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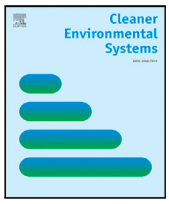

Circular economy, circularity, and sustainability: A systematic review and conceptual framework

Anteneh D. Sewenet [a,*], Youssef Boulaksil [b], Paola Pisano [a]

[a] Department of Economics and Statistics, University of Torino, Italy
[b] College of Business and Economics, United Arab Emirates University, United Arab Emirates

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ABSTRACT

Circular economy (CE), circularity, and sustainability are conceptually distinct yet intrinsically interconnected frameworks that collectively offer transformative potential for addressing global environmental, economic, and social challenges. While each has received substantial scholarly attention, their integrative relationships and cumulative implications remain under-theorized and operationalized. In particular, the link between circularity (the extent to which materials and products circulate within closed loops) and broader sustainability outcomes lacks systematic examination. This study presents a systematic literature review of 151 peer-reviewed articles retrieved from the Scopus and Web of Science databases following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) protocol. Through a critical synthesis and thematic analysis, this review evaluates foundational conceptual constructs, emergent research themes, and enduring conceptual and methodological gaps within the CE–circularity–sustainability nexus. In response, this review proposes a conceptual framework that elucidates the dynamic interlinkages among these concepts, thereby providing a structured pathway to guide interdisciplinary research, policy development, and strategic practice towards integrated and systemic sustainable development.

1. Introduction

The concepts of circular economy (CE), circularity, and sustainability have become pivotal frameworks for addressing the systemic environmental, economic, and social challenges posed by linear production and consumption models (Ghisellini et al., 2016a; MacArthur et al., 2013).

Circular economy represents a systemic economic paradigm that seeks to redesign production and consumption systems to decouple economic activity from finite resource extraction and environmental degradation through restorative and regenerative strategies (Korhonen et al., 2018; Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2015). Within this paradigm, circularity denotes the operational and measurable expression of circular economy principles, referring to the extent to which materials, products, and resources are retained within economic loops through practices such as reuse, remanufacturing, recycling, and sharing. Circularity therefore functions as a performance-oriented concept that quantifies how effectively resource flows are closed, slowed, or narrowed over time, translating circular economy ambitions into assessable outcomes (Kirchherr et al., 2017; Geissdoerfer et al., 2017; Scheepens et al., 2016; Xavier et al., 2021). While circular economy provides the strategic and systemic framework, and circularity captures its degree of implementation, sustainability constitutes the overarching normative objective. Sustainability extends beyond material and resource efficiency to encompass long-term environmental integrity, economic viability, and social well-being, emphasizing inter generational equity and balanced development (Brundtland, 1987). Accordingly, circular economy and circularity are best understood not as ends in themselves, but as instrumental pathways that contribute to sustainability outcomes when aligned with broader social and environmental goals (Korhonen et al., 2018; Purushothaman et al., 2025).

Despite the proliferation of CE-related studies, a critical synthesis of how circularity contributes to sustainability, particularly when assessed through integrated frameworks are still limited. While the environmental and economic impacts of circular practices have been extensively examined, the social dimension remains underrepresented, often treated as a peripheral consideration rather than a core evaluative pillar (Liu, 2024).

Moreover, the conceptual alignment between CE and sustainability is frequently assumed rather than empirically substantiated, leading to gaps in theory and practice. Scholars such as Geissdoerfer et al.

* Corresponding author.
E-mail address: antenehdagnachew.sewenet@unito.it (A.D. Sewenet).

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(2017) and Kirchherr et al. (2017) argue that while CE and circularity have contributed significantly to environmental sustainability goals, the socio-economic impacts and potential trade-offs between the three sustainability pillars (environmental, economic, and social) are rarely addressed in a holistic manner.

In essence, not all circular initiatives are inherently sustainable; some may yield environmental benefits while exacerbating economic disparities or social injustices (Zink and Geyer, 2017). For example, a recycling program may successfully reduce landfill waste; however, if it relies on energy-intensive technologies or exploits vulnerable labor in informal sectors, it risks undermining other key sustainability objectives (Schröder et al., 2019; Gregson et al., 2015). This underscores the need for more integrated evaluation frameworks that can assess circular strategies from a comprehensive sustainability perspectives.

Furthermore, the conceptual inter linkages among these concepts remain insufficiently articulated, despite their shared objective of fostering long-term systemic transformation towards a sustainable future (Barbosa et al., 2014). Existing research often treats these constructs in isolation, obscuring their inter dependencies and limiting a comprehensive understanding of their collective impact (Korhonen et al., 2018). Therefore, Understanding the conditions under which CE practices contribute holistically to sustainability is essential.

Recent empirical studies have begun exploring this nexus. For instance, Walker et al. (2022) found that organizations commonly perceive CE as a strategic mechanism for achieving sustainable development (particularly in environmental dimensions) while expressing uncertainty about its influence on social and economic outcomes. This highlights the need for a more nuanced articulation of how circularity, defined as the extent of loop-closing in an economy. Which can be quantitatively and qualitatively linked to sustainability indicators, such as carbon footprint reduction, operational cost savings, job creation, and social equity. Conversely, Corona et al. (2019) argue that circularity constitutes a core process-oriented mechanism supporting sustainability's broader goals, which is rooted in the principle of inter generational equity. While circularity encompasses closed-loop practices embedded in products, processes, and business models (Ghisellini et al., 2016a), sustainability reflects the systemic impacts and outcomes of these practices, particularly with respect to minimizing environmental degradation and enhancing social resilience (Robinson, 2004). This paradigm shift has attracted increasing academic and policy attention, driven by escalating environmental crises and the imperative for sustainable production and consumption systems (Ghormare et al., 2024). Morales et al. (2021) noted that scholarly publications on CE and sustainability surged from merely five in 2016 to over one hundred by 2020, reflecting the field's rapid maturation.

However, this expanding body of literature continues to exhibit conceptual ambiguity and methodological inconsistency in capturing how circularity contributes to broader sustainability outcomes (Ghormare et al., 2024). Furthermore, most studies remain predominantly focused on environmental and economic dimensions, often neglecting comprehensive analyses of social sustainability (Kirchherr et al., 2017; Geissdoerfer et al., 2017). As Superti et al. (2021) observe, the theoretical and practical relationships among CE, circularity, and sustainability are still not fully delineated. Scholarly debate persists: while some posit that CE constitutes a vital pathway within the broader sustainability paradigm, others caution that CE initiatives, if not carefully designed and implemented, may deliver limited or even adverse socio-economic outcomes (Walker et al., 2022). While prior reviews have examined circular economy and sustainability either separately or in a dyadic relationship, few have undertaken a triangulated investigation encompassing circular economy, circularity, and sustainability as distinct yet interrelated constructs. This study contributes a novel perspective by systematically synthesizing the literature on this triadic nexus and developing an integrative conceptual framework. In doing so, it provides a foundational platform for interdisiplinary theory building and strategy formulation that bridges conceptual fragmentation in the field.

Given these nuances, a systematic literature review is warranted to synthesize recent knowledge on how the three constructs are interconnected with sustainability in theory and in practice. Therefore, a comprehensive understanding of their interconnections and implications is crucial for designing effective social, economic, and environmental strategies and policies. To address this gap, this systematic literature review investigates the relationship between these concepts by synthesizing empirical and conceptual literature.

This study employs a mixed method review design, combining scientometric techniques with qualitative content analysis to reveal both structural patterns and thematic depth, distinguishing it from earlier reviews that relied on singular methods. This review explores how these concepts are defined, operationalized, and assessed in the literature with the objective of developing a robust conceptual framework that integrates these domains and answers the following specific questions:

- RQ1: How are the concepts of circular economy, circularity, and sustainability defined and interrelated in the literature?
- RQ2: What methodological frameworks are employed to assess their environmental, economic, and social impacts?
- RQ3: What are the critical gaps and opportunities in current research for advancing integrated circular-sustainability transitions?

These research questions were developed to address persistent conceptual and methodological gaps in the literature, where circular economy, circularity, and sustainability are often examined in isolation or without clear theoretical integration. These questions aim to clarify their interrelationships (RQ1), assess the methodological approaches used to evaluate their multidimensional impacts (RQ2), and identify research gaps and opportunities for advancing integrated circular-sustainability transitions (RQ3). Collectively, they strengthen both the theoretical foundation and the practical relevance of this study by linking circular strategies to sustainability objectives and global policy agendas such as the United Nations Sustainable Development Goals.

2. Methods

This systematic literature review followed the PRISMA 2020 guidelines (Page et al., 2021). The review period was defined from January 2017 to May 12, 2025. The starting year of 2017 was selected because it marks a conceptual turning point in circular economy scholarship, characterized by the publication of seminal syntheses that systematically clarified definitions, theoretical boundaries, and the relationship between circular economy, circularity, and sustainability. Influential studies published during this period consolidated the field, shifted discourse from fragmented interpretations towards a coherent sustainability-oriented framework, and established a robust conceptual baseline for subsequent empirical and methodological research (Kirchherr et al., 2017; Geissdoerfer et al., 2017; Korhonen et al., 2018).

