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Accelerating the Transition to a Circular Economy for Net-Zero Emissions by 2050: A Systematic Review

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Abstract: Achieving net-zero emissions by 2050 will require tackling both energy-related and non-energy-related GHG emissions, which can be achieved through the transition to a circular economy (CE). The focus of climate change crisis reversal has been on the energy-related continuum over the years through promoting renewable energy uptake and efficiency in energy use. Clean energy transition and efficiency gains in energy use alone will not be sufficient to achieve net-zero emissions in 2050 without paying attention to non-energy-related CO_2 emissions. This study systematically reviews the CE literature across different themes, sectors, approaches, and tools to identify accelerators in transitioning to a CE. The study aims to understand and explore how technology, finance, ecosystem, and behavioral studies in the CE paradigm can be integrated as a decision-making tool for CE transition. The material analysis was carried out by identifying the main characteristics of the literature on CE implementation in the agriculture, industry, energy, water, and tourism sectors. Results of the literature survey are synthesized to engender clarity in the literature and identify research gaps to inform future research. Findings show that many studies focused on technology as an accelerator for CE transition, and more studies are needed regarding the CE ecosystem, financing, and behavioral aspects. Also, results show that CE principles are applied at the micro-, meso-, and macro- (national, regional, and global) levels across sectors with the dominance of the industrial sector. The agriculture, water, and energy sectors are at the initial stages of implementation. Additionally, the use of carbon capture and utilization or storage, conceptualized as a circular carbon economy, needs attention in tackling CE implementation in the energy sector, especially in hydrocarbon-endowed economies. The major implication of these findings is that for CE to contribute to accelerated net-zero emission by 2050, coordinated policies should be promoted to influence the amount of financing available to innovative circular businesses and technologies within an ecosystem that engenders behavioral change towards circularity.

Keywords: circular carbon economy; energy transition; carbon capture and utilization; collaborative energy economy; recuperative technologies; energy efficient economy

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1. Introduction

The path towards net-zero by 2050 between developed and developing countries seem divergent, based on the historical data on CO_2 emissions. While developed countries will see a decline in CO_2 emissions by about 33% between 2020 and 2050, emerging and developing countries will experience an increase in energy demand with its attendant increase in CO_2 emissions [1]. This may be described as a manifestation of the environmental Kuznets curve or even a CO_2 emission life cycle, as the polluted industries move from developed economies into developing economies. The decline in CO_2 emissions in advanced economies may be attributed to the positive impact of climate change-related policies and innovations on the technology front. For developed economies, achieving net-zero emissions by 2050 faces the challenges associated with legacy infrastructure in electricity, industry, and transportation [1]. Increased populations, fast economic growth, infrastructure, and urbanization are the drivers of the relative increase in energy demand and its drag on the CO_2 emissions curb going into 2050 in developing countries [1]. Apart from the opportunity for circular economic growth in emerging and developing countries, developing countries are not affected by linear economic legacy infrastructure. The less legacy infrastructure in emerging and developing economies presents opportunity to innovate and leap frog their transition towards the CE to achieve sustainable development. This highlights the huge potential for CE in emerging and developing economies. Despite this opportunity, CE transition appears more intensively pursued in developed countries than in developing ones [2].

CO_2 emissions emanate from energy-related and non-energy-related sources. The authors in both [3,4] concluded that material extraction and product use accounts for almost half of CO_2 emissions. Specifically, the Ellen MacArthur Foundation's findings show that while the energy consumption in the residential and transport sectors generates 55% of carbon emissions globally, the remaining 45% is attributed to how goods and land are produced and managed [4]. Nonetheless, the focus of climate change crisis reversal has been on the energy-related continuum over the years through renewable energy uptake and efficiency in energy use. Achieving the transition to clean energy and efficiency in energy use alone will not be sufficient to achieve net-zero emissions in 2050 without paying attention to the non-energy-related CO_2 emissions [4]. The 45% non-energy-related CO_2 emissions reduction can be achieved through the transition to a CE conceptualized as "completing the picture of emission reduction . . . " for CO_2 emissions, as described by the authors in [4]. When CE principles are applied to cement, plastic, steel, and aluminum (the demand for these materials is forecasted to double or quadruple in the world), the findings conclude that a CE can potentially drive a reduction in emissions by 40% by 2050. With the addition of the food system, the reduction in carbon emissions can reach 45%, which will be significant in net-zero emissions in these sectors by 2050 [4]. These findings imply that the way products are manufactured has to change from the current linear production model to the circular manufacturing model. The resource-intensive manufacturing sector will thus play a critical role in achieving the transition to CE. Achieving circularity within resource flows such as material, energy, and information in manufacturing is critical but less attention has been given to the information management and sharing aspect [5]. To accelerate the transition to circular manufacturing, data management will play a critical role. This shows that CE transition strategies should be viewed in a holistic manner by identifying accelerators.

Recent years have seen vast literature on various aspects of the CE, including its conceptualization, sectoral applications, business models, ecosystem, financing, policies, behavior, and others. A circular economy is conceptualized as an industrial system that is intentionally restorative or regenerative by design [6]. Instead of the 'end-of-life' concept, it aspires to restore value, shifts towards the use of renewable energy, abhors the use of toxic chemicals that impair reuse, and aims for the elimination of waste through the superior design of materials, products, and systems [6]. CE research has been influenced by the targets of the Paris Climate Conference (COP21), held on 12 December 2015 [7].

For instance, Ghisellini's [8] review of the CE to find a balance between the economic system and environmental outcomes shows that CE origins are mainly rooted in ecological and environmental economics and industrial ecology. They find different approaches to CE transition between China and the EU, the USA and Japan. Whereas China promotes a CE as a top-down national political objective, the EU, the U.S., and Japan use bottom-up. Finally, they identify how various economic units implement a CE through the lens of the micro-, meso-, and macro-levels. A bottom-up approach relates to decision-making channels where decisions emanate from individuals, or the micro-level, to policymakers/government, or the macro–level. In situation where decision-making channels pass from policymakers/government, or the macro-level, to individuals, or the micro-level is termed a top-down approach.

Kevin van Langen et al. [9] also investigated the perception and awareness of stakeholders towards a CE and concluded that academics prefer a more holistic top-down approach, while administrators and civil society use a bottom-up approach. They also showed that administrators utilize CE principles for economic growth and job creation and academic's expectation include environmental benefits from the CE transition.

