frontiers | Frontiers in Sustainability

TYPE Mini Review
PUBLISHED 12 October 2023
DOI 10.3389/frsus.2023.1267282

OPEN ACCESS

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RECEIVED 26 July 2023
ACCEPTED 20 September 2023
PUBLISHED 12 October 2023

CITATION
Hassan H and Faggian R (2023) System thinking approaches for circular economy: enabling inclusive, synergistic, and eco-effective pathways for sustainable development. *Front. Sustain.* 4:1267282. doi: 10.3389/frsus.2023.1267282

System thinking approaches for circular economy: enabling inclusive, synergistic, and eco-effective pathways for sustainable development

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The Circular Economy (CE) concept is rapidly gaining space in mainstream policy in many developed countries, but it remains a contested and underdeveloped notion in scientific circles, largely due to its fragmented nature and absence of a unified framework. This fragmentation is attributed to the concept's diverse roots, its varying utilization by distinct interest groups, and its evolution over time. Though there are strong implicit links between CE and sustainability, the explicit connections are seldom addressed. Current CE views tend to heavily concentrate on the economic aspect of sustainability, marginally on the environmental one, and largely neglect the social aspect. The prevailing reductive interpretations of CE often lead to subpar or even unsustainable results, thereby posing significant challenges to its implementation and questioning its legitimacy as a sustainable development model. This systematic literature review, through an examination of CE's varied origins, its role in integrated socio-economic dialogues, its sustainability implications, and the challenges presented by its existing reductive approaches, underscores the necessity for a systemic exploration of the CE concept. Given that CE is rooted in Systems Ecology, adopting a pluralistic, transdisciplinary perspective is crucial to overcome challenges and limitation associated with CE implementation. The authors propose that the implementation of CE must be guided by holistic systemic evaluations of organizations with equal emphasis on environmental and social apprehensions along with economic concerns. Such systemic evaluations can ensure that CE meets its sustainability objectives and remain a legitimate pathway towards sustainable development.

KEYWORDS

circular economy, sustainability, sustainable development, systems thinking, transformative circularity, circular society, circular economy transitions, circular economy policy

1. Introduction

1.1. Circular economy: the concept, antecedents, evolution, and contemporary perspectives

1.1.1. The current state of circular economy literature

The Circular Economy (CE) concept is gaining significant traction among diverse scholars and practitioners (Wiesmeth, 2021a), with a 112% increase in published academic articles from 2014 to 2017 (Ruiz-Real et al., 2018). This growth is partially correlated to the adoption of CE

policies in regions like China and Europe, where CE concepts have been integrated into mainstream public policy on sustainable development (Schöggl et al., 2020). Although CE represents an economic system minimally tied to environmental impacts (Ghisellini et al., 2016), it remains a developing and debated concept in the scientific community (Korhonen et al., 2018a; Velenturf and Purnell, 2021). Recent bibliometric and scientometric studies reveal that despite increased academic interest, CE literature is largely fragmented and lacks a unified conceptual framework (Homrich et al., 2018; Merli et al., 2018; Ruiz-Real et al., 2018; Türkeli et al., 2018; Alnajem et al., 2021; Anaruma et al., 2022; Majiwala and Kant, 2022).

1.1.2. Origins of the CE concept

While Circular Economy (CE) is often seen as an individual concept in consultancy and advocacy, scientific literature regards it as an umbrella term encompassing various influential ideas from diverse theoretical backgrounds (Ghisellini et al., 2016; Reike et al., 2018). CE's origin is linked to Kenneth E. Boulding's "spaceship earth" analogy, emphasizing the need for a balance between human economic activity and the environment (Millar et al., 2019). Subsequent scholars expanded on Boulding's ideas, leading to key concepts like industrial ecosystems, regenerative design, and eco-efficiency, which inform contemporary CE perspectives (Jelinski et al., 1992; Lyle, 1996; Haas et al., 2015).

The term' Circular Economy' itself emerged in 1989 when Pearce and Turner advocated for a transition from traditional linear economic models to closed and circular systems that are sustainable (Wiesmeth, 2021b).