The search strategy was designed to identify high-quality, peer-reviewed journal articles that explicitly addressed the intersection of circular economy, circularity, and sustainability. In both Scopus and WoS, searches were conducted across article titles, abstracts, and author keywords. The core search string combined the terms "circular economy", "circularity", and "sustainability" using Boolean operators to ensure conceptual co-occurrence. To enhance the relevance and rigor of the retrieved literature, several filters were applied consistently across both databases. These included restriction to journal articles only, exclusion of conference proceedings and non-peer-reviewed sources, limitation to publications written in English, and inclusion of only final, published records.

In Scopus, the search was further refined using database-specific filters to limit the source type to journals and the publication stage to final versions. An equivalent filtering logic was applied in WoS by restricting document types to articles and reviews and excluding

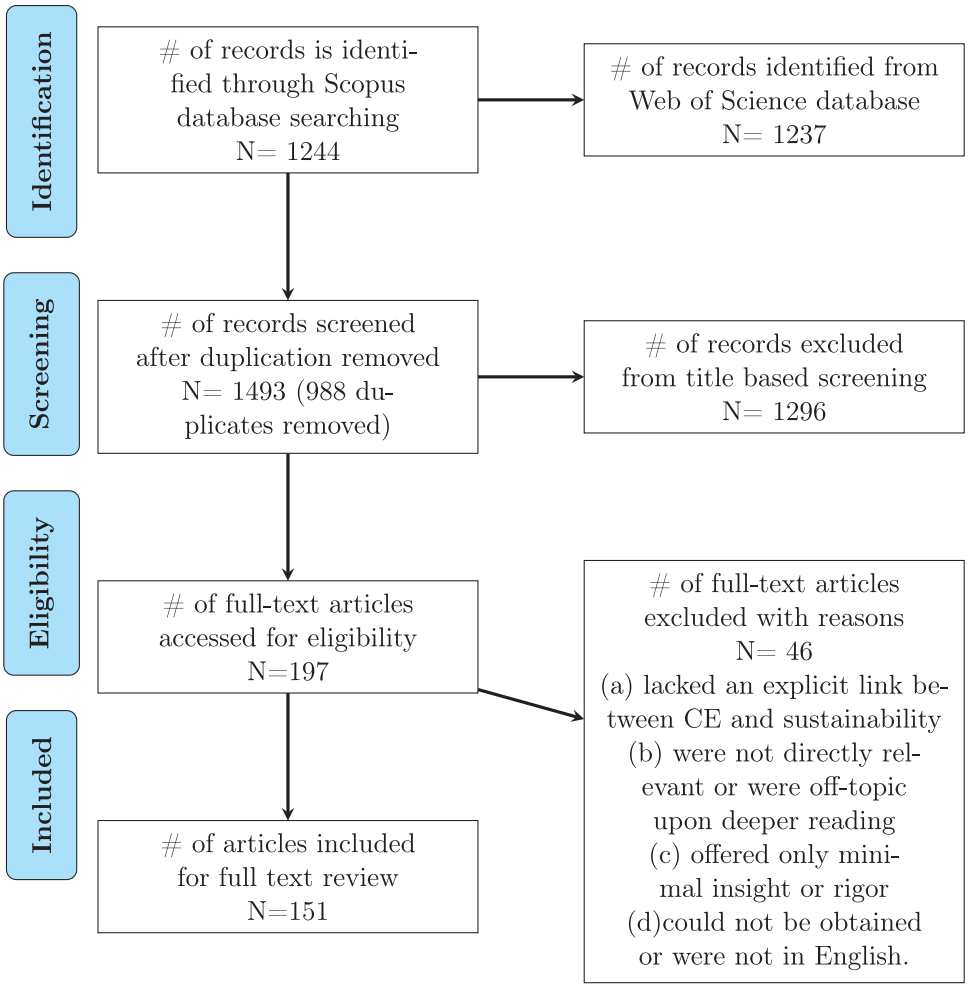

Fig. 1. PRISMA flowchart for the systematic review.

early access records where applicable. This harmonized search and filtering approach ensured methodological consistency, transparency, and replicability across databases. The database search returned a total of 2481 articles (Scopus = 1244 and WOS = 1237). Given the continued growth of publications, our search yielded a larger initial dataset.

After an initial total of 2481 records was retrieved from the selected databases, A total of 988 duplicate entries were identified and removed manually using Microsoft Excel, resulting in 1493 unique records for screening. The screening and eligibility assessment were performed independently by two researchers to ensure consistency and reduce potential bias.

We then screened the titles and abstracts to filter out irrelevant items. We excluded articles that did not substantially address both circular economy (or circularity) and sustainability. For example, articles focusing on technical recycling processes without discussing sustainability implications, or conversely, articles on sustainability that only tangentially mentioned circularity were set aside. After this stage, approximately 197 articles remained potentially relevant. We obtained the full texts of these articles and assessed each against the inclusion criteria.

1. The study explicitly examines the relationship or integration between CE (or circular strategies) and sustainability outcomes.
2. It presents original analysis (theoretical, empirical, or review) in a peer-reviewed journal.
3. Sufficient detail is provided to extract insights on frameworks, methods, or findings relating circularity to environmental/economic/social outcomes.

At this stage, we excluded 46 articles for various reasons: (a) lack of an explicit link between CE and sustainability (e.g., focusing only on the engineering aspects of circular processes without addressing sustainability goals), (b) not directly relevant or off-topic upon deeper reading, (c) offering only minimal insight or rigor (e.g., opinion papers or very case-specific articles without generalizable findings), and (d) not obtainable or not in English.

A total of 151 journal articles met all the criteria and were included in the qualitative synthesis (see PRISMA flow diagram (Fig. 1)). We first conducted scientometric mapping using VOSviewer to visualize keyword co-occurrence networks and research trends across 151 articles. From the final corpus of 151 articles, 11 were selected for in-depth qualitative analysis based on a structured multi-criteria screening process that considered citation impact as a proxy for scholarly influence, conceptual relevance to circular economy, circularity, and sustainability, and representativeness across the principal thematic clusters identified in the review, thereby ensuring both analytical rigor and thematic balance. Table 1 summarizes these articles, highlighting their primary focus, key contributions, and specific role in informing the analytical development of the proposed framework.

The subset in Table 1 serves as an analytical foundation for developing our integrative framework. This was followed by an in-depth qualitative content analysis of selected key publications to derive conceptual insights and support framework development. To enhance reliability, we cross-checked the coding and resolved any discrepancies through discussion. Any quantitative results (e.g., measured impacts and statistical relationships) were noted for potential meta-analysis. However, owing to the heterogeneity of study designs and outcomes,

Table 1
Selected key articles from the systematic review.

Author	Year	Focus area	Key findings	Contribution to this study
Geissdoerfer et al. (2017)	2017	CE vs Sustainability	Conceptual analysis reveals overlaps and tensions between CE and sustainability paradigms.	Anchors the theoretical discussion on definitional boundaries and integration challenges.
Kirchherr et al. (2017)	2017	CE Definitions	Identifies 114 CE definitions, revealing divergent interpretations across fields.	Justifies the need for conceptual clarity and coherence in CE discourse.
Blomsma and Brennan (2017)	2017	Circularity	Critiques loop closing metaphors and proposes circularity as a continuum.	informs the analytical framing of circularity beyond material flow metaphors.
Murray et al. (2017)	2017	CE Foundations	Explores theoretical roots and tensions between CE and sustainable development.	Provides a foundation for the conceptual separation of CE and sustainability.
Prieto-Sandoval et al. (2018)	2018	CE Core Elements	Identifies four CE dimensions: design, product, process, and business model.	Supports the dimensional deconstruction of CE in the framework.
Haupt and Zschokke (2017)	2017	Circularity Metrics	Reviews material flow indicators and challenges in quantification.	Contributes to the operationalization of circularity indicators.
Korhonen et al. (2018)	2018	CE Critique	Examines theoretical inconsistencies and implementation issues in CE.	Frames critical limitations of CE discourse in the discussion section.
Elia et al. (2017)	2017	CE and SDGs	Maps CE strategies to SDGs, revealing synergy potential.	Supports positioning CE within the sustainability transition lens.
Sauvé et al. (2016)	2016	Sustainability Theory	Reviews diverse interpretations of sustainability.	Informs a flexible conceptual treatment of sustainability within the framework.
Geng et al. (2012)	2012	CE Policy	Examines CE implementation in China and links to industrial symbiosis.	Provides empirical grounding and policy relevance for the CE pillar.
Bocken et al. (2016)	2016	Business Models	Proposes business model archetypes for CE.	Informs the strategic-level integration of CE in the conceptual model.

a formal meta-analysis could not be conducted; instead, we integrated quantitative evidence narratively where appropriate. The next sections present the review results, including summary tables of the studies, thematic analyses, and visual mapping of the research themes.

