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Review

On the Definition, Assessment, and Enhancement of Circular Economy across Various Industrial Sectors: A Literature Review and Recent Findings

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Abstract: The circular economy (CE) has recently emerged as a key strategy for promoting sustainability and reducing waste in various industrial sectors. This paper provides an overview of the definition, assessment and enhancement of circularity in general and in five key industries, including aerospace, wind energy, transportation, automotive and sports goods, by using data and information from the literature and for the section of the definitions of the CE also using information from the EC funded project "RECREATE". The survey reviews in detail the different definitions, assessment methods and metrics used to explore and evaluate circularity, including assessment frameworks such as Life Cycle Assessment (LCA) and assessment indicators. Furthermore, it explores the challenges, possibilities and available tools for enhancing circularity, focusing on digital tools. The survey highlights the importance of a holistic and systemic approach to circularity concerning all stakeholders along the value chain. Overall, this study aims to contribute to a better understanding of the circular economy's definition, assessment, and enhancement and provides insights for future research.

Keywords: circular economy; circularity assessment; industries; circularity enhancement; digital tools

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1. Introduction

Both researchers and professionals remain highly interested in the concept of the circular economy (CE). The quantity of published works featuring the term 'circular economy' has seen exponential growth in the past two years [1]. The imperative to address the intricate equilibrium between industrial progress, environmental integrity, human well-being, and economic advancement has led to the adoption of contemporary resource management and low-carbon development strategies exemplified by the implementation of the CE framework [2]. This demonstrates the increasing attention and research dedicated to the topic.

Despite the enthusiasm and efforts from various stakeholders, the transition to a CE presents significant challenges. The CE concept is indeed crucial for achieving sustainability goals. It offers a different approach to the traditional linear economic model of "Take-Make-Dispose". In the linear economic model, raw materials are sourced, transformed into finished products, and sold to consumers. This leads to waste generation when consumers eventually discard the goods, approaching the conclusion of their usable life cycle [3,4]. The linear economy operates under the implicit assumption that resources are limitless and not at risk of depletion during manufacturing products [5]. However, industries are increasingly focused on improving resource and process efficiency throughout the production and consumption stages to align with the principles of the CE. These principles prioritize waste and pollution reduction, optimizing product and material utilization, and regenerating natural systems. Fundamentally, the CE is built upon several pillars, such as designing manufactured products with added value to extend their lifespan, creating versatile products for multi-purpose use, systematically reintroducing solid waste into the industrial sector for competitive recycling of secondary raw materials, and adopting a systemic approach to supply chain management that evaluates the interrelationships between energy production, material extraction and environment [3]. By adopting these principles, industries can shift toward a circular flow of goods and materials, contributing to more sustainable resource utilization. CE has emerged as a potential approach for fostering sustainable development [6]. CE advocates for a strategic shift in addressing pressing environmental degradation and resource shortage issues. The core 3R principles (reduce, reuse, and recycle) aim to establish a circular system where materials are continuously recycled, energy is derived from renewable sources, and resources are utilized to create value while ensuring human health and society [7].

With growing engagement from researchers and strategists in CE practices, various R frameworks have emerged to enhance the long-term preservation of resource value over multiple product life cycles (such as 4Rs, 6Rs, and 9Rs). Presently, the implementation of the CE often relies on utilizing the 9R principles (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover) [8]. In Figure 1, the 9R framework is presented, and the source of this is adapted from [9].

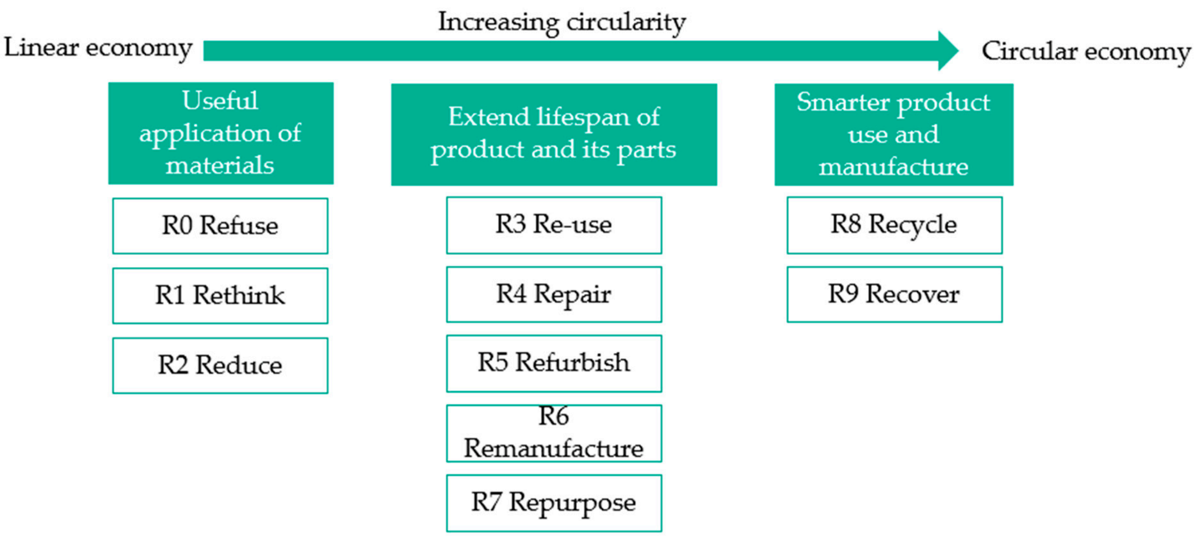

Figure 1. The 9R framework.

The importance of the CE and the widespread adoption of its principles have never been more essential due to the ever-increasing consumer demand, which has a significant negative impact on the environment and society. It offers a sustainable approach to sustaining the manufacturing of products and services while mitigating negative effects on the environment and communities [10].

The term CE has gained familiarity among scholars, politicians, and practitioners. Due to its origin in various epistemological fields, there is limited consensus in the literature regarding its precise meaning and implications [11]. Current research will focus on the target sectors of the EC-funded project "RECREATE". The main goal of the RECREATE project is to develop a set of innovative technologies aimed at exploiting the circularity potential of End-of-Life (EoL) complex composite waste (mainly carbon fiber reinforced composites CFRC and glass fiber reinforced composites GFRC) as a feedstock for profitable reuse of parts and materials in the manufacturing industry. The choice of industries for in-depth investigation within the 'RECREATE' project was strategic, guided by their significant environmental impact, resource consumption, and the potential to enhance circularity and sustainability. The rationale behind selecting these specific sectors—namely, aerospace, wind energy, automobile industry, transportation, and sports equipment—is rooted in their diverse contributions to the economy and distinctive environmental footprints. Each industry represents a unique set of challenges and opportunities for applying and advancing circular economy principles. By focusing on these key sectors, the research aims to provide comprehensive insights that align with the overarching goals of the "RECREATE' project": the aerospace industry, involving the manufacture of aircraft, spacecraft and related products; the wind energy industry, which includes the processing and use of wind to generate electricity; the automobile industry, which involves the manufacture of automobiles and other vehicles; the transportation industry, including goods and people using vehicles, such as ships, trains, trucks, and airplanes; and the sports equipment industry, which includes a variety of products used in sports, such as tennis rackets, skis, etc. Considering the varying levels of environmental impact, resource consumption, and potential for enhancing circularity and sustainability, this study will comprehensively examine circularity within each industry. Considering the diversity across sectors, this work will include definitions, challenges, and opportunities.

This paper endeavors to refine and clarify the introductory section, explicitly outlining the research questions that drive our investigation. Our primary research inquiries revolve around nuanced definitions, assessment methodologies, and enhancement strategies about circularity, particularly within the aerospace, wind energy, transportation, automotive, and sports goods industries. The distinctive contribution of this study lies in its thorough examination of the CE within these specific sectors, drawing from a wealth of literature and insights gathered from the EC-funded project "RECREATE". While the concept of the CE has garnered increased attention, its application and implications in key industries remain unexplored. Our study bridges this gap by providing a focused exploration of the CE definitions, assessment methodologies, and enhancement tools, emphasizing each industry's unique challenges and opportunities. This study is a critical addition to the existing body of knowledge, offering a comprehensive roadmap for understanding and promoting CE principles.

2. Research Methodology

2.1. Inclusion Criterion

The studies included in this literature survey were focused on the exploration of the CE in general and across various industrial sectors. Both circularity assessment and enhancement methods applied in different industrial contexts were considered, covering a range of sectors. One major limitation was that only studies published in the English language were included. In addition, for exploring definitions of the Circular Economy, only review papers or studies involving a redefinition of this concept were investigated due to the large volume of existing publications.

2.2. Literature Identification

The scope extended to both theoretical investigations and practical implementations. The literature review was carried out from May to August 2023 through all Science Direct and Springer databases. The scientific database Google Scholar was primarily utilized to retrieve papers, with a specific focus on conference proceedings articles. The search was implemented based on keywords (as presented in Figure 2) such as "Circular economy", "definition", "assessment", "enhancement", "industry 4.0", "digitalization", "aerospace industry", "wind energy industry", "transportation industry", "automotive industry", and "sport equipment industry".