1.1.3. Evolution of the CE concept

The CE concept has evolved from its inception, encompassing a spectrum of perspectives from technocentric to transformational views. Analysing this progression is crucial for understanding the present state of CE literature.

Authors have identified developmental phases for the CE concept in academia, characterized by distinct discourses (Reike et al., 2018; Friant et al., 2020). The timeline includes a "Preamble Period" (1945–1980), an "Excitement Period" (1980–2010), and an ongoing "Validity Challenge Period" since 2010. CE discourses have evolved from technocentric "Circularity 1.0" and "Circularity 2.0," focusing on waste management and eco-efficiency, to "Circularity 3.0," integrating socioeconomic approaches to resources, consumption, and waste, with both reformist (3.1) and transformational (3.2) views. Figure 1 provides a typology of diverse circularity ideas presented by various thinkers.

The current "validity challenge" arises from the differing perspectives of Circularity 3.1 (Reformist views) and Circularity 3.2 (Transformative views). Reformist discourses focus on modifying capitalist systems to achieve circular futures. In contrast, transformative discourses question the ability of existing systems to embrace circular economy visions and propose a complete revamp of traditional socioeconomic structures (Reike et al., 2018).

1.1.4. Current dominant perspectives in CE literature

Friant et al. (2020) analyse the evolution of circularity discourses in CE literature, revealing that currently, Transformational and Reformist perspectives are the most prevalent, constituting 42 and 28% of reviewed

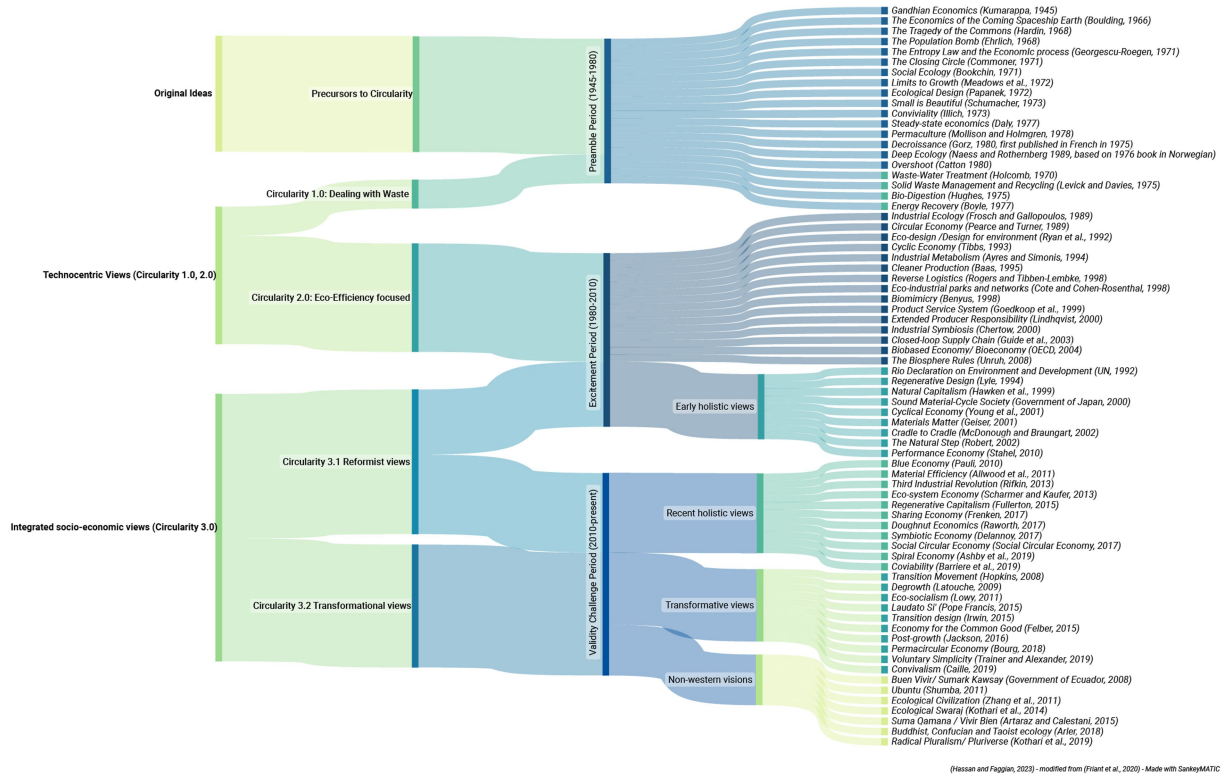

FIGURE 1
Typology of circularity discourses [modified from Friant et al. (2020)].