The final sample encompassed a mix of theoretical papers, empirical case studies, and literature reviews or meta-analyses. For each included study, we extracted key attributes: bibliographic information (authors, year, journal), study focus and context, methodology, and main findings. We then employed a thematic coding approach to group the findings into major themes. These studies represent the core literature on CE–circularity–sustainability conceptual interconnections. We prioritized articles in reputable, high-impact journals (e.g., Journal of Cleaner Production, Resources, Conservation & Recycling, Business Strategy and the Environment, Ecological Economics, International Journal of Production Research, etc.) to ensure academic rigor, as well as recent review papers to capture the overarching insights.

3. Result and discussion

This review builds upon and extends earlier scholarly efforts that have examined the intersections of the circular economy and sustainability, including works focused on definitional clarity (Geissdoerfer et al., 2017; Kirchherr et al., 2017), typological classifications (Reike et al., 2018), and implementation barriers (Korhonen et al., 2018; Merli et al., 2018). However, many of these studies have treated circularity, the circular economy, and sustainability as conceptually adjacent but analytically fragmented domains. By systematically synthesizing more recent literature, this study advances the discourse by offering a comprehensive integration of descriptive and thematic insights. The descriptive analysis traced the temporal evolution, research orientations, and conceptual interconnections within the literature, supported by keyword co-occurrence mapping with VOSviewer. Thematic analysis further identified dominant patterns, tensions, and research gaps. Collectively, these analyses culminated in the development of a conceptual framework that positions circularity as a bridging construct linking circular economy practices to sustainability outcomes. This framework provides researchers and practitioners with a clear, theory informed foundation to guide future research, strategic planning, and practical implementation.

3.1. Descriptive analysis of reviewed papers

3.1.1. Papers reviewed by years of publication

Based on studies published since 2017, we were able to access the most current information on the topic and analyze the most current trends and developments in the field, which is essential for understanding the potential of this emerging field. As shown in Fig. 2, a noticeable increase in scholarly output was observed. The number of publications addressing the nexus of circular economy, circularity, and sustainability has grown steadily since 2017, reflecting the rapid expansion of scholarly interest in this field. The annual output rose from fewer than ten papers per year before 2020 to more than forty papers in 2023 and forty-five in 2024, representing nearly a nine-fold increase. The most pronounced growth occurred between 2022 and 2024, coinciding with a global surge in circular economy policy initiatives and sustainability reporting frameworks. The slight decline observed in 2025 is attributed to the partial indexing of publications for the current year. Rather than a mere increase in quantity, this trend indicates a shift in scholarly focus from conceptual foundations to integrated assessment frameworks and policy-oriented solutions. Notably, earlier studies predominantly addressed environmental dimensions, whereas more recent contributions incorporate life cycle thinking and cross-disciplinary approaches. Quantitatively, publications on circular economy, circularity, and sustainability increased from only 1 paper in 2017 to 45 in 2024, representing an average annual growth rate of approximately 40%. More than 70% of all reviewed papers were published between 2022 and 2024, indicating a sharp acceleration in research activity over the last three years.

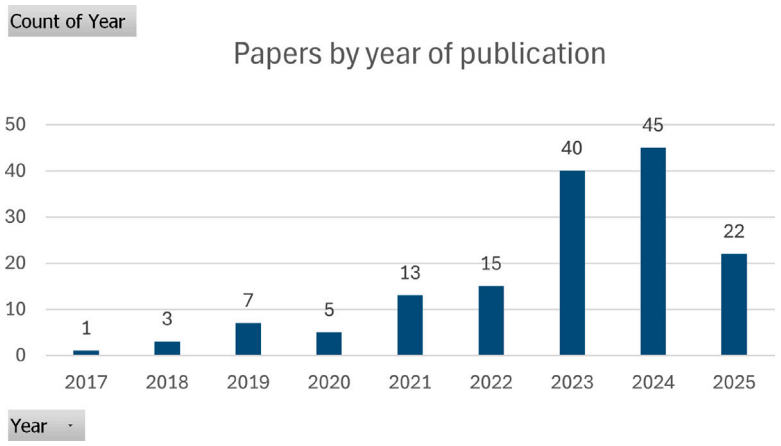

Fig. 2. Papers reviewed by years of publication.

Table 2
Report of reviewed articles by focus area of the study.

Study focus	Number of papers
Theoretical Foundations: Linking CE and Sustainability	43
Circular Strategies and Life-Cycle Approaches	37
Business Models and Organizational Transition	29
Policy, Governance, and Stakeholder Engagement	16
Sustainability Outcomes and Impact Assessment	26

3.1.2. Papers reviewed by focus area

Through inductive coding of the 151 selected studies, we identified the primary focus area of the studies, which we grouped into five major themes in the CE–circularity–sustainability literature. These themes represent clusters of related ideas, research questions, and findings that have been the focus of recent scholarship, as presented in Table 2.

In Section 3.3, each theme is discussed under thematic analysis along with representative insights from the literature. These themes often overlap and interconnect; indeed, one finding of this review is the increasing integration of previously separate discourses (technical, managerial, policy, etc.) into a more holistic conversation on the circular economy and sustainability. Fig. 3 provides a visual "thematic map" of the knowledge domain, illustrating how clusters of keywords/topics from the literature are related.

This conceptual co-occurrence map, generated through VOSviewer using author keywords (see Fig. 3), reveals the structural backbone of scholarly discourse on circular economy (CE), circularity, and sustainability. The visualization identified four tightly connected thematic clusters: a methodological cluster (red) emphasizing life cycle assessment (LCA), circularity assessment, and metrics; an environmental systems cluster (green) focused on industrial ecology, waste management, and environmental sustainability; a business-oriented cluster (blue) integrating circularity and circular business models; and a normative policy cluster (yellow) anchored in sustainable development.

The central node, "circular economy", emerged as the intellectual hub, underscoring its conceptual centrality and integrative capacity. Its strong interconnections with "circularity", "sustainability", and "life cycle assessment" support the argument that the CE increasingly serves as a framework for operationalizing sustainability principles. As shown in Fig. 3, the bibliometric co-occurrence map illustrates the main conceptual clusters emerging from the reviewed literature. The node size reflects the frequency of keyword occurrence, whereas the thickness of the connecting lines represents the strength of the co-occurrence links between terms. Four major clusters are visible: (i) the green cluster centered on "circular economy", linked to "waste management", "industrial ecology", and "environmental sustainability"; (ii) the red cluster focusing on "circularity assessment", "life-cycle assessment", and "circularity metrics", indicating methodological evaluation themes; (iii) the blue cluster associating "circular business models" with "circularity", representing managerial and strategic perspectives; and (iv) the yellow cluster connecting "sustainable development" with policy-oriented discussions. Collectively, these clusters reveal a multidimensional structure of research connecting the operational, methodological, and strategic aspects of circularity and sustainability.

The map also reveals a mature field with high thematic cohesion, indicating that the foundational pillars, namely measurement, systems thinking, and business models, are now well established. For this review, these findings provide a rigorous basis for organizing the literature and affirm the need to build a conceptual synthesis around these clusters. They also align with the first and second research questions by revealing the theoretical frameworks (e.g., LCA, industrial ecology) and empirical domains (e.g., waste, circularity metrics) that dominate this field.

Fig. 4 expands the co-occurrence network to include broader thematic relationships. Node size denotes keyword frequency, while proximity and link thickness indicate the degree of conceptual association. "Circular economy" and "sustainability" appear as the dominant and most interconnected nodes, bridging diverse themes such as "life-cycle assessment", "policy", "industrial ecology", and "business models". The dispersion of smaller nodes (e.g., "automation", "digitalization", "stakeholder engagement") suggests emerging subfields integrating technological and social dimensions into circular economy research. The structure highlights the interdisciplinary evolution of the field from core environmental and industrial ecology foundations towards more systemic sustainability transitions.

This VOSviewer co-occurrence map, based on terms from titles and abstracts (see Fig. 4), captures the broader thematic landscape of CE, circularity, and sustainability research. While the central terms "circular economy", "circularity", and "sustainability" again form the network's core, the surrounding nodes provide deeper insights into application domains, emerging methods and thematic fragmentation. Key peripheral clusters include sector-specific applications (e.g., "agri-food sector", "automotive industry", "recycling"); managerial and governance themes (e.g., "ESG", "business case", "stakeholder engagement"); technological and design considerations (e.g., "product design", "digital transformation", "adaptive reuse"); and methodological refinements (e.g., "9Rs", "data envelopment analysis", "systems thinking", "frame analysis"). The proximity of nodes indicates co-occurrence frequency, whereas a larger node size signifies higher keyword prominence. This visualization reveals the centrality of assessment methodologies and governance in the current CE discourse while underlining the peripheral positioning of social sustainability-related terms, a