2.3. Quality and Eligibility Assessment

The present review's scientific sources were first selected based on their quality, with a focus on peer-reviewed studies published in reputable journals within the circular economy sector. Moreover, each study was comprehensively examined to ensure that it fulfilled the eligibility criteria.

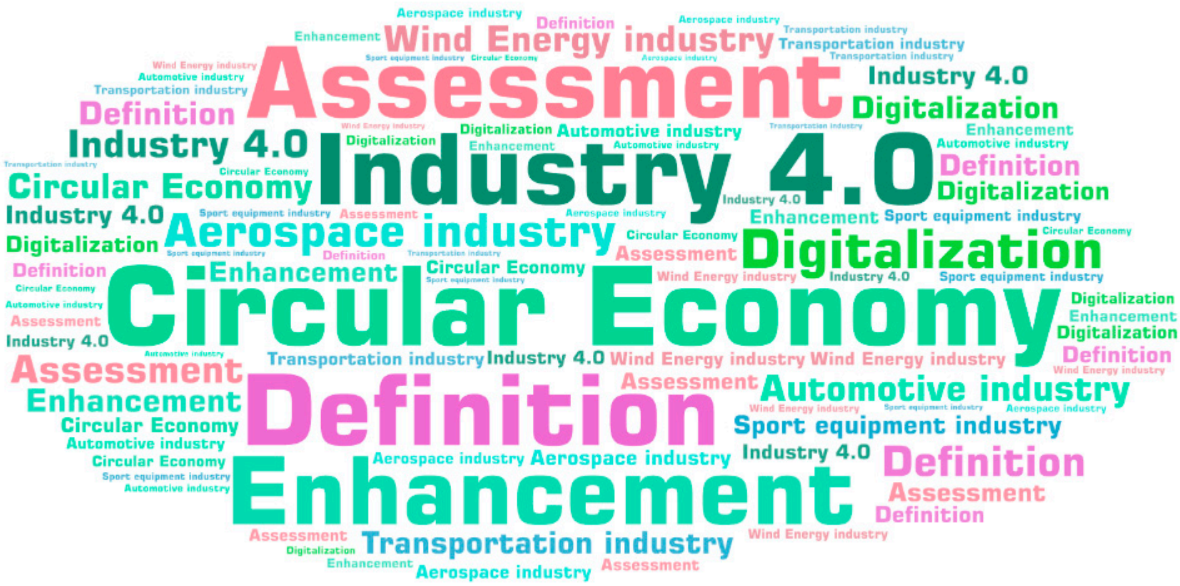

Figure 2. Word cloud on the keywords of the study.

2.4. Screening for Inclusion

Fundamentally, each potential research publication and article considered for inclusion in this study underwent an evaluation for their relevance to the subject of investigation. Initially, the study involved checking the titles and abstracts of all related papers, and any that did not align with the inclusion criteria were excluded from consideration. Following this initial screening, a comprehensive assessment of the articles was carried out, and a thorough review of their references was undertaken, both forward and backward. This process was repeated until no more relevant publications could be found.

3. Definitions and Assessment of Circular Economy

3.1. Definitions of the CE

3.1.1. Literature Review of Definitions of Circular Economy (CE)

The concept of the CE has a rich historical background and has evolved to address sustainability challenges in economic systems. An early definition in the 1970s proposed by Walter R. Stahel and Genevieve Reday, in addition to the waste hierarchy framework, laid the foundation for more sustainable resource management practices. The term CE originated in reducing input consumption in industrial production. However, its application extends beyond industry and may be adapted to diverse sources and sectors [12]. Additionally, industrial ecology in the 1990s emphasized mimicking natural ecosystems to minimize waste and optimize resource utilization [13]. However, the Ellen MacArthur Foundation significantly influenced the contemporary understanding of the CE principles. The foundation's most well-known is: *"Circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models"* [3]. Another significant definition is as presented in the EU Action Plan for the Circular Economy: *"In a circular economy, the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value"* [14].

The CE concept has a significant history that involves scholars, thinkers, and organizations who have each contributed differently to the definition. The aim is to comprehend the complete scope and the possibilities of the circular economy by examining various viewpoints. Different definitions of the CE concept have been studied and analyzed in modern sustainability methods. As a result, a variety of literature has emerged, presenting comprehensive reviews that include the interpretations of the CE across different industries. This review examines different viewpoints from researchers, practitioners, and organizations worldwide using important resources, as detailed in Table 1.

Table 1. Previous reviews and redefinitions of the circular economy.

Authors	Focus	References
Awan et al.	Review of 26 CE definitions	[15]
Geissdoerfer et al.	Investigation of the relationship between CE and sustainability	[16]
Geisendorf et al.	Review of current definitions of the CE	[17]
Alhawari et al.	Review of CE definitions across 91 studies	[18]
Nobre et al.	Review of the most known CE definitions and inputs from 44 Ph.D. specialist researchers	[19]
Korhonen et al.	Contribution to the scientific research on CE.	[20]
Kirchherr et al.	Review of 221 CE definitions	[1]
Figge et al.	Discussion about good CE definitions	[21]

In more detail, Awan et al. [15] studied 26 publications and recorded the various definitions of Circular Economy. Based on the characteristics identified in this paper, proposed a new definition for CE is as follows: "Circular Economy (CE) is an approach and a series of processes aimed at minimizing material usage in production and consumption, enhancing material resilience, closing loops, and fostering sustainable exchanges to maximize ecological system benefits". Furthermore, Geisendorf et al. [16] examined the status and analyzed the similarities, disparities, and interconnections between the concepts of circular economy and sustainability. Conceptual links between the CE and sustainability vary in the literature, encompassing conditions, benefits, and trade-offs, with the subset relationship being suggested as suitable to preserve diversity and highlight complementary strategies for practitioners and policymakers. Finally, they characterized the CE as a regenerative framework where the inflow of resources and the generation of waste, emissions, and energy loss are minimized by controlling, closing, and constraining material and energy cycles. This objective can be attainable through enduring design, effective upkeep, repair, reuse, remanufacturing, refurbishment, and recycling. In addition, Geisendorf et al. [17] suggested a modified circular economy definition following an analysis and comparison of the most prominent associated concepts. The definition they proposed for the circular economy is as follows: "Within a circular economy, the value of products and materials is preserved, waste is avoided, and resources are retained within the economic system once a product's lifecycle concludes".

Alhawari et al. [18], in a review of 91 studies on the CE, concluded that there are significant differences in how the key constructs are defined and conceptualized. While some focus more on economic and industrial aspects, little attention is given to the ecosystem. Finally, they suggested a comprehensive definition of the CE as follows: "CE involves a set of organizational planning processes aimed at creating and delivering products, components, and materials to achieve their highest utility for customers and society. This is achieved through the effective and efficient utilization of ecosystem, economic, and product cycles by closing loops for all related resource flows". Moreover, Nobre and Tavares [19], after reviewing the six best-known CE definitions and their inputs from 44 Ph.D. specialists about their perspective of the definition of the CE, analyzed their findings and concluded with one revised definition. This revised definition of the CE is as follows: "The Circular Economy is an economic framework aspiring to eliminate waste and pollution across the entire lifecycle of materials. This encompasses the stages from raw material extraction within the environment to industrial processing and eventual consumption by end-users across various ecosystems. Upon reaching the end of its lifespan, materials are reintegrated into either industrial processes or, in the case of treated organic residuals, safely returned to the environment as part of a natural regenerative cycle. The essence of this approach lies in generating value at macro, meso, and micro levels while maximizing the intricate notion of sustainability. Clean and renewable energy sources are employed, and the use and consumption of resources are optimized. Both government entities and responsible consumers actively participate in ensuring the sustained operation of this system".

In addition, Korhonen et al. [20] took a critical scientific approach to examining the emerging business concept of the CE. By carefully evaluating CE through the focal point of feasible improvement and its three key dimensions—economic, environmental and social—proposed a revised definition of the CE: "The circular economy denotes an economic system derived from societal production-consumption frameworks, aiming to maximize the utility obtained from the linear flow of materials and energy through the interconnected nature-society-nature cycle. This objective is achieved by implementing circular material flows, harnessing renewable energy sources, and adopting energy flows akin to cascading processes. A successful circular economy substantially contributes to all three dimensions of sustainable development. It does so by constraining the material and energy throughput to a level harmonious with nature's capacity and by integrating ecosystem cycles into economic cycles, respecting their inherent reproduction rates".

Kirchherr et al. [22] first gathered 114 definitions of the CE in 2017 and then, in 2023, contributed an overhauled, precise investigation of 221 CE definitions and conceptualizations. After analyzing the center components shown within the inspected definitions, proposed the following meta-definition for the circular economy: "The circular economy is a regenerative economic system that requires a fundamental paradigm shift, replacing the traditional 'end of life' concept with a focus on reducing, reusing, recycling, and recovering materials throughout the supply chain. The essential objective is to advance value maintenance and feasible improvement, fostering environmental quality, economic growth, and social value for both present and future eras. This transformative model relies on a collaborative alliance of stakeholders, including industry, consumers, policymakers, and academia, leveraging their technological innovations and capabilities" [1].

