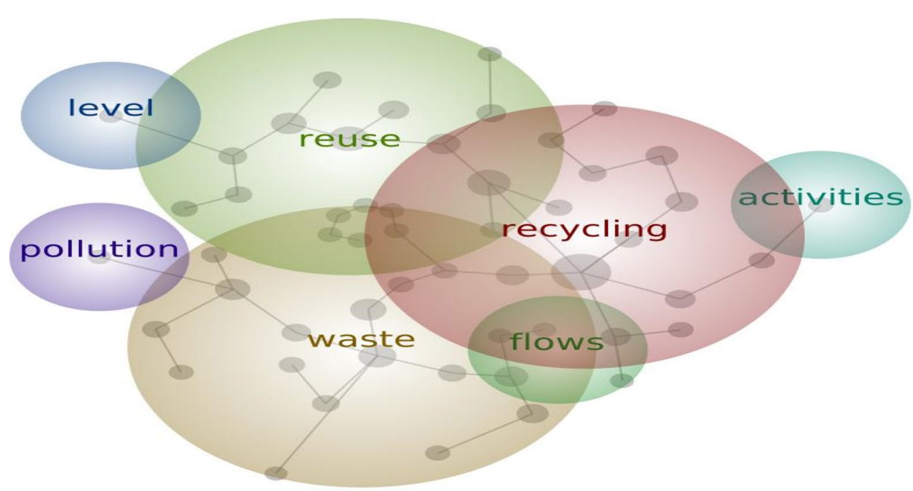

Fig. 6 Basic dimensions related to the structural variable "Recycling"

Similarly, the principles of CE are described by combining the words "recycling", "reduce", "reducing", "restoration", "restorative", and "reuse" into the single term "4R principles". Additionally, to describe the economic aspect of CE, the words "economic" and "economy" are merged into the term "economy". The terms used to describe the environmental dimension of CE have been reconfigured by combining the words "environment" and "environmental" into a single term, namely "environment." The term "circular economy" has been identified as a structural concept from the "Required Concepts" list. Upon parameterizing the terms, the results indicate that the concept of "environment" holds a central position in CE descriptions. Furthermore, the terms "economy," "waste," "4R principles," "materials," and "energy" are frequently mentioned (Fig. 7) (RQ_2).

The results of the study suggest that CE is viewed as an autonomous concept that incorporates the "4R" principles, with the goal of raising awareness about the impact of serious biodiversity loss, resource scarcity, and energy deficits. CE is designed to maintain natural capital while contributing to economic viability through material savings. This is reflected in the links between the various concepts and themes, as outlined in Table 4.

CE definitions give considerable attention to "waste management", "resource scarcity", and "recycling" activities (RQ_3) to establish a knowledge base on the threats of unsustainable trends in waste generation, resource use, and recycling issues. The relevance ratios concerning the concept of the "circular economy" indicate that "waste management", "economy", "materials", "resources", and "recycling" receive the highest weights in the CE descriptions (Table 5) and are, therefore, more closely associated with CE (RQ_4). Considering that circular actions are determined by a "bottom-up" approach that specifically starts with families, schools, and society, it is necessary to adopt more effective methods dedicated to waste elimination and recycling. It is worth noting that although recycling rates tend to increase for EU countries and regions, they still significantly deviate from the targets set by Directive 2018/851, which aims to achieve a target of 55% by 2025.

Table 4 Links between concepts and themes: structural variable "Circular Economy"

Keyword	Concept count	Relevance (%)
Circular economy	275	100
Environment	180	65
Economy	128	47
4R principles	127	46
Waste	76	28
Materials	74	27
Energy	57	21
System	54	20
Products	53	19
Use	52	19
Industrial	52	19
Value	41	15
Material	41	15
Production	40	15
Development	37	13

5 Discussion

In recent times, environmental degradation has emerged as a central area of academic research. CE has been recognized as a recurring positive growth cycle that sustains and improves natural capital, optimizes resource allocation, and minimizes system risks through a combination of policies and tools, while considering environmental boundaries. This closed-loop system can operate efficiently at any scale, by emphasizing effective planning of operations and resource utilization to optimize flows and maintain physical and technical flows.