concepts, respectively. Over time, the prominence of these discourses has shifted: Transformative views were dominant in the 1960s and 1970s due to the growing awareness of planetary limits; however, Technocentric discourses (Circularity 1.0, Circularity 2.0) rose to prominence during the 1990s and 2000s alongside neoliberalism and faith in technological solutions. The 2008 economic crisis sparked scepticism of traditional socioeconomic systems, gradually steering the focus back towards Reformist and Transformational perspectives on circularity.

The resurgence of integrated socioeconomic CE discourses can be linked to the close relationship between pluralistic CE concepts and sustainable development (SD) concepts. Velenturf and Purnell (2021) note that both CE and SD originate from the systems ecology literature of the 1960s–70s, with transformative views on CE regaining prominence through recent advancements in sustainability and sustainable development discourses.

2. Materials and methods

2.1. Search strategy

This systematic literature review followed established guidelines and protocols to ensure a rigorous and comprehensive search. In this regard, all relevant studies published up to May 2023 were identified. Electronic databases, including Scopus and Google Scholar, were systematically searched using broad keywords, such as "circular economy" and "sustainability" and "sustainable development."

2.2. Inclusion and exclusion criteria

Since the objective of the review was to identify broad themes, research gaps and current trends in the Circular Economy field, a broad inclusion and exclusion criteria was established by authors prior to the selection of reviewed studies. Studies were included if they met the following criteria:

- Published in established journals before May 2023.
- Written in English language.
- Focused on "circular economy" as a holistic economic model for achieving "sustainability" and "sustainable development" rather than "circularity" that has been widely discussed in narrow technical context, e.g., in terms of specific materials, products or processes etc.
- Journals from field areas such as Environmental Sciences, Social Sciences, Business, Management and Accounting, Economics, Econometrics and Finance, Agricultural and Biological Sciences, Earth and Planetary Sciences, Decision Sciences, Arts and Humanities, Multidisciplinary studies.
- Only published journal articles, reviews, book chapters, books.

Studies were excluded if they:

- Were duplicates.
- Were conference papers, conference reviews, editorials, notes, erratums, retractions or data papers.
- Were unpublished or articles in press.
- Lacked relevance to the research question.
- Were not accessible in full-text form.
- Were narrowly focused on Energy, Engineering, Computer Sciences, Chemical Engineering, Chemistry, Biochemistry, Genetics and Molecular Biology, and Material Sciences.

2.3. Study selection process

HH carried out the initial screening of titles and abstracts to identify potentially relevant articles. The included and excluded titles were then critically reviewed by RF to mitigate the chances of bias. Subsequently, full-text articles were retrieved for further assessment.

2.4. Data extraction

Data extraction was performed by HH, with RF verifying the accuracy of the extracted data for a subset of studies.

2.5. Quality assessment

The quality assessment process was also conducted independently by authors, with discrepancies resolved through discussion.

2.6. Data synthesis and analysis

A narrative synthesis approach was employed to summarize the findings from the included studies.

2.7. Reporting guidelines

This systematic literature review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and completeness in reporting methods and results. Supplementary Figure S1 below provides a flow diagram for the systematic review based on PRISMA 2020, which includes searches of databases and other sources.

By following these rigorous methods, the authors aim to provide a comprehensive and unbiased synthesis of the available literature on circular economy, allowing for a thorough evaluation of the current state of knowledge in the field.