Finally, Figge et al. [21] challenged and considered that the definition proposed by Kirchherr et al. does not meet the requirements of a good definition. Therefore, they proposed a new definition as follows: "The CE embodies a resource utilization framework operating across various levels. It mandates the full closure of all resource loops, with recycling and other strategies that enhance the scale and direction of resource movements serving as integral components of the circular economy. In an ideal conceptual scenario, all resource loops would be entirely closed. However, in practical implementation, some utilization of virgin resources is unavoidable". In the process, they tried to offer their critique of how the circular economy is often defined in contemporary literature and encouraged other researchers to discuss and share their ideas with other researchers and continue the discussion on a proper definition of CE. Figure 3 shows a timeline of the definitions of the circular economy we presented above.

3.1.2. Definitions of Circular Economy (CE) in the EC-Funded Research Project "RECREATE"

CE is a promising concept for addressing sustainability. In order to realize the full capability of this model, it is important to understand various perspectives. In the EC-funded research project "RECREATE", the circular economy was explored for inputs from partners. Questionnaires were distributed to our partners from the project, and we invited them to define the term "circular economy" from their perspectives. This subsection presents the responses, as demonstrated in Table 2, gathered from this effort, providing an insight into the views of those actively participating.

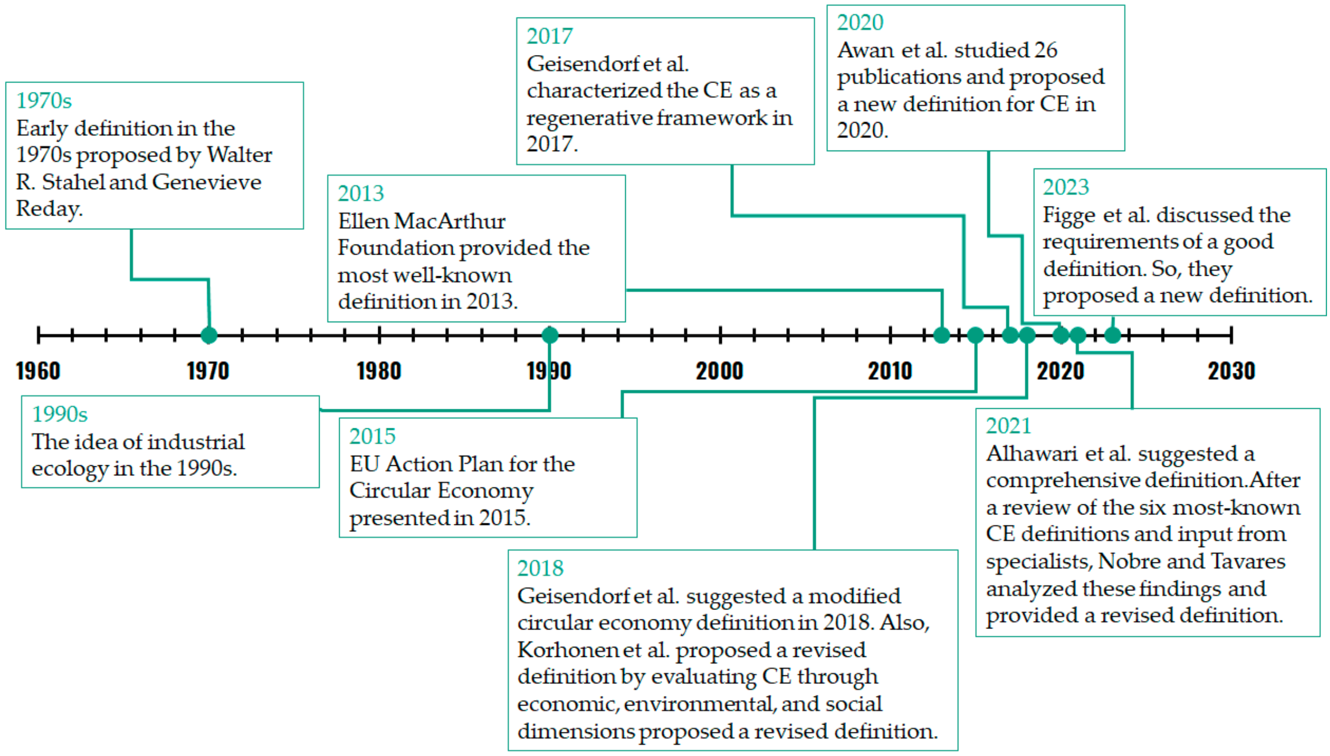

Figure 3. Timeline of the reviewed definition of the CE that is presented in this work [3,12–21].

Table 2. Definitions of the term "Circular Economy" in the context of the EC-funded research project, "RECREATE".

Responses from the Questionnaire	Definitions of Circular Economy
A	The circular economy is a constant optimization process of minimal waste and product value loss. In an ideal case, this would mean every batch or gram of any material would slowly downcycle through several product lifetimes, always entering new suitable applications until none are found, and the remaining value in the material is recovered either as chemical components or as energy.
B	From the perspective of circular business models, slowing, narrowing and closing loops of resource flows are equally important for the circular economy.
C	Circular economy means returning the intrinsic value of a material/raw material to existing cycles as best as possible after the first phase of its life. This can be both as a substitute for new raw materials and to increase the property level of other materials.
D	Reuse of products, assemblies, parts, materials and molecules, possibly without any loss.
E	Creating a society and business economy that uses materials and products in multiple cycles.
F	Reuse of products, upcycle and recycle materials/products/consumables as often as possible for a close-loop economy that benefits all areas of sustainability.
G	A circular economy is the closing of the raw material chain to form a circle, whereby the material, emissions, and energy must be considered.
H	A model aiming to maintain the value of products, components, and materials long-term, characterized by a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields and minimizes system risks while managing finite stocks and renewable flows of materials.
I	Reuse and recycle some end-of-life materials to valorize them to provide the same or new functionalities.
J	A measurement that (a) can minimize usage of non-renewable resources, (b) popularize resource usage best practices, (c) deploy best practices, and (d) build recycling facilities.

3.1.3. Re-Definition of Circular Economy

After a careful comparison of established definitions and the insights gathered from the questionnaires inside the project "RECREATE", we propose a refined definition of Circular Economy as follows: "The Circular Economy (CE) is a visionary economic model that focuses on closed cycles where, ideally, there is an endless regeneration of resources. CE should be shaped through supportive regulations and policies. This transformative concept emphasizes the integration of renewable energy and sustainable practices. CE prioritizes circularity, minimizing waste and maximizing value creation, promoting a harmonious interaction between society, economy and environment, and reflecting a collaborative spirit of innovation and responsible resource management".

3.2. Assessment of the CE

Assessing the principles of the CE is essential in understanding their real-world impact. It provides a way to understand how well different industries are incorporating circular strategies into their practices, essentially showing us how they're adapting to a more sustainable approach. By evaluating the real-world application, knowledge is gained, and various problems, barriers and possibilities for improvement for the transition to a circular economy are identified. In addition, the practice of assessment promotes transparency and continuous improvement, ultimately leading society towards a more harmonious and sustainable relationship with our planet's limited resources.

Circularity assessment tools evaluate the impact or benefits of a circular system, aiding in selecting preferred circular strategies or gauging the sustainability enhancement of existing systems. These tools are divided into two categories: assessment frameworks and assessment indicators. Frameworks offer multiple indicators tailored to specific cases, while indicator-based tools provide assessment through a single indicator, like resource potential. Both types encompass burden-based measures (e.g., CO_2 equivalent, mineral resources, and fossil fuel energy) and value-based indicators (e.g., euros, years) that evaluate economic value added or extended utility within the analyzed system. The most known assessment frameworks for CE are developed upon three foundational methodologies: specifically, Life Cycle Assessment (LCA), Material Flow Analysis (MFA), and Input–Output Analysis.

Life Cycle Assessment (LCA) is a predominant tool frequently utilized for quantifying and assessing the advantages or consequences of the CE strategies, often serving as a means to deliberate and select from various circular approaches [23]. For many years, the main use of LCA was to assess the environmental impacts only. Presently, LCA emerges as the most well-defined framework for scrutinizing environmental aspects, capable of comprehensively evaluating circular systems, Product Service Systems, and recycling mechanisms [24]. Stijn et al. [25] introduced the Circular Economy Life Cycle Assessment (CE-LCA) model, which adapts existing LCA standards to account for multiple use cycles and employs a circular allocation approach to facilitate circular building component development.

Antwi-Afari et al. [26] broadened the scope of LCA to encompass cradle-to-cradle considerations in combination with the prognostic circularity indicator for building systems. This comprehensive approach facilitated assessing the product system's environmental, technical, functional, and systemic aspects. Lei et al. [27] examined the integration of life cycle assessment (LCA) into the circular economy framework, emphasizing its potential to mitigate additional environmental impacts associated with increased circularity. The paper systematically reviews LCA's applications in the context of the built environment within a circular economy approach, highlighting the need for its incorporation. Larsen et al. [28] examined the integration of life cycle thinking, including LCA, Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA), into an integrated methodology called Life Cycle Sustainability Assessment (LCSA) to facilitate the transition of the construction industry toward a CE. Finally, Chen et al. [29] provided a comprehensive summary and systematic evaluation of utilizing LCA and Product Service System (PSS) integration within the circular economy framework, focusing on a micro-level perspective. Drawing from this analysis, the study highlights the research challenges. It suggests possible avenues for future research to advance the implementation of LCA within the circular economy paradigm, particularly from a business perspective.