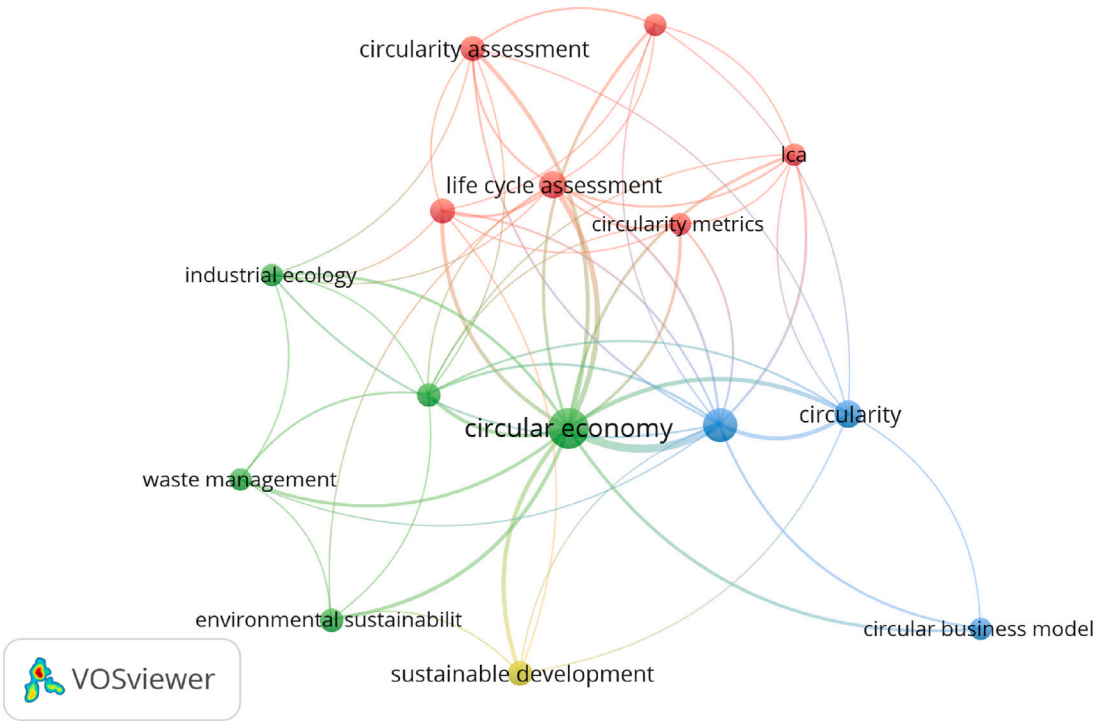

Fig. 3. Bibliometric co-occurrence map of key terms.

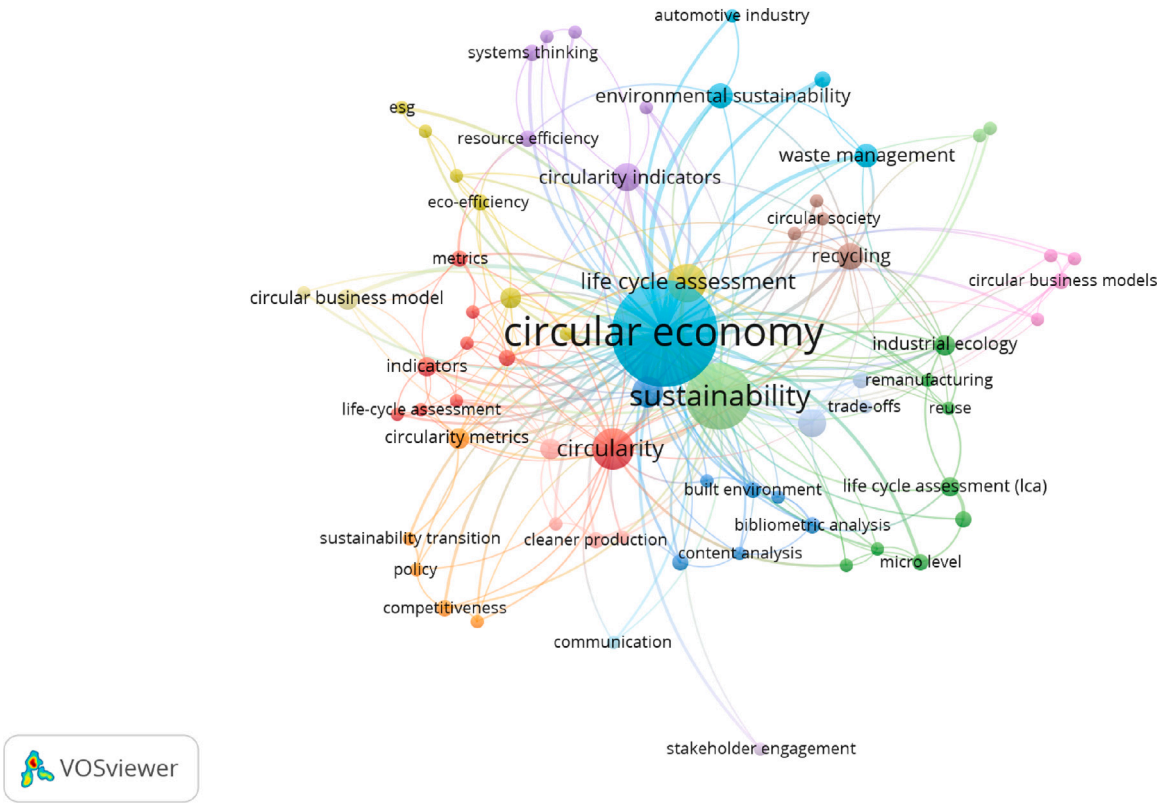

Fig. 4. Bibliometric co-occurrence map, based on terms from titles and abstracts.

notable gap warranting further inquiry.

The thematic clusters identified in Figs. 3 and 4 directly inform the structure of the proposed integrative framework. The methodological cluster translates into the framework's assessment component, operationalizing circularity and sustainability through life cycle-based metrics and evaluation tools. The environmental systems cluster underpins the system-level dimension, emphasizing material flows, waste management, and industrial ecology principles. The business-oriented cluster informs the organizational and strategic component, capturing circular business models and managerial decision-making, while the

normative policy cluster shapes the institutional dimension by embedding circular economy practices within sustainable development and governance contexts. Emerging themes highlighted in Fig. 4, including technology, governance, and stakeholder engagement, are incorporated as cross-cutting enablers that link and reinforce these core components, resulting in a coherent and multidimensional framework grounded in the bibliometric structure of the literature.

3.2. Key findings in the literature

The systematic synthesis of recent literature reveals significant advancements in the conceptualization and operationalization of circular economy (CE) principles across diverse sectoral contexts. At the foundational level, scholars increasingly frame CE and circularity as nested constructs within the broader paradigm of sustainability, emphasizing their instrumental role in fostering regenerative, resilient, and inclusive systems (Geissdoerfer et al., 2017; Merli et al., 2018). However, despite the growing interest, the theoretical and empirical integration of CE, circularity, and sustainability remains fragmented. Many studies treat these concepts in isolation, lacking a systematic articulation of their relational dynamics and failing to apply integrated conceptual lenses, which constrains both theoretical clarity and practical implementation (Korhonen et al., 2018; Geissdoerfer et al., 2017).

The literature underscores the importance of strategic planning, institutional coordination, and stakeholder engagement as critical enablers of CE adoption (Arranz and Arroyabe, 2023). Formal planning instruments, combined with participatory mechanisms, are repeatedly emphasized as necessary for embedding CE practices into organizational and policy routines (Ferrari et al., 2025). Complementing these insights, a growing body of work highlights the value of robust evaluation tools, particularly Life Cycle Sustainability Assessment (LCSA), to assess trade-offs and synergies across environmental, economic, and social dimensions (Luthin et al., 2024; Rigamonti and Mancini, 2021). Innovative governance mechanisms have also gained prominence, especially those integrating Environmental, Social, and Governance (ESG) criteria and nature-inspired design principles, which are proposed as pathways to enhance inclusivity and ecological adaptability in CE transitions (Wamane, 2025; Mhlanga et al., 2022).

Sector-specific findings reveal nuanced implementation challenges. For instance, service-oriented industries face operational complexities that are insufficiently addressed by conventional CE models, necessitating the development of tailored circular strategies (Karpen et al., 2023). Similarly, in developing and emerging economies, sustainable waste management systems often grounded in frameworks such as ADKAR highlight the need for multilevel coordination and inclusive stakeholder participation to navigate the shift from linear to circular models (Sawalkar et al., 2025; Nagamalini and Wesley, 2025). These observations collectively call for context-sensitive, integrative strategies supported by comprehensive impact evaluation frameworks. Table 3 summarizes the key thematic areas and representative findings identified from the reviewed literature.

From a theoretical standpoint, CE scholarship has drawn upon diverse frameworks, including the Triple Bottom Line (TBL), Systems Theory, Industrial Ecology (IE), and the Resource-Based View (RBV). Despite their relevance, their application remains predominantly disjointed, limiting their ability to generate cohesive insights across disciplinary boundaries (Ghisellini et al., 2016a; Murray et al., 2017). Empirical studies have evolved from descriptive analyses of circular practices, such as reuse, remanufacturing, industrial symbiosis, and product life extension, to more sophisticated evaluations using life cycle-based methodologies, such as LCA and LCSA. However, these assessments often fall short of capturing rebound effects, systemic feedback loops, and socio-environmental trade-offs (Bocken et al., 2019).