3. Discussion

3.1. Contextualising sustainability and sustainable development In circular economy literature

3.1.1. CE's implicit connections to sustainability concepts

The core debate within "Circularity 3.0" discourses centres on the sustainability and sustainable development challenge (Reike et al., 2018). A thorough analysis of the literature reveals that the main issue stems from ambiguities in the scope of the CE concept, raising questions about its validity as a radically new vision for achieving

sustainable development. Reformist views assume CE aligns with the neoliberal economic growth philosophy, allowing for a reduction in environmental pressures through circular strategies (D'Amato et al., 2017). In contrast, transformative views question this growth rhetoric and argue that this perspective overlooks the importance of social change (Schröder et al., 2019). Scholars contend that uncertainties in "Circularity 3.0" discourses arise not only from differing views on the scope of the CE concept but also from inherent vagueness in sustainability and sustainable development concepts (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Korhonen et al., 2018a; Schöggl et al., 2020). Velenturf and Purnell (2021) suggest that the joint evolution of CE and SD concepts during the 1960s–90s created an implicit interrelation in the literature, attributing the conceptual limitations of CE to those of sustainability and sustainable development concepts. Thus, it is crucial to examine the evolution of sustainability and sustainable development concepts and their contextualization in CE literature.

3.1.2. Sustainability and sustainable development as inherently contested concepts

The modern notion of "sustainability" originates from the silvicultural principle in forestry, which emphasizes the balance between harvested and regrown wood (Mantel and Hauff, 1990). Later, this concept was adopted in ecological sciences to underscore nature's regenerative ability (Geissdoerfer et al., 2017). Today, the most prevalent representation of sustainability is the "triple bottom line" principle, consisting of three interconnected spheres: environment, society, and economy (Elkington, 1997). This broader depiction allows for diverse and sometimes contradictory perspectives on sustainability, leading to its varied instrumentalization by different interest groups (Geissdoerfer et al., 2017).

Sustainable development (SD) is rooted in the influential "Limits to Growth" report (Meadows et al., 1972) and global discussions on environment and development during the 1972 United Nations Conference on the Human Environment held in Stockholm (Jackson, 2009). The Brundtland Report (Wced, 1987) first introduced the term, defining SD as meeting present needs without compromising future generations' ability to meet theirs (Skene, 2022). This definition implies an interchangeability of the three sustainability arenas: social, economic, and environmental. Skene (2022) terms this notion of sustainability as "Weak Sustainability," as it assumes that natural capital can be indefinitely replaced by human capital (Turner and Pearce, 1990; Sachs, 2015). While "Strong Sustainability" argues that natural capital is irreplaceable and that all three arenas must be maintained separately (Skene, 2022).

The core argument between "Strong" and "Weak" sustainability narratives lies in the role of technology and innovation (Diemer et al., 2020). "Weak Sustainability" emphasizes technology as crucial for exchanging natural and human capital. At the same time "Strong Sustainability" suggests that holistic, systematic social change is necessary due to the integrated and non-substitutable nature of sustainability arenas (Chaminade, 2020; Skene, 2022). Consequently, technology alone cannot address the sustainable development challenge. Overall, the sustainable development concept in scientific literature is often vague and value-laden, with varying perceptions depending on prioritized aspects (Korhonen et al., 2018b).

Despite the implicit connection between Circular Economy (CE) and sustainability concepts in literature, explicit discussions on this link are scarce (Velenturf and Purnell, 2021). Addressing these gaps, recent studies, such as Geissdoerfer et al. (2017), have explored the relationship between the two concepts through extensive bibliometric analyses, identifying key similarities and differences in the wider literature.

3.1.3. Explicit connections between CE and sustainability concepts

Regarding similarities, both Circular Economy (CE) and sustainability emphasize public action for environmental protection and its significance for present and future generations. These globally-oriented concepts call for inclusive, integrated, and interdisciplinary multistakeholder cooperation. They promote change through innovation, systems design, incentives, and regulations. With a strong focus on private commercial entities as agents of change, CE and sustainability see business model innovation and technological progress as the primary drivers of transformation (Geissdoerfer et al., 2017).