Material Flow Analysis (MFA) is a method that evaluates the dynamics and alterations within material flows of a system by quantifying mass balances within a specific spatial context. While MFA provides insights into the quantity of materials utilized, it lacks information regarding material quality and scarcity. The primary hurdles faced in MFA studies include data uncertainty and availability. However, due to its adaptable and uncomplicated nature, MFA can be employed across all levels of analysis, encompassing macro, meso, and micro scales [23]. Barkhausen et al. [30] conducted a systematic literature review, examining 44 prospective studies that utilize material flow analysis and life cycle assessment in combination. The review revealed a diverse landscape of integrated approaches with significant potential for assessing the impacts of circular economy policies, particularly within the context of the eco-design framework.

The last assessment framework for CE is the input–output analysis. Input–output analysis (IO analysis) was developed to explore economic interdependencies among sectors within regional, national, or international economies. It has been extended to assess the environmental and socio-economic impacts associated with these sectors, often in conjunction with LCA, to overcome the limitations of process-based LCA [23].

Furthermore, the second category of the circularity assessment is the assessment indicators. Corona et al. [23] conducted a literature review identifying a range of CE assessment indicators, categorized into distinct types. Among them, four standalone CE assessment indicators were found, including four derived from the LCA methodology and one derived from the MFA framework. The first one is the longevity indicator. It is a non-monetary measure of how long a material remains within a product system, incorporating initial lifetime and durability gained through reuse and recycling without addressing the decrease in recycled material quality [31]. In addition, the Resource Potential Indicator (RPI) evaluates the intrinsic value of a material for reuse, accounting for technological feasibility in recycling based on the average recoverable material share using available recycling technologies [32]. The next one is the Value-Based Resource Efficiency (VRE) Indicator, which quantifies circularity as the percentage of value from stressed resources incorporated in a product returned after its end-of-life, considering both the market value of resources and their societal and environmental implications [33].

Furthermore, the Sustainable Circular Index (SCI) is a composite indicator that reflects an organization's sustainability and circularity degree, comprising economic, social, environmental, and circularity dimensions [34]. The next four indicators are derived from LCA methodologies, offering distinct perspectives on environmental and economic integration. The Eco-Efficient Value Ratio (EVR) [24] and the Eco-Efficiency Index (EEI) employ monetization techniques to integrate environmental and economic considerations. They focus on increasing value-added, benefiting producers and consumers, assuming that such value reflects consumer willingness to pay for a service. The EEI combines value added and ReCiPe method (a method for the life cycle impact assessment)-based environmental impacts with monetization involving stakeholder preferences.

In contrast, the EVR compares environmental burden to value-added, using marginal prevention costs for monetization. The Global Resource Indicator (GRI) was introduced as a midpoint characterization indicator for resource use in LCA. It considers scarcity, geopolitical availability, and recyclability of resources. Scarcity incorporates extraction rates and available reserves; geopolitical availability addresses distribution homogeneity and recyclability factors in recycling and dispersion rates [35]. Finally, the Circular Performance Indicator (CPI) measures the ratio of environmental benefit achieved through waste treatment compared to the maximum potential benefit based on material quality. This indicator quantifies reduced resource consumption through Cumulative Exergy Extraction from the Natural Environment (CEENE), accounting for predefined material quality factors [36]. Khadim et al. [37] examined 35 existing tools for building circularity indicators, revealing a surge in publications, particularly in Europe, but emphasizing the need for a universally recognized framework due to variations in scope, definition, and key performance indicators while noting that many indicators are in the developing stage, with a predominant focus on recycling and reuse and a lack of emphasis on crucial aspects like energy, emissions, and water.

Due to the complex nature of circularity, multi-criteria approaches (MCDM) and fuzzy logic have also been used to assess it. Ng and Martinez Hernandez [38] developed a decision-making framework that combines multi-criteria analysis and process modeling to evaluate the performance of the CE. Shen et al. [39] utilized a fuzzy multi-criteria approach to assess green supply chain performance, while Olugu and Wong [40] employed an expert fuzzy rule-based system for closed-loop supply chain performance measurement. Moreover, Sassanelli et al. [41], in addition to the multi-criteria approaches (MCDM) and fuzzy logic methods mentioned earlier for CE assessment, conducted a literature review and introduced various alternative approaches for conducting assessments. For instance, the assessment of the CE could be achieved with the design for X (DfX) methodologies such as Design for Disassembly (DfD), Design for End-of-Life (DfEoL), etc., and guidelines with the Analytic Hierarchy Process (AHP), which is a decision-making tool that helps evaluate the performance of the CE systems based on multiple criteria. AHP allows for prioritizing and comparing different factors, such as energy consumption, resource recycling, environmental protection, costs, and social aspects. There are also approaches that combine assessment methods to assess CE. Markatos and Pantelakis [42] introduced a decision support tool that combines life-cycle-based metrics encompassing ecological and economic aspects and a circular economy indicator (CEI) centered on material/component attributes. This CEI is associated with quality characteristics and accommodates the decline in the quality of materials through multiple recycling loops. The tool works with a multi-criteria decision analysis (MCDA) approach to mitigate subjectivity while prioritizing the importance of the criteria being considered. The main assessment methods and their main characteristics are presented briefly in Table 3.

Table 3. A brief presentation of the assessment methods, their main characteristics, and references for examples.

Assessment Method	Characteristics	Examples (Ref)
Life Cycle Assessment (LCA)	Evaluates environmental impacts.	[23–29]
Material Flow Analysis (MFA)	Quantifies mass balances.	[23,30]
Input–Output Analysis (IO analysis)	Explores economic interdependencies.	[23]
Longevity Indicator	Measures how long the material remains.	[31]
Resource Potential Indicator (RPI)	Evaluates intrinsic value for reuse.	[32]
Value-Based Resource Efficiency (VRE) Indicator	Quantifies circularity as a percentage.	[33]
Sustainable Circular Index (SCI)	Composite indicator reflecting	[34]
Eco-Efficient Value Ratio (EVR) and Eco-Efficiency Index (EEI)	Monetizes environmental and economic.	[24]
Global Resource Indicator (GRI)	Midpoint characterization indicator.	[23,35]
Circular Performance Indicator (CPI)	Measures the ratio of environmental	[36]
Multi-Criteria Approaches (MCDM)	Decision-making framework combining multiple criteria analysis and fuzzy logic.	[38–41]
Design for X (DfX) methodologies	Includes Design for Disassembly (DfD), Design for End-of-Life (DfEoL), etc.	[41]
Analytic Hierarchy Process (AHP)	Decision-making tool for evaluating the performance of the CE systems.	[41]
Integrated Decision Support Tool	Combines life-cycle-based metrics, circular economy indicators, and multi-criteria decision analysis.	[42]

Lastly, there are currently existing tools for assessing circularity in various sectors or industries. Valls-Val et al. [43] conducted a review to evaluate distinct tools specifically designed to assess organizational circularity. The investigation extends to the essential information these tools require, covering inquiries, categorizations, input data, achievable outcomes, and communication methods. The review underscores the escalating presence of circular assessment tools while underlining the lack of standardization in terms of features and content. Although these tools offer an initial reference, it is crucial to recognize that their application in decision-making could yield contrasting outcomes within the same context, depending on the tool chosen. In reference, some of the available tools are the Acodea [44], CEEI [45], CIRCelligence [46], CircularTRANS [47], Circulytics [48], CTI Tool [49], Inedit [50], ready2LOOP Transition Toolbox [51], MCI (Material Circularity Indicator) [52], andTECNUN [53].

3.3. Circular Economy in Different Industries

3.3.1. Aerospace Industry

The aerospace industry appears to be one of the leading industries that profits from big investments that consistently drive advancements in science and technology. The aviation sector, which extensively utilizes aerospace technologies, stands out as the most rapidly developing field. This progress in aviation brings forth new technological achievements aimed at minimizing energy consumption, environmental impact, and costs, particularly concerning sustainable development from the perspective of thermal scientists [54]. The disposal of end-of-life aviation composite waste and aircraft structures presents significant challenges that need to be addressed [55]. According to the International Air Transport Association (IATA) [56], approximately 11,000 aircraft are projected to be retired by 2030. The integration of CE concepts throughout the aircraft manufacturing supply chain process can offer numerous benefits to companies. By adopting CE principles such as recycling, remanufacturing, and reuse, companies can develop strategies that create mutually beneficial outcomes, enhance brand image, expand market share, and increase profitability while minimizing environmental degradation [57]. However, the aerospace industry encounters considerable obstacles in transitioning from linear to circular approaches. This shift is particularly challenging due to the stringent quality demands necessary to adhere to safety standards [58].