The discourse on circular business model innovation is gaining momentum, with models such as product-as-a-service (PaaS), sharing platforms, and closed-loop supply chains positioned as key mechanisms to align profitability with sustainability outcomes (Franco, 2017; Lüdeke-Freund et al., 2019). However, the successful adoption of these models depends on organizational transformation, including leadership commitment, the cultivation of dynamic capabilities, and fostering an adaptive, sustainability-oriented culture (Massaro et al., 2021). Digital technologies, particularly the Internet of Things (IoT), blockchain, Building Information Modeling (BIM), and digital twins, are increasingly recognized as critical enablers for enhancing operational transparency, traceability, and data-driven decision-making, although their uptake remains uneven across sectors and regions (Qureshi, 2022; Chamorro-Premuzic, 2021).

Governance and regulatory instruments play pivotal roles in accelerating CE implementation. Regulatory levers, such as Extended Producer Responsibility (EPR), right-to-repair legislation, and green public procurement, are widely cited as effective mechanisms for incentivizing circular practices (Arranz and Arroyabe, 2023). However, regulatory fragmentation, limited inclusion of marginalized communities, and insufficient integration of social justice concerns continue to hinder the systemic uptake of CE frameworks (Kanda et al., 2021). Environmental benefits, such as emissions reductions and improved resource efficiency, are increasingly documented, while economic outcomes, including innovation and cost savings, are receiving growing empirical attention. However, the social dimension remains significantly underrepresented, underscoring the urgent need to integrate Social Life Cycle Assessment (S-LCA), Multi-Criteria Decision Analysis (MCDA), and other holistic evaluation tools into mainstream CE assessments (Rigamonti and Mancini, 2021; Millar et al., 2019).

The literature also calls for clearer conceptual boundaries and more unified perspectives on the CE, circularity, and sustainability. Most existing research continues to prioritize environmental and economic impacts, with social sustainability often treated superficially or omitted (Kirchherr et al., 2017; Geissdoerfer et al., 2017). Persistent research gaps include definitional ambiguities, a lack of conceptual coherence, underrepresentation of empirical studies from the Global South, and insufficient standardization of performance metrics (Elia et al., 2017). These challenges highlight the need for interdisciplinary collaboration, enhanced policy alignment, and the development of integrated frameworks that synthesize technological innovation, circular business models, and socio-technical system thinking to effectively support the transition towards sustainable circular futures (Geissdoerfer et al., 2017; Pedersen et al., 2021).

3.3. Thematic analysis

Fig. 3 shows the bibliometric co-occurrence map of key terms in the CE and sustainability literature (created using VOSviewer on the review dataset). Clusters highlight interconnected themes, such as a green cluster for foundational theories and concepts (circular economy principles, organizational change, etc.), a red cluster centered on products, resources, and strategies (life cycle, reuse, resource efficiency), a blue cluster on sustainability and practice (business, innovation, implementation), and a yellow cluster relating to environmental impact and operational aspects. Larger nodes indicate frequently occurring concepts, and link density reflects how often topics co-appear in the same article.

1. Theoretical Foundations: Linking CE and Sustainability

Fundamentally, the CE is conceptualized as a regenerative economic model aimed at minimizing resource inputs, waste, and environmental emissions by closing material loops and maintaining the value of products and resources within the system for as long as possible. Although CE has been lauded for integrating economic activity with ecological principles, its theoretical alignment with the broader goals of sustainability, encompassing environmental, economic, and social dimensions, remains underdeveloped and contested (Geissdoerfer et al., 2017; Kirchherr et al., 2017). For example, an analysis by Kirchherr

Table 3
Summary of key findings in circular economy literature.

Focus area	Key findings	References
Strategic Planning and Stakeholder Engagement	Strategic planning and formal stakeholder engagement mechanisms are critical for effective CE implementation.	Ferrari et al. (2025), Murray et al. (2017), Schröder et al. (2019)
Assessment Methodologies (LCSA)	Robust LCSA frameworks capture multifaceted implications of CE initiatives, including environmental, economic, and social dimensions, revealing opportunities and trade-offs.	Luthin et al. (2024), Rigamonti and Mancini (2021), Corona et al. (2019)
Governance and Regulatory Frameworks	Innovative governance frameworks integrating ESG and biomimicry principles enhance social inclusion and ecological resilience. Multi-level regulatory instruments like EPR, right-to-repair laws, and green procurement accelerate CE but face fragmentation and limited stakeholder engagement.	Arranz and Arroyabe (2023), Kanda et al. (2021), Wamane (2025), Mhlanga et al. (2022), Kirchherr et al. (2017), Schröder et al. (2019)
Sector-Specific Approaches	CE frameworks need customization for sectors such as services, given unique operational challenges.	Karpen et al. (2023), Ghisellini et al. (2016b)
Waste Management in Developing Economies	Sustainable waste management using models like ADKAR emphasizes stakeholder engagement and multi-level strategies, essential for transitioning from linear to circular economies in developing contexts.	Sawalkar et al. (2025), Nagamalini and Wesley (2025), Kumar et al. (2022), Schröder et al. (2019)
Conceptual and Theoretical Clarity	Conceptual clarity is required because CE, circularity, and sustainability concepts often lack systematic integration. Theoretical foundations like TBL, Systems Theory, IE, and RBV exist but are inadequately applied in an integrated manner.	Geissdoerfer et al. (2017), Korhonen et al. (2018), Ghisellini et al. (2016a), Murray et al. (2017)
Circular Strategies and Life-Cycle Evaluations	Empirical studies advanced from descriptive circular strategies (reuse, remanufacturing, and symbiosis) to holistic evaluations using LCA. However, studies still inadequately address rebound effects and complex feedback loops.	Bocken et al. (2019), Ghisellini et al. (2016a), Sassanelli et al. (2019), Korhonen et al. (2018), Zink and Geyer (2017)
Circular Business Model Innovation	Product-as-a-Service (PaaS), sharing economies, and closed-loop supply chains have emerged as key transformative business models aligning incentives with sustainability, though their success heavily depends on organizational capabilities, leadership, and culture change.	Franco (2017), Lüdeke-Freund et al. (2019), Massaro et al. (2021), Tukker and Tischner (2006), Lewandowski (2016), Ranta et al. (2018)
Technological Enablers	Digital technologies (IoT, blockchain, digital twins, BIM) enhance traceability, efficiency, and informed decision making but adoption varies significantly by sector and geography.	Qureshi (2022), Chamorro-Premuzic (2021)
Sustainability Outcomes and Social Dimensions	Environmental outcomes (emissions, resource efficiency) and economic benefits (cost savings, innovation) are increasingly documented, but social sustainability remains underexplored, requiring broader integration of S-LCA and MCDA methods.	Rigamonti and Mancini (2021), Kirchherr et al. (2017), Geissdoerfer et al. (2017), Millar et al. (2019)
Research Gaps and Recommendations	Persistent gaps include definitional ambiguities, limited conceptual coherence, scarce empirical data from emerging economies, and inadequate standardization of measurement indicators. Interdisciplinary collaboration and policy alignment integrating technological, business, and socio-technical approaches are essential for advancing CE.	Elia et al. (2017), Geissdoerfer et al. (2017), Pedersen et al. (2021)

et al. (2017) of 114 CE definitions found that the concept is most frequently described in terms of the "reduce-reuse-recycle" loop, focusing on economic gains and environmental quality, whereas social equity and intergenerational justice are rarely mentioned in most definitions. Similarly, Murray et al. (2017) traced the intellectual roots of CE to industrial ecology, cradle-to-cradle design, and biomimicry, arguing that CE represents a continuation of efforts to reconcile economic growth with environmental limits but cautioned that the neglect of social sustainability poses ethical and practical limitations. Korhonen et al. (2018) further emphasized that CE's potential contributions to sustainability are undermined by unresolved issues such as system boundary definitions, thermodynamic constraints, and rebound effects, which challenge the assumption of net positive outcomes.

Despite this, recent literature increasingly positions CE as an operational subset of sustainability, particularly in its capacity to achieve environmental and economic goals (Geissdoerfer et al., 2020; Merli et al., 2018). CE's alignment with global frameworks such as the United Nations Sustainable Development Goals (SDGs) reinforces its instrumental role, particularly in advancing goals related to responsible consumption, climate action, and innovation (Velenturf and Purnell, 2021). Nonetheless, the broader sustainability paradigm, rooted in the Brundtland Commission's definition and expanded through the triple bottom line (TBL) framework, emphasizes the equal importance of social equity and intergenerational justice dimensions that are only marginally represented in dominant CE narratives (Brundtland, 1987). This conceptual gap has prompted critical engagement with the CE paradigm. Scholars contend that, without explicit attention to social justice, inclusiveness, and ethical governance, CE risks depoliticizing sustainability and perpetuating unsustainable consumption patterns under the guise of green growth (Corvellec et al., 2022; Liu, 2024). In response, emerging discourses call for a transition towards a "just circular economy" or "circular society", wherein social and political dimensions are explicitly embedded within circularity frameworks (Pansera et al., 2021; Calisto Friant et al., 2024).