There is no doubt that technology will be an essential lever in the transition to a CE, and the authors in [10] confirmed the existence of a wide range of influences that Industry 4.0 technologies can offer companies for improved circularity. However, technology alone is not enough to achieve a CE due to path dependence and possible rebound effects [11]. Additionally, technological innovation toward a CE should be "economically reasonable". Consequently, neither economic guidance nor technological guidance alone can sufficiently support a CE [11]. A combination of technological advances, policy tools, building ecosystems, understanding CE principles, and tackling behavior seem necessary to guide relevant decisions to transition to a CE and help achieve climate change containment and sustainable development.

Finance is an important enabler of technological innovation as it efficiently allocates resources to the most productive economic agents [12]. Thus, technological innovation toward the CE transition will require financial resources. Nonetheless, financing circular economy projects might not be a priority for traditional investors, and both businesses and the financial sector perceive insurmountable barriers and mostly blame each other for failing to play their expected roles [13]. The argument from the business sector is that the financial sector is not able to assess the benefits of circular approaches and exaggerates the risks associated with circular business models. The financial sector, on the other hand, argues that circular economy projects are applying new technologies and business models that are inherently risky and not bankable. Risk, its perception, and assessment by various players become stumbling blocks in deploying financial resources to accelerate the transition to a CE.

As the CE transition evolves, there is still no consensus on the best policy fit for uptake. Some CE policies and strategies have been criticized for not being resilient [14]. They conclude that further research is needed to analyze complex adaptive system thinking, allowing for more socially equitable development in a sustainable environment. Domenech and Bahn-Walkowiak [15] highlight the complexity of CE policymaking in Europe due to fragmented and competing goals and visions. Achieving net-zero emissions using the CE as a lever will require policies to mobilize financing of CE technologies with new business models within an ecosystem that promotes resource-efficient behaviors. Achievement of the CE transmission faces several dynamic and interrelated barriers that form what has been referred to as the "web of constraints" [16].

Meseguer-Sánchez et al. [7] propose further research on how the CE paradigm can help to achieve net-zero emissions by 2050 after their extensive review of the CE literature to understand the future directions of research in this area. Despite the recognition of the role of the CE in achieving net-zero emissions, the understanding and path towards this remain unclear within CE scholarship. Merging previously disjointed and less visible published material from a varied body of scientific literature across various levels of study, this systematic literature review explains the state of research on financing technologies for building the CE ecosystem with behavioral acceptability. Premised on this background, our study systematically reviewed the CE literature across different themes, sectors, and approaches to identify accelerators for transitioning to a CE. Also, to respond to major components of the CE supply-side technology and finance, and demand-side behavior and ecosystem, the research explored how technology, finance, behavioral, and ecosystem studies in the CE context can be integrated as a decision tool for CE transition. The findings of this review will help unify the literature around CE technology, finance, ecosystem, and behavior and provide the basis for conceptualizing the accelerators of CE transition as an integrated phenomenon. The study will also contribute to highlighting the research gaps within CE accelerators, the technology, finance, ecosystem, and behavior. The objective of the research was achieved by using a systematic literature review methodology. The rest of the paper is structured as follows: Section 2 presents the data collection and methodology. Section 3 briefly discusses CE principles and concepts. Section 4 looks at findings and discussions, and Section 5 concludes the paper.

2. Data Collection and Methodology

For the CE transition to occur, there is a need for support from varied stakeholders including policymakers. CE policymaking should respond to technology, infrastructure, behavioral change, and context [17]. To achieve CE transition, policies have to respond to many barriers that stifle its uptake, as reported in the literature reviews. Among these barriers are the lack of financial support for circular businesses; social issues owing to lack of public awareness; institutional challenges manifesting in a lack of government support, technology and information due to reduced sharing of knowledge and organizational attitudes; and circular supply chain issues occasioned by partnerships and networking limitations [17,18]. A recent study built on the work of Kivimaa et al. [17] conducted an extensive review of circular manufacturing with a focus on data as an accelerator of CE [5,19]. They conclude that specific and general data categorization, when gathered and processed for information, can enable CE adoption. The conceptualization of the type of data to be gathered and monitored includes the "product", "processes", and "management", using appropriate "technologies" to gather and use them. Following the findings of Acerbi et al. [5], a conceptual data model was developed, verified, and validated through the scientific literature and experts interviews. This provides an important conceptualization of how CE information can be managed and shared within an organization and ecosystem to accelerate and guide decision-making and aid the adoption of CE practices.

For CE uptake, both supply-side and demand-side aspects of the CE must be considered. The supply side of the CE is driven mainly by circular business models [20]. Ghisellini [8] cited EUKN (2015), who described the circular business model as "the driving force in the shift towards a CE". The demand side of the CE is anchored on the consumer, similar to any other product or service offering. Supply chains within the CE involve the consumption process including production and distribution [21]. The authors in [1] note the relegation of the consumer to the background in CE definitions. This is identified as a research gap regarding the consumers' perspective on CE. The authors in [22] concluded that "little is known about consumers' willingness to participate in [CE]." The authors in [23] asserted that excluding the consumer's perspective in CE product and service offerings risks developing non-viable business models because of a consumer demand deficit. The consumer, in other words, is seen as the most central enabler of circular business models [24]. The current research themes of technology, finance, ecosystem, and behavior are built on the work of [8,21–24]. The supply side, represented by the circular business models is influenced by technology and financial availability. The rationale for this is that financial allocation plays a role in determining which technology is developed and which business models should be allocated capital. Even though the ecosystem and behavior affect business models as well, the latter is seen to affect the demand side more. Consumer behavior, for instance, influences the market demand for products and services, and the acceptability of circular products and services will depend on the acceptability from consumers. The ecosystem may have an overarching impact on both the offerings of circular businesses and the behavior of consumers; the CE ecosystem may influence demand more as it fosters public convenience towards circular products and services. These elements are represented in Figure 1.