Salesa et al. [59] focused on examining airlines' strategies to integrate circular economy principles into their waste management systems. Additionally, they introduced a suggested framework for evaluating materials management, recycling procedures, and utilizing eco-efficient designs within the airline sector. It underscores the significance of sustainable practices in waste management, resource utilization efficiency, and the integration of novel materials and products.

It is worth noting that one of the most important tools, the ReSOLVE framework, which was developed by the Ellen MacArthur Foundation, is a comprehensive tool designed to guide businesses and organizations in assessing and implementing circular economy strategies. This framework proposed six actions that businesses and governments can adopt to shift towards a circular economy. It stands for Regenerate, Share, Optimise, Loop, Virtualize, and Exchange [60]. Dias et al. [57] pointed out the practices that could potentially be used for applying circular economy principles in the aerospace industry, promoting environmental sustainability, cost savings, and resource optimization. They observed that circular strategies for financial benefits, alternative and renewable fuels, reuse and recycling of materials, circularity-oriented product designs and integration of Industry 4.0 technologies drive CE in the aerospace industry, as shown in Figure 4. In their work, the study followed a specific protocol, which included workshops with professionals from different companies in the aerospace industry. These workshops were recorded and transcribed for data collection. In addition to the primary information obtained through the workshops, secondary data were collected from official company websites and electronic communication channels. They used the ReSOLVE framework to analyze and discuss the effect of CE practices on environmental sustainability in the aerospace industry. They also presented the framework to the companies involved in the study and discussed its applicability. The use of the ReSOLVE framework helped to identify CE initiatives.

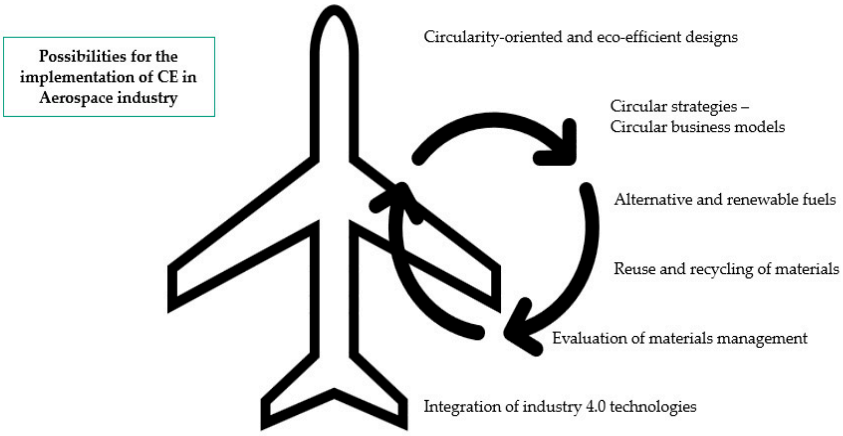

Figure 4. Possibilities for the implementation of circular economy in the aerospace industry.

They also mentioned the barriers and challenges to implementing CE in the aerospace industry. The first issue is that the aerospace industry has a specific and limited supply chain, which creates a dependency on suppliers to develop and produce environmentally friendly materials. The complexity and long life cycle of aerospace products make it difficult to develop components and materials that support circular economy initiatives. Similar supply chain-related obstacles have been observed in the CE literature [61]. In addition, Ritzén and Sandström [61] presented the absence of accessible technologies as obstacles to CE integration. Thus, the aerospace industry faces technological challenges in adopting circular economy practices. Finally, Jabbour et al. [62] mentioned Brazil's insufficiency of appropriate legal frameworks (regulations).

Furthermore, Andersson and Stavileci [63] mentioned that three pivotal dimensions are important for implementing the CE: business model, sustainable development, and technology, and these insights were garnered from GKN Aerospace Sweden. The key challenges faced by GKN Aerospace Sweden were the prioritization of critical materials within existing product compositions, the exploration of additive manufacturing for circular material flows, the identification of prime lifecycle stages for delivering value, and the definition of aerospace's role in advancing Circular Economy principles. The strategic approaches to tackle these challenges include early critical material analysis using tools such as material criticality lists, leveraging additive manufacturing for efficient material use and supplier independence, tailoring lifecycle strategies to align with customer preferences, and shifting industry focus toward high-value services in addition to physical products. This knowledge sheds light on the complex interplay of dimensions and challenges in pursuing a circular and sustainable economy while offering realistic solutions to drive progress in the aerospace sector.

Due to the fact that the aviation sector's reliance on carbon fibers and petroleum-based matrices for lightweight structures raises environmental concerns, Bachmann et al. [64] explored eco-friendly alternatives like bio-based and recycled materials for aircraft components, which are supported by comprehensive Life Cycle Assessments, aligning with Circular Economy principles to advance aviation's carbon neutrality goals by 2050.

3.3.2. Wind Energy Industry

Wind energy has rapidly developed as a promising and economically viable renewable energy source. Characterized as a clean and sustainable natural resource, it is abundant in Europe. Despite challenges like public acceptance and technical limitations, Europe's wind resources could generate over 33,000 TWh of energy annually, satisfying the region's electricity needs tenfold [65]. Wind energy, a significant decarbonization solution, has rapidly grown as a global energy source [66]. While it is often promoted for its emission-free operational phase, the issue of unrecyclable wind turbine blades, a significant component, poses a challenge [67]. Although contemporary wind turbines generate higher energy output per unit, their environmental footprint is often amplified by increased material demands during manufacturing. This underlines the importance of extending the use of materials to the maximum extent possible. Priority must be given to the optimal design of wind turbines and effective life cycle management through applying circular economy principles focusing on resource conservation. This approach is essential for a successful transition towards resource-efficient and sustainable wind energy systems [68].

Savvidou and Johnsson [66] addressed the knowledge gaps related to material needs during the shift to low-carbon electricity and the possibility of utilizing secondary materials from the energy system. Through an investigation of Sweden's wind power sector until 2050, the study underscores the vital role of circular approaches and the reduction of carbon-intensive material production in meeting emission goals and establishing closed material cycles within the realm of renewable energy infrastructure. Gennitsaris et al. [69] introduced a novel integration of LCA and Data Envelopment Analysis (DEA) for assessing diverse end-of-life strategies for decommissioning wind turbines in a circular economy context. Through scenarios focused on a representative wind turbine type, including options like mechanical recycling, landfill disposal, and advanced thermal recycling methods, the study not only evaluates their effectiveness but also suggests circular economy-based policy scenarios to enhance sustainable waste management. Real-world calculations reveal that enhancing the efficiency of energy-intensive thermal recycling processes could optimize environmental outcomes, while a circular approach emphasizing remanufacturing, reusing, designing, or recycling of wind turbine blades holds promise for long-term sustainability. Sherwood et al. [70] introduced a methodology termed Performance-weighted Resource Depletion (PwRD), which evaluates the sustainability of products based on their resource usage efficiency and lifespan, enabling direct comparison between different products in terms of circularity. By quantifying concerns related to resource supply risk and indicating practical actions for circular economy preservation, the PwRD metric is applied to the case of neodymium for wind turbine generators, demonstrating that the electricity generated by a wind turbine in the USA does not justify the required neodymium quantity. The demand for product functionality is a crucial variable in PwRD, equally significant as resource utilization for maintaining a circular economy. In regions with low per capita electricity demand, like the Philippines and Pakistan, the same neodymium quantity used in a US-installed wind turbine was deemed acceptable for circular economy retention. Diez-Cañamero and Mendoza [71] examined the relationship between circular economy performance and carbon footprint for seven end-of-life wind turbine blade management options: repurposing, grinding, solvolysis, pyrolysis, cement co-processing, incineration with energy recovery, and landfilling. Utilizing circularity indicators, a life cycle assessment and solvolysis showed the highest circularity and lowest carbon footprint. Ghosh et al. introduced the Circular Economy Lifecycle Assessment and Visualization (CELAVI) framework, which assesses supply chain environmental impacts during the transition to a circular economy. By analyzing circularity pathways, costs, and wind turbine installations, the researchers suggested that higher circularity costs could be advantageous due to revenue from circular approaches. In addition, Nag et al. focused on addressing challenges faced by aging wind farms in India by proposing a research framework that identifies and prioritizes value requirements for the life cycle extension of wind turbine products, emphasizing circular services such as repair, upgrade, and smart monitoring as key priorities.

However, the transition to innovative renewable energy generation and consumption systems must be actively pursued by embracing CE strategies supported by circular business models (CBMs). These approaches aim to enhance resource efficiency and overall sustainability [72]. Circular business models can potentially bring significant economic and social benefits to the wind energy sector. Despite significant research on sustainability, the wind industry has mainly focused on technological developments at the level of materials, components and products, with limited attention to the implementation of CBMs. Mendoza et al. [73] evaluated 14 CBMs that can be applied to the wind industry. They offer insights into their drivers, value creation, sustainability benefits, challenges, and opportunities and provide comprehensive guidelines for policy, industry and academic actions to promote their adoption. Although the focus is on wind energy, the broader implications extend to the renewable and low-carbon energy sectors. They concluded that there are many challenges to implementing CBMs, such as the lack of comprehensive sustainability studies and the limited availability of holistic frameworks, standards, tools, indicators, etc. However, applying CBMs in the wind industry presents various opportunities for enhancing competitiveness, capitalizing on circular economy strategies, and generating comprehensive economic, social, and environmental value. CBMs can optimize resource efficiency, reduce risks, and contribute to the industry's sustainability goals.