Furthermore, ecological economists have challenged mainstream CE narratives that implicitly promote "green growth", arguing that such strategies often overlook the necessity of absolute reductions in material and energy throughput, which are central to strong sustainability and degrowth paradigms (Bocken et al., 2019; Schröder et al., 2019). This critique is reinforced by sufficiency oriented approaches, which emphasize moderation and behavioral change over purely technological solutions (Hobson, 2020). In response, recent theoretical

advances have sought to integrate CE with resilience theory, doughnut economics, and socio technical transition frameworks, thereby offering more holistic and normative guidance (Purushothaman et al., 2025).

To advance these debates, scholars emphasize the need for interdisciplinary integration between CE and sustainability theory (Pieroni et al., 2019). This includes rearticulating CE principles to incorporate values such as equity, ecological limits, and long term resilience. Additionally, operationalizing this integration requires robust assessment tools capable of evaluating circular strategies not only in terms of resource efficiency but also their broader impacts on environmental integrity, economic viability, and social inclusion (Elia et al., 2017; Rigamonti and Mancini, 2021).

Finally, realizing the transformative potential of CE depends on enabling conditions such as supportive regulatory frameworks, multi stakeholder governance, and innovative business models that align economic incentives with sustainability outcomes (Lahti et al., 2018; Kumar et al., 2022).

2. Circular Strategies and Life-Cycle Approaches

Central to the circular economy (CE) are the strategic mechanisms that operationalize its core principles across product life cycles. The foundational "3Rs" framework (reduce, reuse, recycle) has evolved into more complex hierarchies such as the 4Rs, 9Rs, and 10Rs, incorporating additional strategies like refuse, redesign, repair, refurbish, remanufacture, repurpose, recover, and remine (Kirchherr et al., 2017; Reike et al., 2018). These typologies are designed to narrow resource flows through efficiency improvements, slow loops via product life extension, and close material loops through improved recovery and recycling processes (Bocken et al., 2016). The underlying objective is to preserve the functional and economic value of products, components, and materials for as long as possible, thereby reducing the need for virgin resource extraction and minimizing waste generation.

Contemporary design led approaches emphasizing modularity, reparability, and standardization are increasingly viewed as foundational enablers of CE. Bocken et al. (2016) proposed a strategic design framework that prioritizes product longevity and adaptability while also fostering the emergence of service based models such as Product-Service Systems (PSS) and leasing arrangements that decouple ownership from usage and align incentives for durability. Life-cycle thinking is embedded in these strategies, encouraging evaluation of environmental impacts across cradle-to-grave or cradle-to-cradle systems using tools such as Life Cycle Assessment (LCA) and Material Flow Analysis (MFA) (Geissdoerfer et al., 2020; Niero and Hauschild, 2017).

Empirical research has demonstrated that high order strategies such as reuse, remanufacturing, and product-life extension often yield the most substantial environmental benefits by significantly reducing the demand for new production and extending material utility (Psarommatis and May, 2025). In sectors like construction, the reuse of structural elements has been shown to dramatically reduce embodied carbon compared to recycling or new production (Hosseini et al., 2023). These practices are increasingly supported by digital technologies, including the Internet of Things (IoT), blockchain, and additive manufacturing, which enhance traceability, facilitate reverse logistics, and optimize circular operations.

Nevertheless, the implementation of circular strategies is not without limitations. Recycling, while central to most CE frameworks faces challenges related to quality degradation (downcycling), high energy inputs, and inefficient material recovery systems (Makov and Font Vivanco, 2018). Furthermore, the rebound effect, wherein gains in efficiency lower costs and stimulate increased consumption can partially or entirely negate environmental benefits (Zink and Geyer, 2017; Warmington-Lundström and Laurenti, 2020). These findings underscore the necessity of prioritizing high impact strategies such as design-for-durability and of complementing circular practices with robust sustainability assessment tools to detect potential tradeoffs and unintended consequences (Corona et al., 2019; Rigamonti and Mancini, 2021). Remanufacturing and refurbishment have emerged as key pillars of CE, offering significant resource savings and value recovery. Case studies highlight the economic and environmental advantages of remanufacturing, particularly when supported by advanced technologies such as automation and digital twins (Prosman and Cagliano, 2022).

However, successful implementation depends on conducive product design, consumer acceptance, and institutional support, including standardized certification and reverse logistics infrastructures (Bocken et al., 2016; Korhonen et al., 2018; Murray et al., 2017). Empirical studies across sectors consistently affirm the positive environmental and resource efficiency outcomes achievable through circular strategies. Yet, these studies also highlight critical nuances and potential tradeoffs, stressing that the success of circular interventions significantly depends on their specific contextual implementation (Sandin and Peters, 2018). Optimal outcomes are achieved when circular strategies are carefully balanced with systemic considerations such as aligning product lifetimes with technological advancements, enhancing recycling processes, and actively mitigating rebound effects through complementary policies.

The strategic role of reverse logistics and closed-loop supply chains is well recognized in CE implementation (Sassanelli et al., 2019; Guide Jr. and Van Wassenhove, 2009). However, these systems face barriers such as regulatory fragmentation and high costs (Govindan and Hasanagic, 2018; Genovese et al., 2017).

Recent studies also emphasizes the integration of dynamic and consequential LCAs, along with circularity indicators such as the Material Circularity Indicator (MCI), to better capture the environmental impacts and circular performance of products over multiple life cycles (Elia et al., 2017; Geissdoerfer et al., 2020). Nevertheless, there is growing recognition that LCA methodologies must evolve to better reflect the complexity of circular systems especially multi-loop scenarios, secondary material degradation, and long temporal horizons (Corona et al., 2019).

Although the literature affirms the theoretical and empirical viability of circular strategies across various sectors, implementation remains uneven. High value loops such as remanufacturing and reuse are often underutilized in practice due to operational, institutional, and behavioral barriers, while low value strategies like recycling continue to dominate due to their relative simplicity (Sihvonen and Ritola, 2015). To overcome these challenges, scholars call for greater alignment between conceptual strategy hierarchies and practical implementation, supported by system-level interventions and policy coherence (Potting et al., 2017; Hartley et al., 2023).

3. Business Models and Organizational Transition

The transition from a traditional linear economy to a circular economy (CE) necessitates a fundamental rethinking of how businesses create, deliver, and capture value. At the core of this transformative shift lies business model innovation, increasingly recognized as an essential mechanism for operationalizing the principles of circularity. Ritala et al. (2023) highlights the significance of circular business models (CBMs) as indispensable tools for aligning economic prosperity with sustainability imperatives, highlighting their ability to reduce environmental impact and resource dependence while fostering economic resilience and competitive advantage. With CBMs, value creation can be decoupled from resource consumption by creating closed-loop systems, prolonging product lifespans, and providing alternatives for consumption (Bocken and Ritala, 2022).

Implementing circular strategies at the firm level necessitates profound shifts in both business models and organizational structures (Kanda et al., 2021). Organizations successful in embedding circularity often cultivate an internal culture conducive to sustainability, long-term thinking, and experimentation, thereby enabling smoother transitions from linear practices to circular ones (Jabbour et al., 2019). Rather than adhering to the traditional linear "take-make-dispose" model, firms are increasingly exploring circular business models (CBMs) that prioritize the prolonged use and reuse of products and materials.

Recent scholarly discourse delineates several prominent circular business model archetypes that collectively facilitate the operationalization of CE principles across sectors. These models include Product-as-a-Service (PaaS), sharing and platform economy models, performance-based offerings, and reverse logistics coupled with closed-loop supply chain practices (Franco, 2017). Each of these archetypes exemplifies a strategic realignment away from conventional, volume-driven models towards sustainable value creation based on resource efficiency, durability, and lifecycle stewardship. Bocken et al. (2016), Lewandowski (2016), Tukker and Tischner (2006), Hopkinson et al. (2018) emphasize these busness models are fundamental mechanisms through which circularity can be operationalized. These models enable value creation by decoupling growth from resource consumption, thereby fostering sustainability alongside economic viability.

Transitioning to these models, however, requires a holistic reconfiguration of a firm's value proposition, supply chain, and revenue logic. For instance, when firms adopt leasing models under the PSS approach, they retain ownership of products, which creates a financial incentive to design for durability, modularity, and easy disassembly factors essential for enabling reuse, remanufacturing, and recycling (Lewandowski, 2016). Lewandowski (2016) Furthermore, underscoring that adapting traditional frameworks such as the Business Model Canvas to incorporate CE specific components such as take back systems and adoption enablers provides practical guidance for firms undertaking this transition.

Furthermore, achieving a "triple fit" where customer value, company profit, and environmental benefit align is deemed critical for the viability of CBMs (Lewandowski, 2016). Organizational case studies reveal that inter-departmental collaboration and visionary leadership are essential for overcoming siloed structures and fostering system wide innovation (Antikainen and Valkokari, 2016). To support firms, frameworks like the ReSOLVE model proposed by Ellen MacArthur Foundation (2015) offer strategic pathways such as regenerate, share, optimize, loop, virtualize, and exchange tailored to operationalizing CE principles across different industries.