The traditional method of conducting a systematic review was adopted for this paper [25]. The systematic review process entails planning the review, conducting the review, and reporting of review [26]. A systematic review is a creation of the medical sciences and is mainly undertaken using the requirements of the "Preferred Reporting Items for Systematic

Reviews and Meta-Analyses" (PRISMA) statement [27]. The PRISMA statement details a checklist of 27 points and an informational flow template for conducting a review [27]. Figure 2 summarizes the steps implored in the methodology for our study.

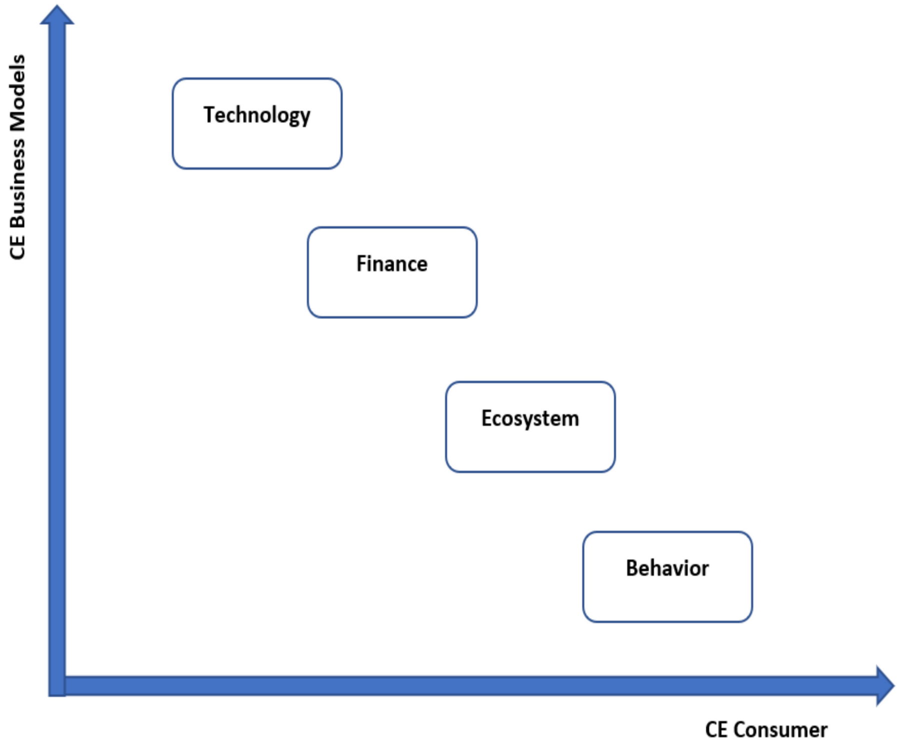

Figure 1. Theoretical Framework. Source: Adapted and revised by authors from [8,21–24].

Peer-reviewed published studies were selected based on the research question of accelerating the transition to a CE to achieve net-zero emissions by focusing on technology, ecosystem, finance, and behavior. We searched for published English papers on the topics of interest spanning 2016–2021. The topic of interest included the CE and economic sectors (agriculture, industry, commerce, energy (fuel production, electricity, and transportation), water, and tourism), CE, and accelerators (technology, ecosystem, finance, and behavior). The literature search was performed using the ScienceDirect database [8]. The keywords used included "CE" and „industr*", "CE" and "agriculture", "CE" and "commerce", "CE" and "tourism", "CE" and "energy", "CE" and "water", and "CE business model*", "CE principles", "CE" and "recycling", "CE" and "public policy", "CE" and "carbon capture and storage" or "carbon capture and utilization", "CE" and "technolog*", "CE" and "ecosystem", "CE" and "finance" and "CE" and "behavior*".

The search results were exported to Rayyan for screening. Rayyan is a cloud-based platform for screening citation data [28]. The number of papers initially extracted was 427, and 74 duplicate papers from the search results were excluded (see Figure 3). The Journal of Cleaner Production featured more circular economy related articles (94 articles) as shown in Figure 4. The research inclusion/exclusion criteria were then applied based on a study of abstracts by one reviewer and a blind review by another reviewer. The research inclusion criteria were based on selected articles that addressed the identified thematic areas of the systematic review, including technology, finance, ecosystem, and behavior; the scope of the article was within the identified areas of the CE, such as agriculture, industry, commerce and services, energy, water, and tourism; the article scope covered the CE principles. Exclusion criteria were applied to the papers based on the topic's relevance to the research interest and non-primary papers such as the literature review studies. Also, non-English papers and papers that did not have a transparent methodology for arriving at findings were excluded. The title and abstract review of the articles led to the exclusion of 229 papers. The remaining 124 papers were subjected to a full paper review, and a further 88 were excluded. The exclusion criteria for the papers regarding the full paper review included removing papers that were literature reviews, book chapters, or conference papers, or had an unclear methodology, had a lack of clear findings, or were papers that could not be classified under any of the thematic areas of the review. Forty-four (44) papers were then synthesized, and the results were reported.