Fig. 7 Basic dimensions related to the structural variable "Circular Economy"

Table 5 Frequency scores (using Bayesian statistics) for the structural variable "Circular Economy"

Term	Score
Circular economy	10.06
Waste	8.06
Economic	8.02
Materials	7.85
Resource	7.8
System	7.51
Recycling	7.48
Energy	7.42
Products	7.42
Industrial	7.42
Economy	7.39
Resources	7.39
Use	7.29
Reuse	7.26
Material	7.09
Environmental	7.05
Production	7.02
Value	7.02
Development	6.94

Since 2014, the circular strategy has emerged as a crucial factor in achieving sustainability. New ideas and principles, such as the sharing economy and the exploitation of natural capital through cooperative social stakeholders, have sparked a renewed focus on lifecycle thinking. Thematic and content analysis applied using the co-occurrence approach, indicate that "environment," "economy," "waste," and "recycling" are among the most significant terms in CE descriptions. Institutionalizing additional incentives for waste management and recycling systems is essential to accelerate the circular transition. However, recycling and waste management patterns depend largely on each country's educational system. Reinforcing and enhancing knowledge-sharing through joint partnerships is necessary to promote CE development.

Based on the results of the thematic and content analysis, it is evident that CE policies are a suitable tool for addressing the trade-offs between economic pressures and the need to conserve, renew, and restore ecosystems (Baxter et al. 2017). It is based on use value rather than exchange value (Dajian 2008). CE creates a win–win situation where the "economy" and "environment" share mutual benefits (Geng and Doberstein 2008). The CE approach may vary from country to country, but reflects a growing global concern regarding industrial production and pollution, with a focus on the hierarchy of waste management and its spatial implications. In this context, European policies on CE are mainly defined by environmental and economic conditions, with a focus on enhancing competitiveness by improving resource efficiency. However, compared to China (Fan and Fang 2020) the European concept of CE is characterized by a narrower environmental perspective. It tends to concentrate on "waste" and "resource" issues (Castellani et al. 2015), while largely ignoring problems related to pollution and spatial hierarchy. It is therefore important to note that just as the market is indivisible, nature is also indivisible. As a result, it is only through acknowledging this fundamental assumption and implementing effective social and political actions that economic units can internalize the long-term social and environmental costs of their activities.

The findings of this analysis reveal the prominent position of the concepts of "waste" and "recycling" in the CE descriptions. CE is primarily approached through the lens of "recycling" and "waste" reduction, achieved by implementing long-lasting design and adopting the "4R principles" (Geissdoerfer et al. 2017). The importance of "waste" recovery is underscored, as it can be repurposed as a valuable resource by other organisms (Zhu et al. 2010). When considering the optimal product life cycle within a CE framework, the value of longevity, renewability, and dematerialization is emphasized (Bakker et al. 2014). There is also recognition of the necessity to "deliver capability rather than ownership" to fulfill users' needs without requiring physical product ownership (Bocken et al. 2016).

The subject tags highlighted as most relevant to the economic dimension of CE are the concepts of "growth", "economic development", "industrial economy", and "cost". Regarding the environmental dimension, the analysis emphasizes the significance of "waste", "efficiency", "energy", and "cleaner production" (RQ_1). It is worth noting that the over-exploitation of natural capital is strongly linked to the linear industrial economic structure. The excessive waste generated poses a significant threat to modern economies and societies due to the high costs associated with environmental and waste management. To effectively incorporate CE thinking and make it useful to economic actors, it is of paramount importance to encourage the adoption of environmentally friendly behaviors that promote "recycling" and "waste management" activities. As such, CE descriptions place significant emphasis on concepts such as "environment", "economy", "waste", "4R principles", "materials", and "energy" (RQ_2). However, the rebound effects related to material savings are not necessarily associated with a lower ecological footprint (Birat 2015). Ample attention is given to "waste management", "resource scarcity" and "recycling" activities as the optimum strategies that can foster EU's circular transition *(RQ_3)*. At the same time, the attainment of CE targets necessitates recognizing the significant importance of promoting and strengthening "recycling" initiatives. Various forms of resource "reuse" and "recycling" actions occur when resources are integrated into a circular flow rather than being utilized in a degraded state (Chertow and Ehrenfeld 2012). Increased emphasis is placed on "recycling" due to its potential for increasing the availability of cost-effective materials while also driving consumer demand for disposable products (Zink and Geyer 2017). "Recycling" plays a crucial role in the development of eco-systemic and self-sustaining capabilities (Zhu et al. 2010) and serves as a primary driver of the ecological economy (Zhijun and Nailing 2007). Consequently, the significance of adopting a "recycling" mindset to achieve CE targets is underscored (Xin et al. 2014), along with the role of CE in advancing resource "recycling" systems (Fang et al. 2007). While a healthy "economy" is a significant driving force in achieving higher levels of prosperity, it is equally crucial to prioritize the promotion of environmental literacy. Modern societies tend to consume an increasing amount of "resources" and generate more "waste" due to their consumption of larger quantities of raw "materials". CE is based on the restructuring of "material flows" where there is a bidirectional relationship between resources, products, and "waste" (Yong 2007). The feedback "material" process of primary resource to renewed resource is a crucial determinant for achieving the goal of minimum "waste" in the production process (Zhijun and Nailing 2007). Therefore, adopting the CE principles and engaging in further "environment"-oriented actions, such as "waste management" and "recycling" activities, is of immense importance (RQ_4).