Empirical examples further illustrate the scaling potential of CBMs. For instance, pilot initiatives in sectors such as electronics (e.g., remanufactured product lines and trade-in schemes) and fashion (e.g., take-back programs) demonstrate the commercial feasibility and environmental promise of circular models (Ranta et al., 2018). However, as Antikainen and Valkokari (2016) argue, sustained success depends not only on innovation but also on organizational readiness to undergo transformative change. In this regard, dynamic capabilities, leadership commitment, and aligned performance metrics emerge as critical enablers for embedding circularity across business practices.

4. Policy, Governance, and Stakeholder Engagement

The circular economy (CE) transition is increasingly conceptualized as a complex, systemic shift that transcends technical innovation, demanding coordinated policy frameworks, institutional realignment, and inclusive stakeholder engagement. Governance and regulatory architectures thus play a crucial enabling or constraining role in accelerating circularity. This transition signals a move away from voluntary, industry led initiatives towards formalized policy instruments that align fiscal, legal, and public procurement systems with circular objectives (Kirchherr et al., 2018; De Jesus and Mendonça, 2018).

Policy instruments such as landfill taxes, recycling mandates, eco-design regulations, and extended producer responsibility (EPR) schemes are instrumental in shaping business incentives towards reuse, repair, and recyclability. EPR, for instance, obligates producers to assume responsibility for their products' end-of-life impacts, thereby fostering upstream design innovations (Corvellec et al., 2022). However, in the absence of coherent and supportive policy environments, firms frequently encounter what De Jesus and Mendonça (2018) describe as "linear lockin", a structural inertia where prevailing regulatory and market incentives continue to favor linear economic models. Overcoming such systemic inertia necessitates governance approaches that transcend sectoral silos and address institutional, behavioral, and infrastructural dimensions.

In this regard, multi level governance has emerged as a strategic imperative. The European Union's Circular Economy Action Plan (Plan, 2020) exemplifies how supranational frameworks can set strategic direction, while national and municipal actors are increasingly recognized for their capacity to operationalize circular interventions tailored to local contexts (Plan, 2020; Su et al., 2013; Losa, 2025). Municipalities, in particular, play a pivotal role due to their oversight of urban planning, waste systems, and public procurement, enabling them to experiment with grassroots innovations such as repair cafés, industrial symbiosis parks, and decentralized composting (Losa, 2025; Kirchherr et al., 2018).

Alongside public regulation, private governance mechanisms have gained prominence. Voluntary tools like the Ellen MacArthur Foundation's Circulytics and Cradle to Cradle certification offer frameworks for firms to assess and communicate circular performance. While these instruments may catalyze internal organizational change, concerns about transparency, credibility, and greenwashing persist (Patala et al., 2022).

Given the complexity of CE transitions, scholars increasingly advocate for polycentric governance models that distribute authority across multiple, interacting actors. Such configurations promote adaptability, knowledge exchange, and resilience in policy implementation (Schultz et al., 2024). Platforms like the European Circular Economy Stakeholder Platform (ECESP) and regional "Hubs for Circularity" exemplify institutional innovations that foster collaboration among governments, industries, researchers, and civil society (Patala et al., 2022).

Stakeholder engagement is not merely instrumental but foundational to circular governance. Early and meaningful participation across diverse actor groups enhances legitimacy, facilitates context-specific solutions, and mitigates resistance (Kirchherr et al., 2018). Participatory mechanisms such as living labs, collaborative procurement processes, and co-design workshops are increasingly employed to co-create knowledge and embed iterative learning. Moreover, addressing social justice imperatives—such as job security for displaced workers, equitable access to resources, and affordability of circular products—is critical to ensuring a just and inclusive CE transition (Corvellec et al., 2022).

Despite growing momentum, significant challenges remain. Fragmented policy environments, weak enforcement, and superficial stakeholder involvement undermine progress. Critical scholars caution against overly optimistic assumptions about CE as an automatic "win-win" solution, highlighting potential trade-offs, rebound effects, and socio-economic disparities (Corvellec et al., 2022; Losa, 2025). Moving forward, research and policy must prioritize policy coherence, rigorous monitoring frameworks, and robust metrics that capture multidimensional sustainability impacts. A shift towards adaptive governance, characterized by experimentation, feedback loops, and institutional learning will be essential to navigate the evolving landscape of circular transitions.

5. Sustainability Outcomes and Impact Assessment

As circular economy (CE) practices scale across industries and regions, their proliferation demands rigorous, systems-level assessment of sustainability outcomes. Moving beyond conceptual advocacy, scholars increasingly emphasize the need for empirical scrutiny of CE's environmental, economic, and social tradeoffs (Luthin et al., 2024; Ravikumar et al., 2024). While CE frameworks are lauded for advancing resource efficiency, waste reduction, and climate mitigation with co-benefits such as employment in secondary material sectors emerging research reveals a contingent reality. The alignment of CE strategies with Sustainable Development Goals (SDGs) 8 (decent work), 12 (responsible consumption), and 13 (climate action) remains context dependent, mediated by implementation design, infrastructural capacity, and systemic coherence (Schröder et al., 2019). For instance, without equitable labor safeguards, circular transitions risk reinforcing informal or precarious

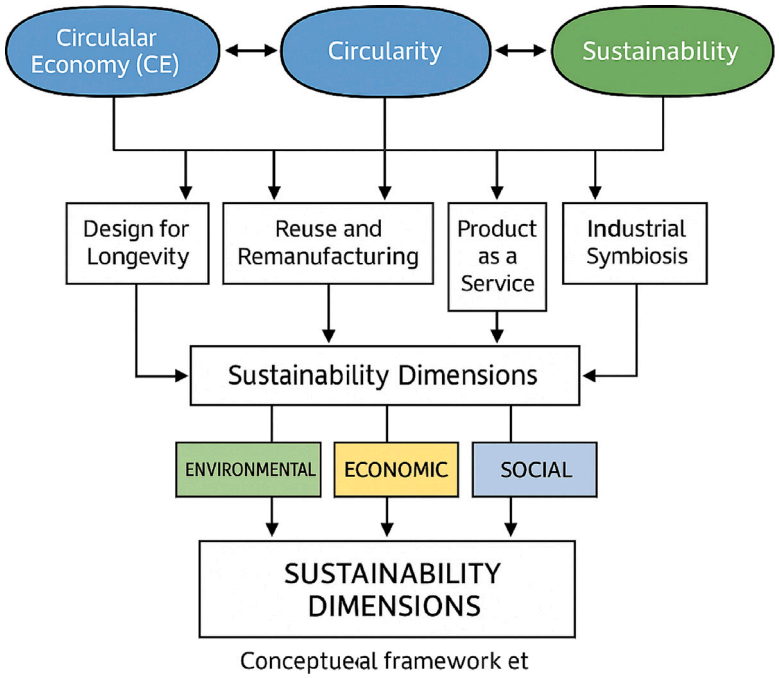

Fig. 5. Conceptual framework showing how Circular Economy(CE) principles enable sustainability through circularity and key strategies.

work in recycling economies (Murray et al., 2017). Similarly, material recovery systems may reduce virgin resource extraction yet exacerbate energy demands or toxic byproducts (Korhonen et al., 2018). This ambivalence underscores a critical insight: CE's net sustainability contributions are not intrinsic but derive from intentional governance, innovation, and cross-sectoral collaboration

Life Cycle Assessment (LCA) remains the cornerstone of environmental evaluation in circular economy (CE) systems, quantifying reductions in emissions and resource demand across reuse, recycling, and remanufacturing pathways (Ravikumar et al., 2024). However, its methodological rigidity, static system boundaries, linear modeling assumptions, and inadequate accounting for burden shifting constrains its ability to capture the dynamic, iterative nature of circular systems. For instance, LCAs frequently overlook toxic byproducts generated during recycling processes, leading to incomplete sustainability narratives. Emerging solutions propose dynamic boundary conditions, CE specific allocation methods, and scenario based modeling to better reflect systemic complexity (Ravikumar et al., 2024).

While Social Life Cycle Assessment (S-LCA) has emerged to evaluate CE's human impacts from labor conditions to community equity, its application lags behind environmental LCA due to inconsistent metrics, sparse data, and a lack of CE specific indicators (Bhatnagar et al., 2024). Robust S-LCA frameworks must integrate disaggregated socio-economic data to ensure CE transitions prioritize justice alongside environmental goals.

Unified frameworks like C-LCSA, which combine LCA, S-LCA, LCC, and circularity indicators, offer a holistic lens to identify tradeoffs and synergies across sustainability domains (Luthin et al., 2024). Parallel efforts to map CE interventions to the SDGs provide normative alignment but face critiques for their qualitative nature and inability to establish causal linkages. However, energy intensive processes like chemical recycling and rebound effects, where efficiency gains spur increased consumption—complicate net outcomes (Millar et al., 2019). Economically, CE enhances resilience but remains contingent on regulatory support and stable markets, with SMEs often excluded due to high upfront costs. Socially, CE generates employment while risking the perpetuation of informal sector inequities, demanding policies that explicitly tie circularity to labor rights. Hence, the CE paradigm necessitates methodologies that reconcile environmental, economic, and social metrics while addressing context-specific vulnerabilities. Without such integration, CE risks replicating the very linear extractivism it seeks to disrupt.