3.3.3. Transportation-Automotive Industry

Transportation plays an essential part in our economy and everyday lives, giving essential portability and contributing to both the internal market and citizens' well-being through the flexibility of movement. As a driver of economic development and employment, transportation must evolve to meet emerging sustainability challenges [74]. The transportation sector holds a significant responsibility for CO2 emissions and air pollutants. Despite differing impacts of climate change and air pollution, there's a lack of comprehensive evaluations regarding alternative fuels and advanced vehicle technologies to combat both issues [75]. Environmental policies aim to reduce emissions and increase the diversity of energy sources, often supporting alternative fuels such as electricity [76]. In this complex situation, the concept of circular economy has captured the interest because it presents an approach aimed at minimizing environmental impacts and optimizing the utilization of resources, serving as a sustainable strategy. To facilitate the move towards a circular economy, governments have introduced targeted measures to encourage the automotive industry's sustainable and circular evolution. These policies motivate companies to move away from conventional vehicles and embrace electric vehicles (EVs) [77].

Demartini et al. [78] developed a model utilizing both system dynamics and agent-based methodologies to assess how the shift to electric and net-zero economies impacts automotive supply chains and associated stakeholders. By integrating principles of circular economy, the study reveals that while this transition presents opportunities like novel business prospects and decreased raw material use, it could also lead to workforce challenges, notably within manufacturing. The study highlighted the need for proactive measures by companies and policymakers to mitigate the potential impact on jobs by focusing on skill enhancement and strategic support for workforce relocation, particularly within end-of-life processes in the supply chain. Bruggen et al. [79] enhanced the solution-focused sustainability assessment (SfSA) framework by incorporating a "chain approach", involving stakeholders along a specific product chain to explore different views on possible solutions. Focusing on plastics in the automotive sector, this method reveals interlinked barriers, highlighting the role of policy and economic measures alongside systemic changes. Mügge et al. [80] developed a data-driven decision support framework using digital twins and circular economy Key Performance Indicators (KPIs) to facilitate optimal end-of-life circular vehicle strategies, incorporating user-centered design and involving stakeholders across the value chain. In addition, Kanellou et al. established key performance indicators (KPIs) for monitoring the adoption of circular economy models in the automotive industry. Nag et al. [81] proposed a multi-theoretical framework and employed a decision-making method to identify and evaluate drivers and sub-drivers for the adoption of circular principles in transitioning from a Product-Service System (PSS) business model to a CBM in the context of the emerging CE in the Indian automotive industry.

In addition, some researchers [82,83] investigated the CE initiatives of the automotive industry under Industry 4.0. For instance, Yadav et al. [84] addressed the challenges in sustainable supply chain management (SSCM) by developing a framework that leverages the principles of Industry 4.0 and the circular economy, identifying key challenges and solution measures through expert input and applying a hybrid methodology to prioritize these measures for the effective adoption of SSCM in an automotive organization.

Rodríguez-González et al. examined the impact of CE practices on the financial performance of Mexican automotive manufacturing companies, considering also the mediating role of sustainable supply chain management (SSCM). In general, some publications refer to the circular economy implementation in the automotive industry, analyzing factors such as regulations, business models, emerging technologies, and best practices [85,86].

Finally, Baldassarre et al. [87] investigated the drivers and barriers to increasing the use of recycled plastics in new vehicles within the EU automotive sector, utilizing literature analysis and stakeholder interviews to outline the value chain, identify specific challenges and opportunities, and contribute to advancing circularity in the sector. Kayikci et al. [88] examined Smart and Sustainable Circular Economy (SSCE) barriers within an automotive industry Eco-Cluster, utilizing interrelated concepts of intelligence, sustainability, and circularity, identifying key cause and effect barriers and proposing solutions using the Fuzzy DEMATEL method, aiming to guide the establishment and improvement of Eco-Clusters in the automotive sector, with policy-related barriers emerging as significant challenges. Urbinati et al. [89] addressed a notable research gap by presenting a comprehensive framework of enablers, barriers, and contextual factors affecting CBM design, focusing on the automotive industry. Through a case study of the Italian automotive industry, the study shed light on the relative importance of these factors and offers practical insights for managers and policymakers while recognizing limitations in the methodology, the sample, and the potential for future qualitative and quantitative research to investigate the interactions and customer interactions further.

3.3.4. Sports Equipment Industry

In 2016, the global sports market, which includes events, teams, sports equipment and infrastructure, was estimated to have an annual value of $600–700 billion, outstripping the GDP growth of many countries [90]. The sports goods sector includes sports equipment, clothes, footwear and related items. Nevertheless, there has been limited research on measuring the carbon footprint at the end of sporting equipment use. Recognized as an important catalyst for promoting sustainable development, scientific studies covering ecology, management and economics strongly support the sports sector. Organizations representing public and business sectors strongly recognize the potential of sport to positively impact critical global challenges.

Nevertheless, these efforts remain insufficient, leading to the realization that a fundamental transformation is urgently needed. To truly embrace the principles of sustainable development, changes are needed in societies and businesses. The CE model encompasses natural ecosystems, business activities, everyday lifestyles and a proactive orientation that departs from the reactive attitude of waste management that focuses solely on dealing with the consequences [91].

Fuchs and Hovemann [92] examined the implementation of CE practices in the outdoor sporting goods industry (OSGI) using a qualitative approach involving document analysis and expert interviews. Findings reveal that many OSGI brands and retailers adopt CE-related practices, suggesting the presence of institutional isomorphism and the potential for increasing uniformity in CE practices within the industry. By identifying the core principles of these practices, such as reducing, recycling products and materials, and regenerating nature, companies can strategically adapt CE approaches to their circumstances, differentiating and leading the conversation rather than simply following trends while improving communication with consumers. In addition, Fuchs and Hovemann [93] focused on identifying the most appropriate CE practices for the outdoor sporting goods industry, analyzing the challenges and contributing factors through expert interviews. Findings highlighted challenges such as product complexity and low return rates, while design for durability and repairability emerges as a key factor, suggesting that 'reduction' practices should be the foundation on which other CE elements can be built. Petronis and Valušytė [94] explored how Circular Design (CD) practices are employed in CE implementation within sports while emphasizing the role of this in driving the transition to a CE in the sports industry. The research offers insights into potential CD principles that are appropriate for specific scenarios in sports, enhancing practical understanding of the CE's application in the field.

In light of growing environmental concerns, Szto and Wilson [95] examined the post-usage fate of sporting goods, specifically focusing on bicycles and their contribution to waste accumulation through planned obsolescence. The research highlighted structural environmental barriers in the bike industry and supported the extended producer responsibility and the CE as crucial strategies. It urged governments, manufacturers, marketers, and consumers to collectively engage in more sustainable practices to address the ecological footprint of sporting goods and calls for further research on consumer perspectives and environmentally friendly production.

Table 4 provides a comprehensive overview of key challenges and corresponding circular economy strategies across diverse industries, including aerospace, wind energy, transportation-automotive, and sports equipment.

Table 4. Key challenges and circular economy strategies across industries.

Industry	Key Challenges	Circular Economy Strategies
Aerospace	End-of-life waste disposal. Stringent safety standards. Limited supply chain for eco-friendly materials.	Adoption of CE principles. Integration of eco-efficient designs. Identifying CE initiatives using the ReSOLVE framework.
Wind energy	Unrecyclable wind turbine blades. Increased material demand during manufacturing. Carbon-intensive material production.	Optimal design of wind turbines. Circular economy-based policy scenarios. Remanufacturing, reusing, and designing for recycling wind turbine blades.
Transportation-Automotive	CO2 emissions and air pollutants. Lack of comprehensive evaluations for alternative fuels.	Transition to electric and net zero economies. Circular business models for automotive supply chains.
Sports equipment	Limited research on carbon footprint at the end of life. Low return rates and product complexity.	Reduction, recycling, regeneration practices in outdoor sporting goods industry. Design for durability and repairability.

4. Enhancement of Circular Economy (CE)

Integrating technologies into the industrial landscape embodies the five major facets of the Fourth Industrial Revolution: digitalization, automation, human-machine interaction, value-added services and businesses, and automatic data exchange and communication. This interconnection among various systems and assets leads to several advantages over traditional CE models. These benefits include increased efficiency and resource utilization, reduced waste through enhanced traceability and optimized waste management, and extended product and equipment lifespans, ultimately contributing to more sustainable CE practices. This transition to digitalized CBMs empowers managers to align their goals with CE principles and utilize Industry 4.0 technologies to support their strategies effectively [96]. However, achieving sustainable benefits from digitalization requires innovative business models, particularly advanced service-based models [97]. In addition, ICT (Information and Communication) solutions help the transition to a circular economy. Some solutions, such as cloud manufacturing and big data, were identified as particularly crucial for supporting the principles of circularity [98].