The key differences between Circular Economy (CE) and sustainability concepts include age, goals, and focus. CE, a relatively new concept, aims to decouple economic growth from environmental impacts by improving resource utilization and minimizing negative externalities. Sustainability, a broader and more open-ended concept, emphasizes a dynamic equilibrium between environmental, social, and economic aspects without specifying how this balance will be achieved. CE offers circular strategies to balance economic and environmental aspects but does not address social improvements. While sustainability stresses shared responsibility without defining specific roles, CE highlights the roles of governments, businesses, and policymakers in transition. Additionally, sustainability goals can be reframed over time without temporal constraints. In contrast, CE operates within specific time limits to achieve its objectives (Geissdoerfer et al., 2017).

Based on these similarities and differences, Geissdoerfer et al. (2017) have identified types of relationships that are broadly viewed in literature. These relationships as either "Conditional" (CE as a condition to achieve a sustainable system), "Beneficial" (CE is beneficial but not conditional for the sustainable system) or mere "Trade-off" (CE as a viable alternative for a sustainable system). Supplementary Figure S2 explains these explicit relationships in detail.

Several studies suggest that Circular Economy (CE) and sustainability concepts share many core ideas, with most scholars viewing positive connections (Conditional, Beneficial) between them. However, due to the broad and value-laden nature of sustainability and sustainable development concepts, they can be differently instrumentalized by various interest groups. Thus, a critical question remains regarding how sustainability concerns are integrated into the overall CE literature.

3.1.4. To what extent sustainability concepts are discussed in CE literature?

Several authors (Kirchherr et al., 2017; Kalmykova et al., 2018; Korhonen et al., 2018a; Schöggl et al., 2020) have analysed CE literature regarding the inclusion of sustainability concerns. In their comprehensive analysis, Kirchherr et al. (2017) reviewed 114 definitions of CE and found that only 13% incorporate all three arenas of sustainability, while only 12% overtly refer to sustainable development. Their findings also suggest that the current literature

on CE widely discusses the economic (46% of definitions) and environmental aspects (38% of definitions) of sustainability, while social aspects are largely missing. Kalmykova et al. (2018) observe that in the context of sustainability, the general theme arising from CE literature is more of an eco-efficiency (focused on the economic dimension) rather than an eco-effective (focused on the environmental dimension) one. One of the reasons for the increased emphasis on the economic aspect is that 53% of the definitions are formulated by practitioners who often evaluate CE in terms of economic growth potential and apply reductionist approaches to CE (Ghisellini et al., 2016). Several studies particularly highlight the lack of focus on the social dimension of sustainability in CE literature. Murray et al. (2017) noted that CE literature is largely silent on social issues, and discussions on how the CE model could contribute towards equitable societies are generally lacking in the literature. D'Amato et al. (2017) argue that a possible reason for this lack of attention towards social issues is that CE is predominantly discussed in industrial context that generally does not concern social issues. However, as noted by Merli et al. (2018), recent studies that adopt transformative discourses on CE have increasingly emphasized the importance of social aspects. Schöggl et al. (2020) argue that the inclusion of social aspects is important for the general acceptance of CE approaches among various stakeholders in society and critical for the effective incorporation of CE strategies in production and consumption. Murray et al. (2017) draw attention to the point that since CE has intergenerational concern at its core, it inherently incorporates social concerns. Therefore, the inclusion of social aspects is critical for implementing sustainable circular economy.

3.2. Implementation barriers to 'sustainable' CE from current approaches

3.2.1. Varied perspectives and instrumentalization of the concept

Emerging from varied theoretical origins and drawing attention from distinct fields, CE serves as an 'empty signifier'—signifying different things to different interest groups (Valenzuela and Böhm, 2017; Corvellec et al., 2020). With sustainability as a common underlying theme, diverse viewpoints have led to a wide range of implementation strategies in the literature, aiming to transform linear models into circular ones (Lieder and Rashid, 2016).

While various Circular Economy (CE) strategies exist, there is a notable lack of in-depth discussion on achieving an optimal sustainable equilibrium between environmental, social, and economic aspects (Galvão et al., 2018). This research gap is emphasized in recent studies advocating integrated socioeconomic approaches to CE (Kirchherr et al., 2018; Korhonen et al., 2018a; Inigo and Blok, 2019). The assessments of CE strategies by practitioners often lack scientific grounding, leading to reductionist viewpoints and overlooking wider systemic impacts (Balanay and Halog, 2021; Skene, 2022). Implementation challenges, such as the absence of collaborative innovation, higher costs, policy deficiencies, incoherent strategies, unintended consequences, and market misalignment (Balanay and Halog, 2021), highlight the need for analysing sustainability context and suggesting appropriate solutions for CE to serve as a legitimate, sustainable development model.