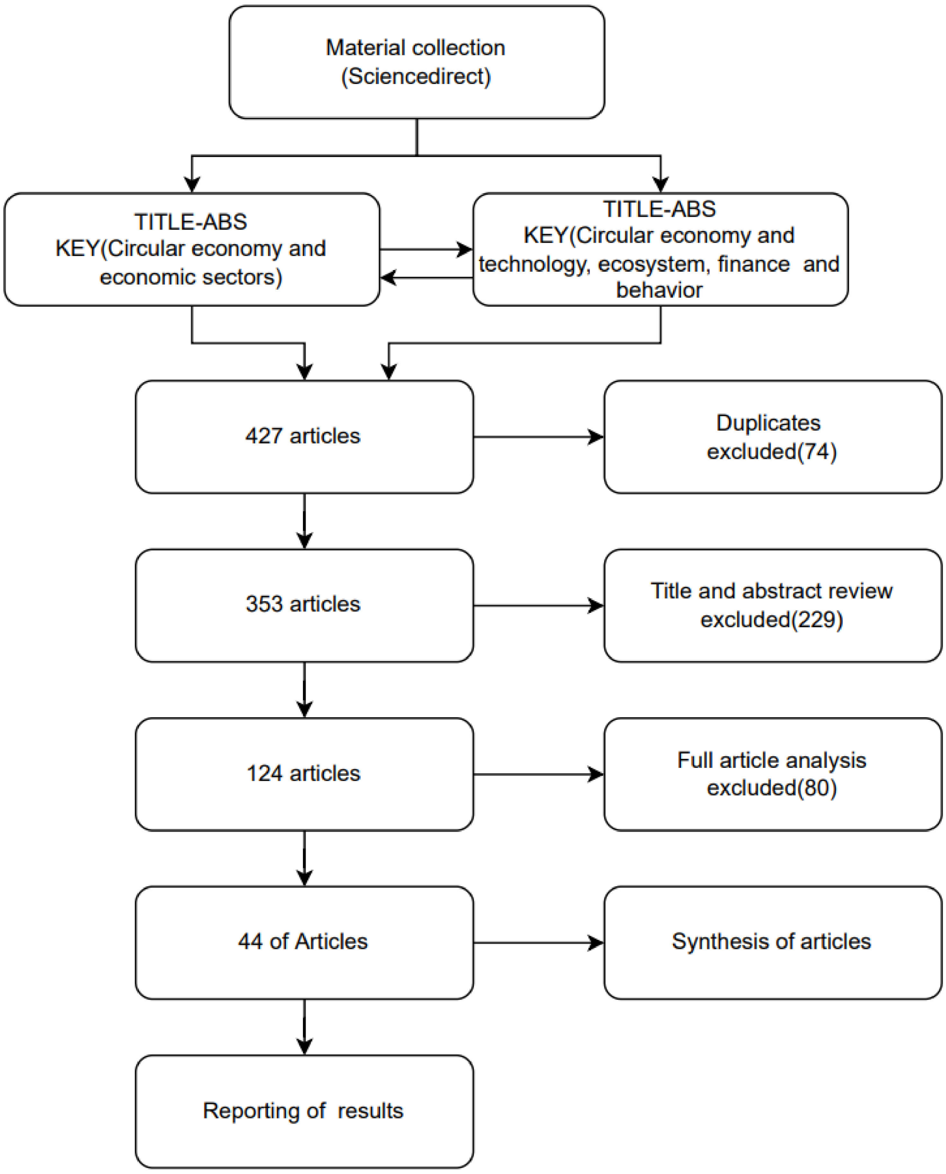

Figure 2. Research methodology flow chart.

The synthesis of the selected papers was conducted to understand the state of the literature and the characteristics of studies, as well as to identify potential research gaps that need to be addressed. Research synthesis is the collective term for a collection of methods for summarizing, integrating, and possibly aggregating the findings of different studies on a topic or research question [29]. Even though both quantitative and qualitative synthesis can be applied to answering a research question, the current research adopted qualitative analysis. The qualitative synthesis paradigm was used due to the nature of the topic. The qualitative synthesis allows evaluation of the effects of intervention and the way it may be influenced by measured study characteristics and data quality [30]. Quantitative analysis, on the other hand, provides estimates of size effect and reasons for heterogeneity in the effect of the intervention. A meta-analysis is a systematic review that uses quantitative methods to synthesize and summarize results and is now applied frequently in ecological research [31].

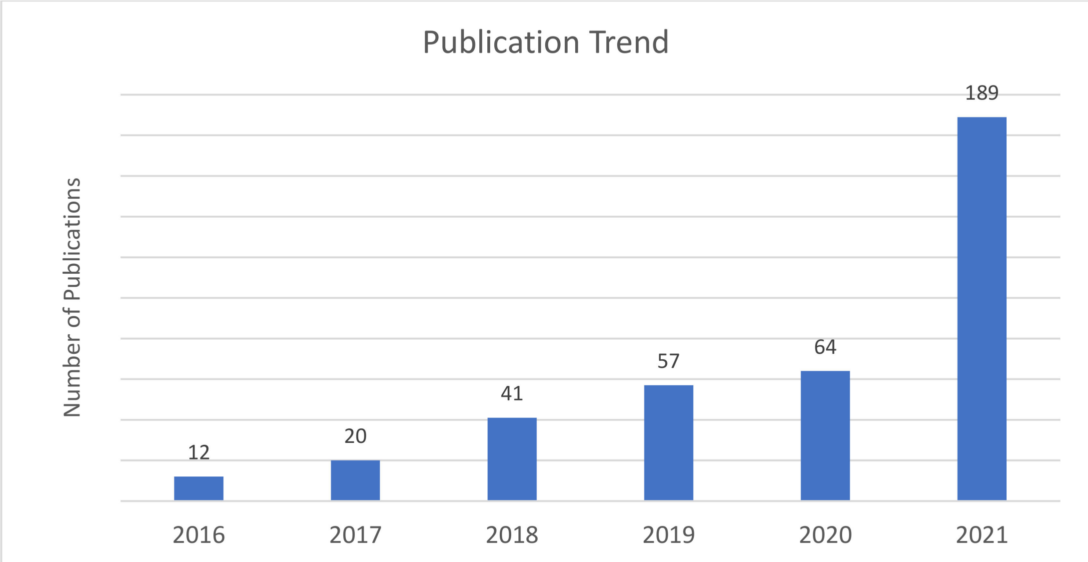

Figure 3. Publication trend. (Authors).