Furthermore, resource accounting, supported by digital systems, is expected to be a key factor in achieving a circular economy. It enables continuous monitoring of resources, data-driven decisions about their lifecycle, and minimizing waste through informed choices. While waste management is vital, a CE goes beyond recycling, and waste management companies are expanding their roles upstream into business markets to prevent resources from becoming waste in the first place [99]. Moreover, Gatenholm et al. [100] explored logistical flows and trade-offs in aftermarket supply chains to enhance circularity by slowing down resource flows. It identified trade-offs in the aftermarket involving material, people, information, and knowledge, highlighting the need to extend the traditional view of logistics to include the flow of knowledge and people. Their study emphasized the importance of "slowing" as a favorable condition to improve circularity, challenging the conventional notion of time in logistics. Additionally, it provided insights for professionals and policymakers to develop environmentally sustainable aftermarket services that prioritize knowledge and customer co-creation, ultimately contributing to circular economy goals. Future research could delve into logistics gap analysis, expand the scope to complete service offerings, and explore the role of different actors in providing logistics services in the aftermarket. Last but not least, various concepts like Material Passports have emerged, enabling the digital registration of data sets describing an object's characteristics, location, history, and ownership status. These passports are implemented and are often leveraging digital platforms to facilitate data management and circular economy practices [101].

Digitalization has the potential to significantly advance the shift towards a sustainable circular economy [102]. It contributes by providing accurate data on product availability, location, and condition, thereby facilitating the closure of material loops. Additionally, digitalization streamlines processes within companies, reducing waste, extending product lifespans, and cutting transaction costs. This support from digitalization enhances CBMs by aiding loop closure, slowing the material loop, and improving resource efficiency [103]. There is a unidirectional connection, with Industry 4.0 driving circularity and a bidirectional relationship, signifying mutual benefits between these concepts. CE's significant domains within Industry 4.0 involve recycling and reusing strategies in smart production and sustainable supply chains. The research emphasizes the relevance of applying these concepts at the company (micro) and industry (meso) levels [104]. Organizations should consider exploring emerging digital technologies to enhance their transition efforts sustainability and leverage available data across the product life cycle [105]. Many publications support the adoption of these technologies [106–114]. The manufacturing and consumption landscape is undergoing significant transformation due to the rise of emerging digital technologies such as the Internet of Things (IoT), big data analytics (BDA), artificial intelligence (AI) etc., as detailed in Figure 5 [115]. With these technologies, devices can seamlessly interact with each other and online services, enabling a range of goals such as automated manufacturing, smart homes and efficient waste management [116–118].

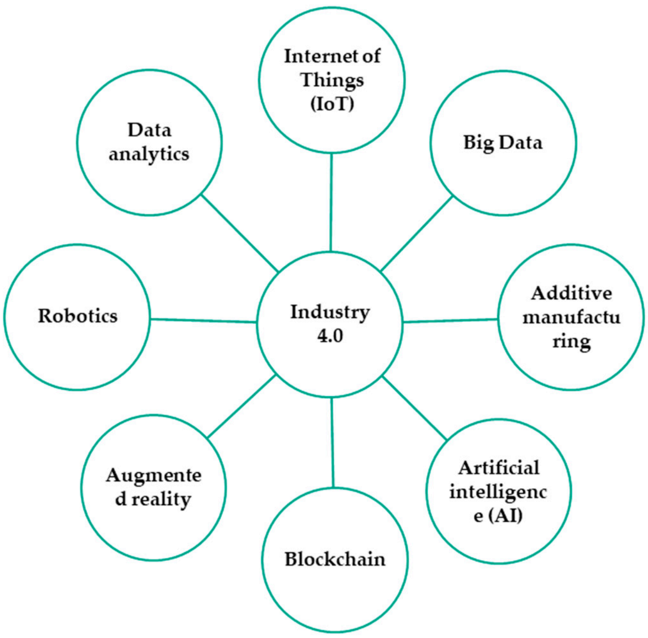

Figure 5. Main emerging digital technologies of Industry 4.0.

In the usage phase, digital tools (DTs), particularly IoT, transform products into "smart" entities, promoting resource efficiency and extending product lifespans by monitoring and optimizing usage. In the end-of-life stage, DTs assist in closing the loop through efficient recycling and second-life utilization, emphasizing the interconnectedness of design, end-of-life activities and end-of-life decision-making process [119,120]. The possibility of using digital technologies to help shift how products are made and used towards a circular economy is becoming more popular. This could be a helpful way to overcome the challenges of transitioning to a circular economy [121]. The application of these digital tools holds the key to overcoming barriers, facilitating resource-efficient smart factories, enhancing workforce productivity and promoting closed-loop manufacturing processes [122]. In addition, these technology-based systems enable knowledge creation, improved experiences, resource accessibility, sustainability, and data-centric decision-making, all contributing to the advancement of circular entrepreneurship [123]. These digital technologies also play a vital role in implementing advanced Circular Economy and Industrial Symbiosis solutions by enabling efficient monitoring of resource and energy flows and supporting human decision-making [124]. By incorporating responsive design techniques and digital tools, the design process can become more efficient and aligned with circular principles. Digital technology can optimize design decisions, enable circular concepts like disassembly, and facilitate efficient maintenance, thereby reducing waste [125]. Nevertheless, there is a recommendation for assessing technology implementation approaches, considering factors like ease of implementation, cost, localization, data privacy, and ethical AI use on public data [126]. Finally, the successful implementation of CE principles depends on engaging various stakeholders, including governments, international institutions, and companies, to transition toward more sustainable and digitalized processes in supply chains [127].

For instance, Bag and Pretorius [128] proposed an integrative research framework that outlines key pathways for adoption. This framework highlights the significance of Industry 4.0 technology adoption, particularly big data analytics-powered artificial intelligence, in enhancing sustainable manufacturing practices and circular economy capabilities. Islam et al. [129] and Bressanelli et al. [130] explored the role of IoT, Big Data, and analytics in facilitating the transition toward a CE through usage-focused Business Models (BMs). It identifies eight key functionalities enabled by these digital technologies that align with the three fundamental CE value drivers: resource efficiency improvement, product lifespan extension, and closing the loop. The study emphasized the importance of coupling IoT with Big Data and analytics. It highlighted that while IoT is instrumental in tracking product usage and preventing premature wear, functions related to the product's lifecycle stages are critical for achieving CE, particularly in extending product lifespan and closing the loop. In addition, the home appliance industry, the textile and clothing industry and the food supply chain present a promising opportunity for the adoption of Industry 4.0 technologies such as the Internet of Things (IoT), Big Data, Blockchain and the Cloud in facilitating serviceable business models within the context of the CE [130–134]. More specifically, combining IoT, machine learning, robotics, transportation management systems, and 3D printing can enhance the link between technology and sustainable practices while improving business performance in Circular Supply Chains [105,135,136]. Agrawal et al. [137] investigated the transition in supply chains from a linear economy to CE and eventually to a net-zero economy (NZE). It identifies 19 key drivers, such as high automation, manufacturing process flexibility, and real-time sensing, through DEMATEL analysis. In addition, Magrini et al. [138] and Joshi et al. [139] focused on the utilization of the Internet of Things (IoT) and Blockchain, using the case study of Electrical and Electronic Equipment (EEE). IoT and blockchain can enable producers to maintain control over products until their end-of-life, promoting circular strategies and aiding decision-making. Liu et al. [140] investigated the role of DTs in advancing CE strategies through a systematic literature review. The findings highlight 13 key digital functions categorized into three groups, along with their mechanisms, resulting in a proposed Digital Function for Circular Economy (DF4CE) framework. The research contributes theoretical understanding, practical insights for collaboration and data security, managerial implications for DT implementation, and outlines avenues for future research, acknowledging the need for wider technology inclusion and validation in subsequent studies, including a focus on specific digital tools like IoT, BDA, and AI, while overlooking other technologies that could offer insights for Circular Economy strategies. Additionally, the literature review did not adequately address the potential energy-related implications of digitalization.

4.1. Internet of Things (IoT)

The officially recognized definition of the Internet of Things (IoT) was provided by the International Telecommunication Union (ITU) as follows: *"Internet of Things is defined as a global infrastructure for the information society, which activates advanced services, connecting physical and digital components, based on existing and evolving interoperable information and communication technologies"* [141]. The combination of Artificial Intelligence (AI) and the Internet of Things (IoT) presents great prospects for the circular economy. This collaboration enables a manufacturing model with reduced costs, enhanced efficiency, and individualized production. For instance, IoT's incorporation of low-cost sensors into reusable products facilitates efficient asset management and recycling in the circular economy. The link between CE principles and IoT strengthens efficiency, enabling institutions to achieve profitability and conservation goals through data analysis and AI. IoT's monitoring of manufacturing and product lifecycles enhances the efficiency of the entire value chain. Moreover, IoT-driven leasing models can transition conventional value chains toward circular economy practices, emphasizing asset durability and reducing waste. The potential of digital transformation and big data to support circular economy models underscores the transformative impact of IoT in promoting sustainability [142].