Recent studies (Alnajem et al., 2021; Vinante et al., 2021) have found that assessing circular approaches and strategies in CE implementation is often fragmented and incoherent. Murray et al. (2017) note that most studies focus on a single aspect, level, or area, with discussions on interconnections between these areas largely missing. This lack of comprehensive analysis can lead to unintended consequences when implementing CE strategies. Furthermore, there is an imbalance in focus on certain aspects, such as discussing production side strategies more than the consumption side (Ruiz-Real et al., 2018). Overall, an emphasis on hard elements (physical flows) and limited knowledge of soft elements (abstract flows and stakeholder behaviours) contribute to oversimplified views among CE practitioners (Korhonen et al., 2018a).

3.2.2. Limitations of the current CE strategies

Regarding the most prevalent CE approaches and strategies suggested in the wider literature, Kalmykova et al. (2018) comprehensively analysed CE approaches and strategies, identifying 45 different strategies and over 100 notable case studies. These strategies are grouped into material sourcing, design, manufacturing, distribution and sales, consumption and use, collection and disposal, recycling and recovery, remanufacturing, and circular input. The analysis reveals that current CE strategies primarily focus on materials, products, and specific technical processes, with a noticeable lack of systemic approaches in the discussions.

The value retention options (R-imperatives) of reduce, reuse, and recycle are commonly discussed in CE literature. Ruiz-Real et al. (2018) identified nine R-imperatives, including refuse, reduce, resell/reuse, repair, refurbish, remanufacture, re-purpose, recycle materials, recover energy and re-mine. These strategies aim to reduce reliance on virgin materials and minimize negative environmental impacts. However, a practical implementation may result in unintended consequences and fail to produce sustainable outcomes due to reductionist viewpoints among practitioners, as noted by Papa (2015), Murray et al. (2017), and Skene (2018, 2022).

Korhonen et al. (2018a) argue that current CE strategies must consider the inherent complexity of socio-ecological systems to achieve sustainability. Challenges with current CE strategies include thermodynamic limitations of material recycling and combustion, system boundary limitations, and societal and economic path dependencies. Eco-efficiency is a popular CE approach but poses challenges like rebound effects and unsustainable consumption. The importance of social governance and justice are critical for CE implementation. Overall, challenges associated with current CE implementation leave room for greenwashing, burden-shifting and negative outcomes, necessitating a systems assessment of production/consumption processes for the sustainable circular economy.

3.2.3. "Economically synergistic, socially inclusive, and environmentally effective CE," no just CE– as legitimate model for sustainable development

Overall, the literature on sustainability, sustainable development, and transformative views on Circular Economy (CE) shares concerns about resource overutilization and the negative impacts of the growth paradigm on the environment and society. The crucial question is how to effectively integrate action-oriented sustainability sciences into action-led CE concepts to mitigate risks during practice and implementation. To achieve this, a pluralist view of CE is needed,

equally respecting environmental, social, and economic aspects. Broadening the scope of collaboration beyond regulators, businesses, and policymakers to include a wider range of societal actors will help create holistic pathways for research-led implementation. Ultimately, systematic rather than reductionist approaches are necessary for a more sustainable, inclusive, and eco-effective CE. Figure 2 provides a conceptual illustration of the limitation of reductive CE strategies and approaches in a systems perspective.

3.3. Why systems thinking approaches are crucial for synergistic, inclusive, and eco-effective pathways for CE implementation?

As analysed above, the diverse origin of the CE concept, its current perspectives in integrated socioeconomic discourses, its sustainability context and the implementation challenges arising from its current reductionist approaches point out the need for systems exploration of the CE concept.