However, the key CE definitions lack consideration for core, broader environmental and economic concepts, stressing the need for researchers to update the CE definitions. Regarding environmental considerations, CE definitions should address the reduction of greenhouse gas emissions and contribute to efforts aimed at mitigating climate change. The integration of ecosystem preservation and restoration, as well as biodiversity conservation, should be central to CE definitions. CE definitions should also prioritize the minimization of pollution and the protection of water and air quality, as well as address human health and well-being concerns. This can be achieved by emphasizing the need to minimize exposure to hazardous materials and promoting sustainable consumption patterns. In terms of economic aspects, establishing resilient economies that are less vulnerable to price fluctuations should also be considered.

6 Concluding remarks, policy implications and future trends

This study underscores the significance of raising environmental awareness regarding waste elimination and recycling to meet the EU targets and bridge the gaps between diverse theoretical starting points that complicate target delimitation. A more comprehensive framework for examining CE descriptions is proposed, which identifies linkages and relationships between the key concepts discussed in CE descriptions. Using a co-occurrence approach, the study analyzes the conceptual content of CE definitions for the first time using Leximancer software. The results indicate that CE definitions give considerable attention to "waste management", "resource scarcity", and "recycling" activities, emphasizing the interplay of environmental degradation with economic growth. The analysis presented in this study has significant implications for waste management and recycling initiatives aligned with the requirements of the "Roadmap for a Resource-Efficient Europe," the European Green Deal, and EU legislative acts. Recycling rates continue to deviate significantly from the targets set by Directive 2018/851, which aims to achieve a 55% recycling rate by 2025, while waste streams continue to exhibit significant fluctuations across EU countries. To meet these targets, recycling and waste management policies must be implemented in a coordinated manner. However, there is a growing lack of understanding regarding the relationship between adopting waste management and recycling activities and EU legislative acts, given the socio-political and economic challenges present.

Regarding the environmental concerns, CE is typically viewed through the lens of waste management, emphasizing the need to reduce unnecessary demand in addition to promoting efficient resource and product usage. As modern societies consume greater quantities of raw materials, they generate increasingly more waste. To address this issue, it is imperative to implement long-lasting designs and adopt the 4R principles, which aim to reduce, reuse, recycle, and recover materials in a sustainable manner. As for the economic concerns, the generation of excessive waste poses a significant threat to modern economies, given the high costs of environmental and waste management. CE represents a strategic approach that decouples resource consumption from economic growth (Wu et al. 2022) and fosters economic development through the integration of various methods for generating value. By reorganizing the existing linear industrial economy, CE offers a means of transitioning towards a circular economy that promotes material savings. While a healthy economy is crucial for achieving higher levels of prosperity, transforming the current predominantly linear system of production and consumption into a circular one is equally essential. Considering the social concerns, institutionalizing additional incentives for waste management and recycling systems and adopting a capability-based approach to satisfy users' needs without requiring physical product ownership, is of great importance. Recycling and waste management patterns largely depend on each country's educational system. As education levels rise, so too does environmental awareness, and the percentage of the population willing to engage in recycling and waste management increases. Given that circular actions often begin with a bottom-up approach that starts with families, schools, and society, investing in human capital through educational programs is necessary. To promote CE development, it is essential to reinforce and enhance knowledge-sharing through joint partnerships.

The study's findings suggest the need for further research, including empirical investigations into the EU's circular transition, estimating the influence of economic, demographic, and social factors. The present research was based on the existing literature available at the time of the study's preparation. It is essential to acknowledge that the field of CE is undergoing rapid evolution, and future definitions should incorporate updated data, employing forthcoming papers published in the field of circular economy, to capture the complex interplay between CE, climate change, and biodiversity. Future research should also focus on investigating the failure factors of the circular transition from the consumer perspective, which scholars, theorists, academics, and practitioners can explore in greater depth.

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Declarations

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