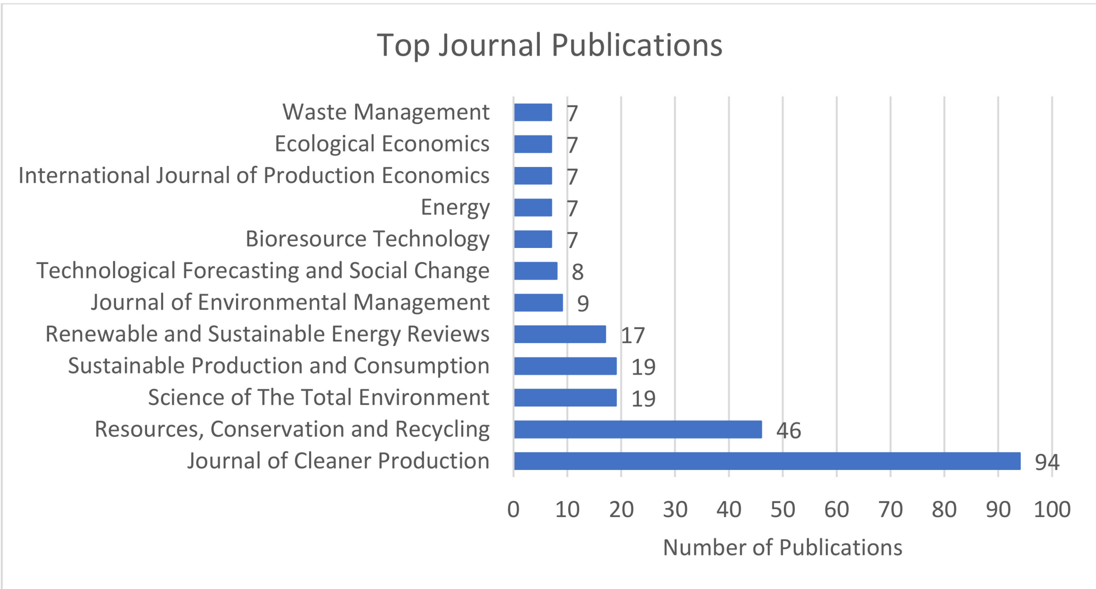

Figure 4. Top Journal Publication (authors).

Unlike physical sciences, research in the social sciences tends to be low on consensus concerning key research questions [32]. Studies in the social sciences do not usually address the same problems and, more importantly, ask the same questions; when the same questions are asked, economic and social contexts are significant in interpretation. Consequently, aggregative approaches to research synthesis in this area may become a daunting task.

3. Circular Economy's Concepts

3.1. CE Principles

There is no consensus on the definition of the concept of a CE due to its continued evolvement. The principles of reduce, reuse, and recycle (3Rs) provide a foundational definition of a CE [33,34]. The European Commission added "recover" to the 3Rs to make it 4Rs [35].

The authors in [8] conducted a thorough literature review of CE and concluded that the CE principles consist of design, reduce, reuse, recycle, reclassification of materials into technical and nutrients, and renewable energy. The authors in [6] conceptualized CE using the following definition: "A CE is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems".

The introduction of the concept of CE is attributed to Pearce and Turner (1989), as noted by [8,36,37]. The CE principle is rooted in industrial ecology, which emerged in opposition to the current conception that the environmental impacts of industrial systems should be studied by keeping separate the source "industrial system" and the receptor of the impacts, "the environment". Industrial ecology philosophy is that the industrial system and the environment should be analyzed as a joint ecosystem characterized by material flows, energy, and information and by providing resources and services from the biosphere [38].

Some prior theoretical studies have influenced the present understanding and practice of the CE. Some of these studies are cradle-to-cradle [39,40], looped and performance economy [41], laws of ecology [42], and the blue economy [43].

In a more recent extensive study, the authors in [44] defined the CE broadly as the following: "CE is an economic system that targets zero waste and pollution throughout materials lifecycles, from environment extraction to industrial transformation and final consumers, applying to all involved ecosystems. Upon its lifetime end, materials return to either an industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle. It operates, creating value at the macro-, meso-, and micro-levels and exploiting the sustainability nested concept to the fullest. Used energy sources are clean and renewable. Resources use, and consumption is efficient. Government agencies and responsible consumers play an active role ensuring correct system long-term operation". This definition was arrived at after an extensive review of the CE literature systematically, by trying to incorporate and consolidate the various aspects of the CE by explicitly mentioning the role played by stakeholders and the scale of accountability (as in individual, ecosystem, and countrywide), and the role played by governments and citizens for long-term sustainability.

3.2. CE at the Micro-, Meso- and Macro-Levels

3.2.1. Micro-Level

Individual and firm strategic decisions relating to allocating and using resources can contribute to CE transition, representing the micro-scale of CE implementation [45]. At the firm level, strategies such as eco-design, design for the environment, and cleaner production may contribute to circular economic transition [45,46]. The micro-level of CE practice focuses on improving the environmental performance of a particular organization, such as the reduction in resource consumption and waste discharge, or even designing products that are more environmentally friendly [47]. Consumer behavior such as promoting and prioritizing the purchase of sustainable products and services is essential [37,48]. Product and service labeling can perform a functional role in greening consumption. Labeling systems are sharply developing in Europe [35], in Asia [49] and across the world [50]. CE implementation at the company level has been focused on recycling, end-of-life management, disassembly, lifetime extension, waste management, and resource efficiency. The authors in [51] criticized the concentration of economic benefits as a motivator of the CE implementation and asserted that environmental and social outcomes should also be prioritized.

Studies on the micro-level CE practice are limited, as was reported by the European Commission [52]. Some methodological frameworks are used to determine how firms contribute to CE. At the organizational level, a comprehensive minimum cost consensus model for large-scale group decision making has been proposed where the initial experts' preferences are automatically adjusted to obtain the measurement and cost of the CE indicators [53]. This methodology is more efficient as it is less time-consuming when it comes to consensus building by experts in the measurement of a circular business. The authors in [54] suggested cleaner production and eco-design practices as alternative techniques for organizations to promote the principles of CE. There is a need to frame a new business model to accelerate the CE concept among consumers and producers, such as incentives or enforced regulations. For example, we can specify green taxes for those who ignore the CE in design and redistribute the revenue to those who consider of CE in their design of products and services.

3.2.2. Meso-Level

The CE within the meso-level view from the supply side involves the development of the eco-industrial park, and the creation of industrial symbiosis at district and network levels [37,55,56]. This creates an ecosystem that allows hitherto separate organizations to converge to form complex interplays of resource exchanges such as water, raw materials, energy, and even by-products [57]. Chertow distinguished between industrial ecology and industrial symbiosis. The industrial ecology level of analysis ranges from facility to national and even global levels, but industrial symbiosis essentializes inter-firm-level analysis with physical exchanges among several organizations. Participation of industries close to each other reduces the distance among participants, positively affecting energy demand. Thus, siting production units to achieve industrial symbiosis can reduce waste and emissions [58].

Industrial symbiosis allows production plants, industrial parks, and networks to utilize shared resources cooperatively for their mutual benefit. This is carried out through resource flow trade and industrial by-product wastage, and can potentially reduce resource use to avert environmental problems and reduce both firms' and the nation's dependency on resources [59]. A reduction in production costs raises industrial productivity and competitiveness [59].