Systems Thinking (ST) is a holistic approach that considers systems' complexity and dynamic nature by analysing their parts and relationships among them, challenging the reductionist view that focuses on the properties of individual parts to understand the whole system. Meadows (2008) and Allen and Merali (2011) emphasize the need for a systems approach to understanding the functioning of complex systems.

ST approaches are highly relevant to CE because CE is rooted in systems ecology (Velenturf and Purnell, 2021). ST approaches allow for a more comprehensive analysis of the complexity and dynamic nature of modern production, distribution, and consumption processes (Jackson, 2019). It helps shift CE goals towards integrated socio-ecological objectives for sustainable development (Voulvoulis et al., 2022). ST provides a holistic perspective by analysing the problems that may arise in distant parts of the system, avoids single-dimensional progression towards dynamic goals, recognises natural systemic delays, and minimises counter-productive reactions (Stroh, 2015). ST minimises tendencies towards authoritarianism in practitioners, which produce unsustainable outcomes in complex systems (Rivlin, 2015).

Currently suggested resource utilisation, value retention and waste generation strategies in industrial contexts generally lack wider systemic evaluations of their economic, environmental, and social side-effects. This absence of systemic evaluations leads to ineffective integration of "action-oriented" sustainability science into "action-led" circular strategies (Kirchherr et al., 2017; Reike et al., 2018). A systems view of industrial systems can offer an effective resolution to the prevailing issue of non-integrated, independently implemented CE approaches, which lack an overarching commitment to sustainability principles. An industrial system's activities, strategies, and policies can be effectively scrutinised through a systems lens to identify appropriate leverage points for employing CE strategies.

Moreover, owing to the diverse origins of CE concept, current literature present fragmented strategies that often end up in business-as-usual scenarios or produce negative outcomes when implemented in isolation (Kalmykova et al., 2018; Balanay and Halog, 2021). Adopting a systems perspective provides the capacity to examine these CE strategies in an integrated, holistic manner, shedding light on the potential for productive synergies.