4. Developing a conceptual framework

The conceptual framework presented in Fig. 5 illustrates the integrative pathways through which Circular Economy(CE) principles contribute to sustainability outcomes, mediated by the concept of circularity and operationalized through key circular strategies. At its core, the framework underscores the bidirectional interlinkages between these frameworks, emphasizing that circularity functions as both a mechanism and a metric for aligning CE interventions with sustainability goals.

The conceptual framework integrates three core domains:- circular economy, circularity, and sustainability, each grounded in distinct literature but interlinked through shared concerns about resource efficiency, value retention, and systemic transition. The broader constructs were derived through thematic clustering of the reviewed literature and iteratively refined to capture both conceptual convergence and divergence. The arrows in the framework denote directional influence, feedback mechanisms, and areas of theoretical overlap. Four central operational strategies, design for longevity, reuse and remanufacturing, product-as-a-service (PaaS), and industrial symbiosis serve as the primary levers to translate CE principles into practice. These strategies collectively support the realization of the three pillars of sustainability: environmental (e.g. emissions reduction, resource conservation), economic (e.g. cost-efficiency, value retention), and social (e.g. job creation, equity). The framework positions sustainability dimensions as both an outcome and an evaluative lens, suggesting that circular strategies must be assessed not only for their technical circularity but also for their contribution to holistic sustainability. By capturing the interaction among systemic CE drivers, operational mechanisms, and sustainability outcomes, this model provides a structured basis for evaluating circular initiatives and guiding policy, business innovation, and research agendas aligned with long term sustainability.

The conceptual framework illustrated in Fig. 6 provides a holistic systems view of how circular economy (CE) strategies, business model

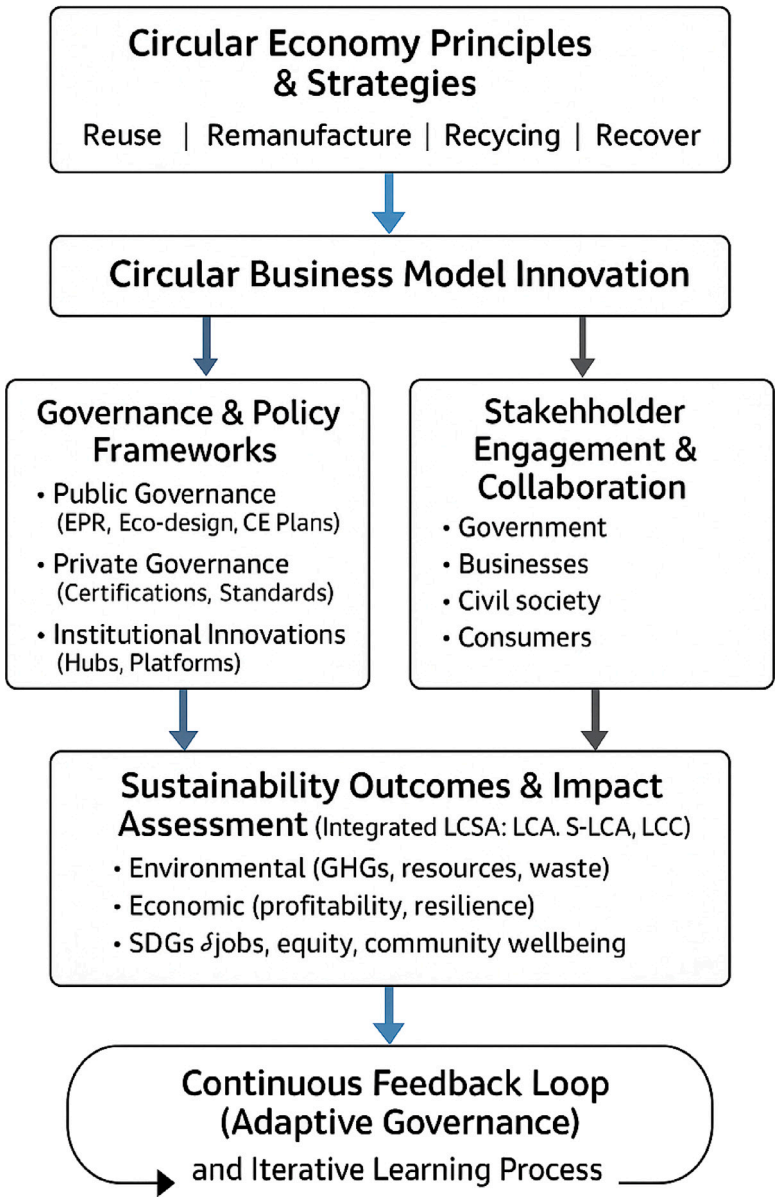

Fig. 6. Systems-based framework linking CE strategies, innovation, governance, and collaboration to sustainability outcomes.

innovation, governance mechanisms, and stakeholder collaboration collectively enable measurable sustainability outcomes. It begins with the foundational CE principles and strategies such as reuse, remanufacture, recycling, reduce, and recover representing core operational practices designed to close resource loops, minimize waste, and extend product lifecycles.

These foundational strategies catalyze circular business model innovation, which serves as the central mechanism for translating CE principles into practical, value generating solutions. Business model innovation in this context involves rethinking traditional linear value propositions and shifting towards service based, regenerative, and performance driven models. This transformation is not achieved in isolation but is embedded within enabling governance and policy frameworks and active stakeholder engagement.

The framework emphasizes that governance structures, both public (e.g. Extended Producer Responsibility, eco-design directives, and national CE roadmaps) and private (e.g., certifications, voluntary standards, and platforms such as industrial symbiosis hubs) establish the regulatory and institutional scaffolding necessary to support and scale circular practices. Simultaneously, multi-actor stakeholder collaboration involving governments, businesses, civil society, and consumers is indispensable for co-developing, legitimizing, and implementing CE initiatives. This interplay between governance and stakeholder networks forms a dynamic governance ecosystem that fosters legitimacy, innovation diffusion, and social acceptance.

The resulting sustainability outcomes and impact assessments were evaluated using an life cycle sustainability assessment (LCSA) approach, combining LCA (environmental), S-LCA (social), and LCC (economic) analyses. This integrative assessment enables stakeholders to measure and manage the triple bottom line: reducing environmental burdens (e.g. GHGs, virgin resource use), enhancing economic viability (e.g. profitability, resilience), and ensuring social inclusivity (e.g. decent jobs, equity, well-being). These outcomes are further aligned with the United Nations Sustainable Development Goals (SDGs) to ensure systemic relevance and global accountability.

At the core of the framework lies a continuous feedback loop, driven by adaptive governance and iterative learning. This loop ensures that policies, business models, and collaborative mechanisms are constantly

refined in response to emerging evidence, contextual shifts, and stakeholder feedback, allowing the circular economy transition to remain responsive, equitable, and sustainability oriented.

5. Conclusion

This study has systematically examined the evolving relationship between circular economy, circularity, and sustainability through a comprehensive synthesis of recent theoretical, empirical, and methodological literature. Addressing RQ1, the review finds that the literature increasingly converges towards viewing circular economy as a systemic paradigm for restructuring production and consumption, circularity as its operational and measurable expression, and sustainability as the overarching normative objective. However, conceptual ambiguities persist, particularly regarding the social dimension of sustainability and the tendency to conflate circularity performance with sustainable outcomes.

In response to RQ2, the analysis reveals that environmental and economic impacts of circular economy initiatives are predominantly assessed using Life Cycle Assessment and Life Cycle Costing, while social impacts remain underrepresented and methodologically fragmented. Although emerging approaches such as Social Life Cycle Assessment and integrated frameworks like Circular Life Cycle Sustainability Assessment offer more holistic evaluation potential, their application remains limited, signaling an imbalance in sustainability assessment practices.

Addressing RQ3, the study identifies critical gaps related to the integration of social equity, governance, and systemic change within circular economy research. While advances in circular business models, stakeholder-oriented innovation, and policy experimentation indicate progress towards more integrated transitions, significant opportunities remain for developing context-sensitive metrics, capturing rebound effects, and addressing global and inter generational equity considerations. The findings caution against assuming that increased circularity inherently delivers sustainability benefits without supportive institutional, organizational, and governance conditions.

Overall, this study contributes theoretically by clarifying conceptual boundaries and interrelations among circular economy, circularity, and sustainability, and methodologically by synthesizing dominant and emerging assessment frameworks under a unified sustainability lens. Practically, the proposed integrative framework offers guidance for policymakers and practitioners seeking to design evidence-based circular strategies aligned with sustainable development objectives and long-term systemic transformation.

This study is limited to English-language journal articles indexed in Scopus and Web of Science and published between 2017 and May 2025, which may exclude earlier foundational contributions and region-specific or policy-oriented research. Future studies should broaden database and language coverage and adopt longitudinal and cross-sectoral approaches to better capture social sustainability, governance dynamics, and context-specific circular–sustainability transitions.

CRediT authorship contribution statement

Anteneh D. Sewenet: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Youssef Boulaksil:** Writing – review & editing, Supervision, Methodology. **Paola Pisano:** Writing – review & editing, Validation, Supervision, Methodology.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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