In evaluating the meso-level uptake of the CE, some methodologies look at the level of cooperation among firms and individuals for achieving important milestones within the industrial symbiosis and industrial ecology. Some findings investigate the level of cooperation between different actors within the supply chain in achieving CE outcomes [60]. Also, the authors in [61] proposed a conceptual framework of green supply chain management that incorporates the principle of CE into the supply chain process through three levels of hierarchical indicators. The authors in [62] contend that even though CE analysis at the meso-level is proposed by the authors in [8,63], the conceptualization is not well presented in the literature. They proposed a conceptual framework that combines micro- and macro-levels with meso-level indicators to address this. They argued that their conceptualization will provide more direct feedback for policymakers. These meso-level indicators put societal needs as the driver of the indicator, with the consumptive perspective taking a central role.

3.2.3. Macro-Level

Macro-level analysis of the CE may involve the city, province, country, or region as the unit of analysis [64]. Macro-level initiatives towards CE transition are usually undertaken by governments and policymakers [65]. Some studies have concluded that macro-level implementation of CE entails integrating and redesigning the industrial system, infrastructure system, social system, and cultural framework [66]. The macro-level, referring to regions, cities, and municipalities, has seen most studies in the CE literature [67]. This development is unsurprising since governments and the public have set the CE transition agenda.

The eco-town is one of the CE implantation nodes and originated from the USA within the domain of urban ecology, and the objective was to redesign cities to allow for more ecological concept realization [68]. Japan has also witnessed eco-towns from the Japanese government since 1997, involving urban and industrial centers in symbiosis projects [69].

This allows for zero-emission goal achievement and economic benefits by solving, for instance, the shortage of landfill sites and resuscitating the textile industry [69].

Collaborative consumption models are also cited as one of the means for a consumer to shift from the present business-as-usual model to a CE [70,71]. Some economic and business models such as sharing, trading, bartering, lending, renting, and collaborative models have also been discussed in the macro-level analysis of the CE. For example, a renting business model ensures that an individual does not own assets but services are utilized by multiple agents through fees [72]. The authors in [8] asserted that various approaches are seen in collaborative consumption depending on their goal. This ranges from profit to non-profit, or both. Collaborative consumption is currently popular in car-sharing and website-based networks sharing different products (music, textbooks, fashion, and art, among others).

Some methodologies have also been proposed to assess the CE at the macro-level. The authors in [73] created a CE index that combines recycled materials with economic value. The authors in [74] developed a CE index that analyzes various CE principles. The authors in [75] also proposed two CE composite measures to evaluate the dynamic and static nature of CE conditions in Europe. These tools provide policymakers with the means to assess the effectiveness of the CE transition.

3.3. Circular Carbon Economy

The last decade has seen CO_2 emissions within the energy sector increase to 31.5 Gt in 2020 [1]. Industries account for one of the most significant contributors to environmental degradation, and this calls for firm strategies and policies to respond to their operational impact on the environment [76]. Products made from CO_2 emissions are in the beginning phase [77]. Theoretically, oil-based fuel or chemicals can be produced using CO_2 conversion technology [78]. The authors in [79] proposed a bottom-up model that characterizes the life cycle of 90% of plastics in the world. They examine paths to achieving net-zero emissions in plastics. Their findings show that net-zero-emission plastics are achievable through biomass and carbon dioxide utilization with an effective recycling rate of 70%, while saving up to 53% of the energy.

Mitigating the carbon emissions impact on the environment for hydrocarbon-endowed countries provides a more sustainable way of tackling climate change, and this may be achieved through the circular carbon economy (CCE). The concept of a circular carbon economy provides a new way of dealing with climate goals, seeking to complement other options by encouraging efforts to mitigate carbon accumulation in the atmosphere [80]. The difference between the CE and CCE is that the CE focuses on the broad sustainability principles to govern firms' and households' behavior, whereas the CCE focuses exclusively on carbon and energy flows. Developing new and sustainable value chains through fossil fuel and waste as substitute raw materials for the chemical industry by coupling the chemical, energy, and waste management sectors presents a viable and future-oriented potential for closing the carbon cycle [78]. This system can achieve zero emissions by integrating renewable energy, fossil fuel, and waste [81]. CCE has benefits, especially in terms of resource conservation, environmental impact mitigation, technological advantages, and product and input flexibility. Implementation obstacles include technological, institutional, and human dimensions [82]. To douse the possibility of path-dependent effects by matured carbon-intensive industries, measures such as responding to information gaps and misconceptions and regulatory actions are proposed [82]. These measures will provide the needed policy intervention to prevent a drag in achieving net-zero emissions.

4. Results and Discussions

4.1. Enablers of CE

The results show that a chunk of the articles analyzed were dedicated to the technological aspect of the CE, with relatively fewer papers discussing behavior and finance themes. Of the 44 articles analyzed for the literature review, 50% related to CE technology. Reviewed papers that addressed finance, behavior, and the ecosystem accounted for 27.3%, 11.3%, and 11.3%, respectively. Despite the importance of technology in the CE transition, accelerating the CE transition will require other enablers such as finance, behavior, and the ecosystem, as the authors in [83] concluded that business models [technology and finance, behavior and the ecosystem] at three levels (micro, meso, and macro) are enablers of the CE. The uneven distribution of the studies highlights a vital research gap that needs to be addressed.

4.2. Technology

Technological innovation provides the ingredients for the advancement of modern society, and CE has not been left out of the possibilities offered by technology. The literature review revealed that most of the studies on technological applications in the CE relate to the regenerative element of the ReSOLVE framework of the CE [84–90]. Closing the loops and digitization have driven CE technologies in the reported literature. Technologies such as refurbishment in the construction sector, disassembly in the electronics sector, battery reuse in the automotive and residential sectors, and wastewater treatment in the water system have been piloted in reported studies with positive results [91–95]. Recognizing that technology needs to be sustainable, especially with socioeconomic agents, [91] investigated eight different technological solutions and concluded that the autonomous disassembly for electronics was compatible with the attainment of social sustainability in implementing the CE. The novelty in their methodology in assessing social sustainability was that they decoupled target performance between the current and future performances. Also, the performance measurement stemmed from wastewater treatment and sewage sludge treatment with targeted use of regenerated products in the agriculture sector. Whereas the authors in [89] concluded that valuable agrochemicals can be drawn by applying subcritical water as a green solvent, other findings show the extraction of energy in the form of hydrocarbon from dry wastewater sludge [90]. Digital technology application in the CE has attracted much research due to the fourth industrial revolution. Some CE applications in the literature review include business analytic capability, additive electric vehicle manufacturing, artificial intelligence, artificial vision, big data, cybersecurity, robotics, and virtual and augmented reality [10,96]. These applications are mainly used in energy consumption, waste management, emission generation, and mitigation.