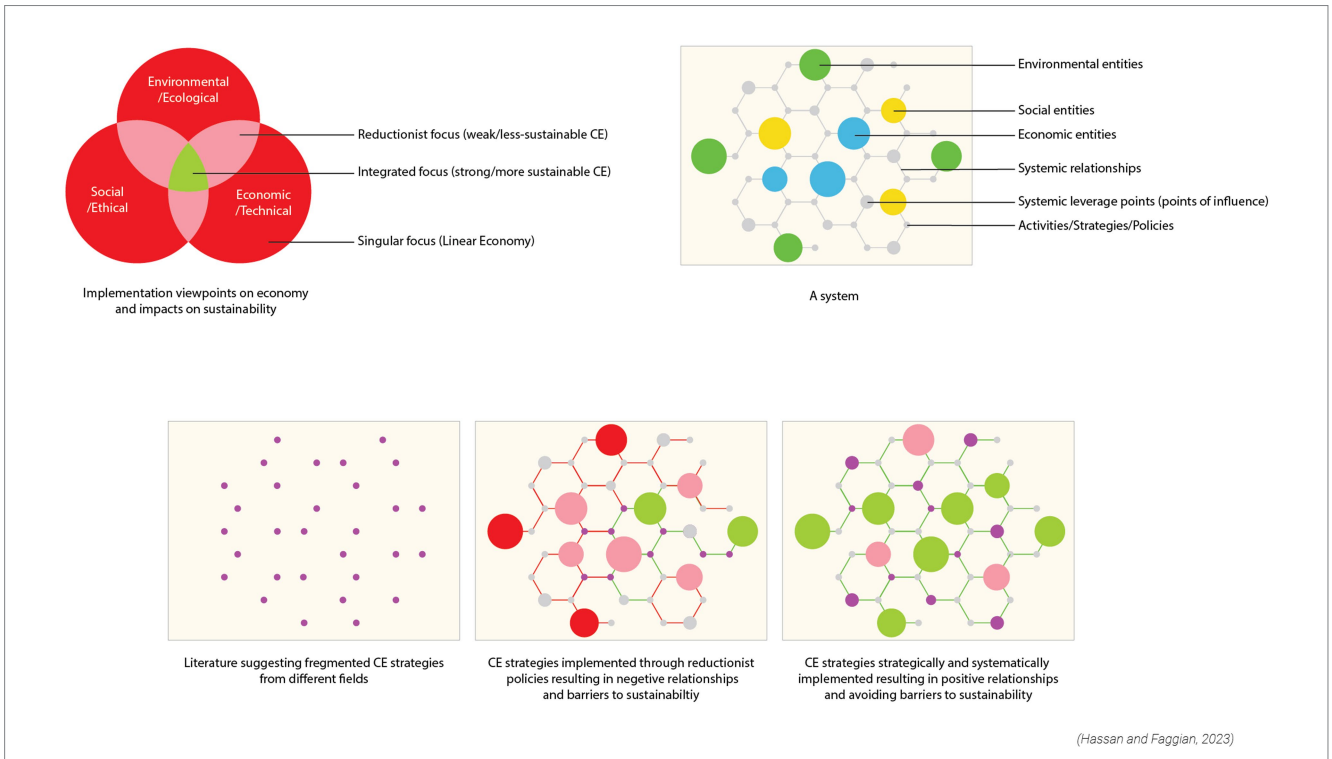

FIGURE 2
Implementation viewpoints and their impacts on sustainability (conceptual).

CE implementation is associated with sustainability challenges on the production and consumption side like Rebound effect from eco-efficiency, Jevon's Paradox, Boomerang effect, Path Dependencies, Material-Energy-Biodiversity Nexus, Social Justice and Cultural Change, Spatial and Temporal Boundary Limits, Problem Shifting, Tragedy of Commons and Prisoner's Dilemma (Korhonen et al., 2018a; Wiesmeth, 2021b). A systems view of CE practices in an industrial system can enable a better understanding of the underlying issues resulting from these challenges. Correspondingly, suitable, integrated, and sustainable policies can be suggested that avoid these issues.

Absolutist claims by CE advocates and critics alike invalidate the inherent potential of CE strategies towards achieving sustainable development (Inigo and Blok, 2019). This is because the CE concept has rarely been viewed on a dynamic systems level. Therefore, nuanced understanding is lacking. Viewing the CE concept from a dynamic systems perspective can cultivate a nuanced understanding and counter such extreme views.

Finally, the development of suitable indicators and indices for circularity is an active area of study and debate (Su et al., 2013). However, the proposed indicators and indices often lack a deeper systematic understanding of the environmental, social, economic, or technical aspects of the concept (Dohmen and Confiado, 2023; Nowaczek et al., 2023). A systematic analysis based on a systems view can effectively guide the measurement of circularity in a way that it leads to sustainable outcomes.

4. Conclusion

As CE has been discussed from diverse perspectives by practitioners and scholars from varied fields and epistemological backgrounds, the literature reveals the interdisciplinary nature of the concept (Wiesmeth, 2021a). As a largely fragmented concept lacking a coherent framework, the CE concept needs more exploration from a systems perspective to enable coherent integration of different ideas and perspectives and as a way to bridge fundamental gaps in theory and practice.

Scientific literature shows positive connections between CE, sustainability, and sustainable development concepts. Still, these concepts are instrumentalized differently by various interest groups, leading to negative outcomes for sustainability. As a participatory approach, system thinking approaches dealing with social complexity can integrate various perspectives from different interest groups and fill the gap in social aspects in CE literature. Systemic assessments on CE can inform economically viable, environmentally protective, and socially equitable policy interventions (Blomsma and Brennan, 2017; Babbitt et al., 2018; Ben-Eli, 2018; Diemer et al., 2020; Skene, 2022).

Author contributions

HH: Conceptualization, Visualization, Writing – review & editing. RF: Funding acquisition, Resources, Supervision, Writing – review & editing, Conceptualization.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The research was funded by Deakin University's Postgraduate Research Scholarship (DUPR-ROUND - 0000018830).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2023.1267282/full#supplementary-material

SUPPLEMENTARY FIGURE 1
PRISMA flow diagram for systematic review.

SUPPLEMENTARY FIGURE 2
Relationships between Sustainability and CE as viewed in the scientific literature (modified from Geissdoerfer et al., 2017).

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