Further, the results show that the energy sector has seen much attention in terms of CE technological studies across various elements of the CE, as most of the studies reported relate to this sector. Renewable energy technologies such as bioenergy, solar PV, energy storage, and energy recovery were also studied [85,86,88,89,92,94,97–100]. To optimize electricity generation by minimizing cost and maximizing production to meet demand sustainably, the authors in [101] used the "nature-inspired optimization" methodology to propose a combination of solar power and traditional power generation. Their findings show that using solar power plants minimizes cost and emissions, which can provide a decision support tool for a utility generator.

Also, it was observed that most of these studies were focused on reducing carbon emissions or eliminating them. This is commendable, but energy security constraints imply that carbon capture and storage technology provides a practical window for circulating carbon that may be produced through fossil fuel production and use. More direct air capture means more direct emissions of fossil fuels are possible, while still meeting climate goals, as their negative impact is mitigated. CCE provides a framework for emission reduction technologies, rather than reducing the use of hydrocarbons, and recognizes the economic value of carbon [102]. To prevent path dependence on hydrocarbons, a CCE index has been developed to track elements of CCE quantitatively, report progress areas toward net-zero emissions, find out how fossil fuel use can be made consistent with net-zero emissions, and report policy experiences [103]. Based on the 2021 CCE index, no single country has yet achieved a CCE with atmospheric carbon dioxide, with Norway, the United Kingdom, and Germany, being the top three ranking countries on the 'performance and enablers sub-indices [103].

Technological adoption within the CE is not without its challenges and always has to contend with balancing the need for innovation with cybersecurity, economic attractiveness, laws, and policies [104]. Even though the systematic literature review results showed that a significant number of articles are dedicated to the technology theme, it was observed that technologies relating to design within the CE are missing. Technology innovations stem from knowledge and accelerating the transition to CE from a linear economy will require knowledge on how to replace current materials with recyclable materials and materials with longer lifespans [105]. Also, a technical skills deficit may create challenges in identifying, assessing, and implementing more advanced technical options for CE technology [106]. More importantly, data technologies need more studies as the lack of databases for sharing waste information and technologies to establish CE business models may stifle CE transition [107]. In summary, more studies are needed regarding circular design technologies and data gathering, transformations, and analysis of circular business practices and circular consumer behavior (the use of artificial intelligence, machine learning, and deep learning will provide useful tools).

4.3. Finance

The literature review examined the research question from four identified thematic areas, including finance. Relatively few papers (5 out of the 44 papers) were reported in the literature findings to have looked at different aspects of CE within finance. The major areas in these papers include the opportunity cost of not implementing a CE [108]; comparison of two bioenergy projects' viability [109]; profit motivation of circular investors [110,111], and payback of circular investment [112]. To assess investment viability within the CE, it is essential to balance private return and environmental sustainability. Profit sends a strong signal to investors in any economic endeavor. Some studies' findings indicate that CE investments are viewed within the prism of profit maximization with economic incentives motivating companies to transition from a "linear economy" to a "CE" [110]. The importance attached to profit is further illustrated by the authors in [111], who investigated the link between recycling investment, product price, and the demand of green consumers within the CE. They applied a structural model to identify cost, markup, and sales as the determinants of the level of recycling and pricing thereof. They conclude that if the recycled resource used to make a product is less expensive than the virgin resource, then a firm will be incentivized to allocate capital to it. According to the authors in [109], in deciding to invest in two technologies for bioenergy between palm oil and microalgae in laminar photobioreactors, a benefit–cost analysis (BCA) methodology considering the present net value (NPV) and the benefit–cost ratio (BCR) as the primary evaluation criteria is applied. When private investment motive alone is considered, biodiesel production from palm oil is more attractive than microalgae in laminar photobioreactors. However, when the efficiency and effectiveness of public funds are considered, then microalgae in laminar photobioreactors becomes superior because the public BCR and NPV are higher with agriculture land use optimization and producing a better carbon balance.

The findings suggest that profit maximization and circular business viability are motivating companies to adopt CE principles and financial assessment has yet to integrate CE principles into evaluation and asset pricing. Profit and viability are influenced by the perception of risk inherent in the circular business. Usually, financial institutions do not price the environmental benefit of circular business, which usually leads to elevated risk and demand for a higher return. Using recycled materials in production provides an opportunity to conserve the environment and this should be recognized in the pricing of the recycled material. This means that when the negative environmental impact of virgin material is internalized, its price will be relatively higher compared to a recycled material and thus provide better asset pricing. Financial institutions need to acquire the knowledge and skills that will allow them to properly assess the impact of circular businesses and price those impacts and develop risk assessment methodologies for circular businesses [13]. Also, circular project promoters need to keep abreast of how to properly present circular business impact to improve project viability. These issues highlight the need for more research on circular metrics for project assessment, and how it can be integrated into financial products and services that will allow the financial sector to contribute to accelerating the transition to CE and net-zero emissions by 2050. Also, policymakers need an instrument that will help to achieve de-risking of circular businesses and allow capital to flow into that sector, and this will require further studies.

4.4. Behavior

According to the reviewed papers, the behavior of consumers towards products within the CE has been investigated by some studies. With few papers compared to CE technology and the CE ecosystem, most studies on the behavior theme are concerned about motivations of behavior towards the CE and the perception of consumers towards recycling [113–116]. Societal norms, social pressure, perceived behavioral control of decision-makers, and income level influence the behavior of consumers [117]; and businesses toward a CE [113,114,116]. Whereas green norms and social pressure drive positive behavior toward a CE, the capability of organizations manifesting in "technological capabilities, financial capabilities human resource capabilities, and infrastructural capacity" conceptualized as firms' perceived behavioral control impedes CE adoption within organizations [114]. Aside from the value proposition of CE products, consumers also behave towards them based on how CE value proposition is communicated. Thus, persuasive communication is seen as a moderator for a positive view of CE-inspired products, as seen in the remanufacturing of fridges [115].

The way the public perceives sustainability and CE can impact greatly on the acceleration of the CE. Linear economic thinking has been ingrained in the minds of many, and much effort is needed to shift mindsets and attitudes toward a CE. Since the CE is still evolving with less awareness, the literature review findings that societal norms and social pressure influences the public adoption of circular products mean that behaviors can still be subjected to linear economic thinking. This will constrain the acceleration to a CE as consumers' mindsets are the foundation of circular consumption systems, as they present the springboard for engaging with circular offerings [118]. The risks perception of circular businesses may also be influenced by attitudes of financial institutions towards them. To provide more information to the public towards circularity, there is a need to understand public behavior toward circular products and services, paying particular attention to context and local conditions. Also, behavioral influence through nudging tools can be used through experimental studies to provide evidence that can support policymakers to design instruments that help foster a transition toward a CE to achieve net-zero emissions by 2050.

4.5. Ecosystem

The complexity and interdependencies of a CE mean that no single company can achieve it alone and, thus, ecosystem-wide orchestration is necessary [119]. The reported studies looked at the CE ecosystem from various scales, such as micro-level incentives, macro-level policies, and cities and municipalities for both the meso- and macro-levels. The important role of the public and private institutions at local and regional levels in driving the CE ecosystem development at the macro-level is emphasized [120]. This is important because building an ecosystem for a CE is a deliberate economic function that needs public policy support to attract the private sector. The lack of CE policies to regulate standards and its possible unintended consequences have been discussed [121–123]. Some proposals on the various areas that policies can target include standards and norms, liberalization of waste trade through virtualization, tax reliefs for circular companies, eco-industrial parks, and public awareness [124].

There is an established theory that economic agents respond to incentives, and this has seen some studies in the reported literature investigate the various incentives that can be used to attract both providers of CE products and services, and consumers. From both the supply and demand sides, some green incentives have been reported to contribute to

CE transition, including subsidy and tax benefits for implementing CE practices, charging a premium price for green products, and the availability of recyclable materials at a cheaper rate [125]. These incentives can be made possible through government and civil society acting as intermediaries to combine the motivations for a lower price from the consumer and the moderation of the appetite for a higher return by the seller [126].

Municipalities and cities can play a critical role in facilitating the CE by building a conducive atmosphere that brings different actors within the CE ecosystem [127,128]. The partnership between governments, businesses, and knowledge institutions can provide the necessary enablement of the CE ecosystem. The municipality, in the case of supporting the construction and textile sectors, saw the use of their own tools as their to support the CE; the use of the ownership of utilities and waste companies to support the CE; the use of rule enforcement and economic regulation, or through facilitating, coordinating, collaborating, and encouraging. The CE ecosystem evaluation perspective has also been reported in the literature review with importance attached to the connection between society's needs and CE product offerings [129]. Such an evaluation methodology is wary of the pitfall of designing products with a positive impact at the individual level but that harms society. This assessment is achieved by applying a life cycle assessment [129].

The systematic literature review findings imply the need for building the CE ecosystem if we are to experience the acceleration of the transition to a CE. Building the CE ecosystem has to be led by governments and civil society and more research is needed to provide evidence in designing incentives for this. This is where understanding the behavior of the public is important. For instance, will the consumers and producers be willing to pay a premium price for circular products and services? What waste management system can be put in place by local municipalities to encourage proper waste collection and sorting to promote the recycling of waste? Recycling may involve circular supply chains and more understanding is required regarding, for instance, balancing recycling inputs such as energy and its net impact on the environment or product quality between recycled materials and virgin materials.

5. Conclusions

Despite the recognition of the role of the CE in achieving net-zero emissions, the understanding and path towards this remain unclear within the CE literature. Merging previously disjointed and less visible published material from a varied body of scientific literature across various levels of study into a single study, this systematic literature review explains the state of research on financing innovation for building the CE ecosystem which is acceptable to the public. This study systematically reviewed the CE literature to identify how technology, finance, behavior, and the ecosystem can be used as accelerators in transitioning to a CE to achieve net-zero emissions by 2050. The review shows a predominance of studies in the literature on CE technologies looking at digitization, the energy sector, construction, waste management, and agriculture. The challenge identified with technology implementation is the need for the flexibility that manual processes have, and the investment required poses a challenge to the CE transition. The research on the other themes, especially finance and behavior, is relatively low and indicates a research gap.

The results show that studies on the connection between technology, the ecosystem, finance, and behavior in accelerating the CE uptake are lacking in the policymaking discourse literature. Most of the studies looked at an aspect of the CE, but for policymakers, there is a need for a unified study that can look at the CE transition from the perspectives of technology, finance, behavior, and the ecosystem. When this unified approach is taken, circular business promoters will be able to offer circular products and services with technologies that can attract needed financing in order to provide products and services that consumers will value because of their affinity for the CE.

Also, other technologies that target CO_2 emission impact mitigations should be investigated, including circular design technologies, data-driven technologies, and CCE. Further, financial instruments to incentivize investments in the CE needs more understanding by policymakers. Indicators and metrics for assessing circular business risks by financial institutions as well as measuring the circular impact by project promoters in the CE needs more research. The theoretical implications of these findings are that there is a need for a shift away from linear economic theory to the CE paradigm across technology, finance, behavior, and the ecosystem. This requires that, for example, the traditional theory of pricing assets by financial institutions using the bifurcated risk–return method needs revision to include environmental cost or benefit. Linear behavioral mindset appears to be the dominant thinking of the public, and this requires more research to gauge the awareness of consumers of circular products and services. Also, investigation on how behavioral study tools can be applied to measure the impact of incentives on consumers' demand for circular products and services is lacking, and future research can address these. Technology, finance, and behavior contribute to the CE ecosystem, and studies to conceptualize the unification of these four elements as a decision-making tool for policymakers will be an important contribution. The major implication of these findings is that for CE to contribute to accelerated net-zero emission, coordinated policies should be constructed to influence the amount of financing available to innovative circular businesses and technologies within an ecosystem that engenders behavioral change towards circularity.

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