Voulgaridis et al. [143] explored the relationship between IoT technologies and Digital CE principles through a review of academic papers. It investigates the application fields, architectural models, and features of IoT technologies, as well as the integration of Digital CE concepts. The findings indicate a connection between Digital CE and IoT within the context of Industry 4.0, with a focus on lifecycle and use-cycle monitoring. Ingemarsdotter et al. [144] used a two-step approach to analyze how companies implement IoT for circular strategies compared to expected opportunities. Akbari and Hopkins [145] proved through a survey of 223 supply chain experts that a relatively low adoption rate of I4.0 technologies, with the Internet of Things (IoT) being the most prevalent. Kazancoglu et al. [146] investigated the significance of IoT-enabled technologies in enhancing supply chain visibility, particularly in food supply chains. The application of IoT technologies aids in the collection and analysis of data in real time, enabling quicker decision-making and minimizing food waste within the supply chain. Garcia-Muiña et al. [147] noticed that the ready access to production data facilitated by IoT technologies has combined with the Canvas Business Model to enable the re-evaluation of the existing linear business model. The integration of concepts such as environmental conservation, social advancement, and economic robustness has led to the creation of a new business model. The fusion of eco-design prediction and real-time digital assessment transforms sustainability analysis into dynamic corporate social responsibility strategies, encouraging long-term managerial perspectives and facilitating the application of circular economy principles by reshaping business models and value creation processes. Chau et al. [148] underscored the significant impact of IoT, emphasizing the need for both policymakers and businesses to adopt this technology for real-time control and optimization of end-of-life product lifecycles. In order to fully utilize the potential of IoT, it is essential to increase the automation of manual remanufacturing procedures. Creating strong and unified laws that align with the trends of Industry 4.0 is crucial for the growth of developing nations. Particularly in significant fields, it becomes crucial when they aim to enact measures to enhance their domestic industries.

4.2. Big Data Analytics

Big Data Analytics (BDA) holds transformative potential for effective decision-making within organizations, offering significant implications for driving and supporting CE efforts [149,150]. BDA is seen as a vital facilitator for obtaining decision-making information in the CE context, with collaborative relationships with stakeholders enhancing access to relevant data. Gupta et al. [151] proposed a model linking CE and BDA, emphasizing proactive management of the entire system through collective stakeholder engagement, suggesting implications for researchers and practitioners in these fields. They also offer a theoretical foundation for future empirical research in this field. Combining CE principles, network-oriented thinking, and digitalization can provide a significant competitive advantage in business facilitated by digitalization and big data technologies. Salminen et al. [152] presented a conceptual tool for responsible business leadership, utilizing Evolute, an intelligent web-based system, to analyze co-evolution throughout the lifecycle of a business's transition to a circular economy. Giudice et al. [153] contributed significantly by empirically confirming the positive impact of circular economy practices, including design, relationship management, and HR management, on firm performance. They also underscored the vital role of a big data-driven supply chain, particularly in enhancing HR management, leading to overall improved firm performance.

4.3. Artificial Intelligence

Artificial intelligence (AI) includes a range of technologies focused on mimicking human cognitive functions like learning and reasoning [154]. By utilizing data from diverse sources such as videos, images, audio, text, and numerical data, AI aids in problem-solving through tasks like pattern recognition, prediction, optimization, and generating recommendations. AI holds the potential to facilitate and accelerate the transition towards a circular economy. Ellen MacArthur Foundation demonstrated that AI can be effectively leveraged across three pivotal domains of the CE: designing circular materials, products and components, operationalizing CBMs and optimizing infrastructures for seamless circular product and material flows. While the global economic prospects of AI are projected at USD 13 trillion by 2030, its substantial application in the circular economy remains largely underexplored [155].

In particular, AI is becoming essential for achieving data-driven circular product design, minimizing biases in testing and prototyping, and enhancing overall efficiency. Ghoreishi and Happonen [156] identified key circular design tools and strategies that enhance product design while highlighting how AI contributes to circularity by facilitating real-time data analysis, reducing time and energy consumption, enabling rapid prototyping, and supporting effective material and product management, maintenance, and reuse. Awan et al. [157] discussed the integration of AI and big data analytics in supply chain management. They highlighted the need for research to identify the most suitable AI and data analytics approaches, underscoring the importance of informed decision-making and its potential for enhancing performance in the circular economy and sustainability.

4.4. Blockchain

Blockchain technology involves a shared database (distribution of information) that continuously records transactions and their chronological sequence. It functions as a decentralized ledger containing digital transactions, data records, and executables shared among participants [158].

Juszczyk and Shahzad [159] investigated the impact of blockchain technology on promoting a CE. Significant effects were observed in sectors like spare parts management, where real-time quality, repair, and reuse status data were enhanced. Additionally, blockchain improved transparency in the manufacturing stage and verified ethical work practices. Furthermore, blockchain's capacity to provide impartial and auditable data about energy sources validated whether energy sold to customers originated from renewable sources. Rehman Khan et al. [160] emphasized that blockchain positively impacts the circular economy, subsequently benefiting green supply chain activities like recycling, remanufacturing, green design, and green manufacturing. In addition, highlights the capability of blockchain to enhance transparency, security, and effectiveness in supply chains while promoting the integration of circular economy strategies for enduring sustainability and economic advantages. Teisserenc and Sepasgozar [111] proposed a conceptual model for integrating blockchain technology and digital twin(s) (DT) in the building, engineering, construction, operations, and mining (BECOM) industry. This model aims to enhance trust, security, efficiency, and transparency by addressing key challenges such as fragmented data and lack of trust in the industry.

5. Discussion

To summarize the findings of this comprehensive review, it is important to acknowledge some limitations of the methodology and scope of this study. Firstly, limited studies published only in English presentations may introduce linguistic biases, which may ignore the valuable contributions made in other languages. Additionally, a focus on redefining the concept of circular economies in searching for research papers or definitions may exclude some of the narrower pathways in earlier research. The research methodology itself, although comprehensive and systematic, has limitations. The literature search focused on "Science Direct", "Springer", and "Google Scholar", possibly removing relevant studies from other databases. The inclusion criteria of quality and relevance, which emphasize peer-reviewed publications, may inadvertently ignore valuable insights provided in non-traditional ways. Furthermore, the period of this survey, conducted from May to August 2023, may not include recent developments in the work. Since the circular economy is dynamic and growing rapidly, there may be some surprising findings after this study is completed. Despite these limitations, the results of this work contribute significantly to the ongoing discourse on the definition of circular finance, research, and development. The following discussion outlines in depth the basic principles underpinning definitions of CE, both generally and in five key industries.

The definitions of the CE encompass different approaches, but they all agree on basic principles. CE is an economic system designed to maximize value from flows of materials and energy through life cycles. Its objectives are to minimize waste, recycle, maintain value, and contribute to ecological well-being, economic growth, and human well-being (social). Common to these definitions is the idea of reducing material and energy consumption. These changes include a shift to renewable energy sources and the elimination of toxic chemicals that inhibit recycling.

An important aspect of the CE is preserving value throughout the life cycle of materials and components. CE aims to reduce waste and consumption by keeping goods and materials as long as possible. Achieving these goals leads to paradigm shifts in production and consumption systems. The CE is not limited to industry but extends across sectors. It emphasizes the importance of control and calibration of material and energy cycles. CE seeks to harmonize resource flows with natural forces, contributing to economic, environmental and social scale.

The definitions also emphasize the importance of collaboration among stakeholders, including industry, consumers, policymakers and academia. Together, these stakeholders can harness new technologies to achieve the objectives of the CE. While the definitions differ in their specific terminology, they are committed to sustainable practices beyond waste reduction. CE is a dynamic concept that has evolved and adapted to meet today's sustainability challenges. General principles emphasize the importance of moving from a wasteful linear approach to a circular regenerative framework.

While these definitions correspond to the basic principles, they also exhibit nuanced differences in their interpretation of the CE. One such difference lies in the emphasis placed on specific aspects. Some definitions emphasize the role of renewable energy, while others focus more on utilities and closed-loop cycles. In addition, the extent of their scope varies. Some definitions incorporate a broader societal perspective, with an emphasis on environmental and human well-being, while others maintain a narrower focus on services. Differences also arise in the collaborative effort required and the analysis of the goals achieved in the CE. Some definitions mentioned above emphasize the importance of collaboration between different stakeholder groups, such as industry, consumers, policymakers and education. However, other definitions do not explicitly mention the collaborative aspect. This distinction reflects the increasing adaptability of the characteristics of the CE to different contexts and the growing challenges of developing sustainability. It allows for the adaptation of definitions to specific applications and industries.

Another issue of this work was the CE in five key industries. It is therefore necessary to discuss some similarities and differences between these industries. The aerospace industry is unique among the mentioned industries due to the complexity of its products, stringent safety and quality standards, and the highly specialized materials used. It shares similarities with other industries in terms of material efficiency, building advanced materials and designs to reduce weight and increase fuel efficiency. However, with the importance of safety, it is still difficult to implement the principles of the CE. The wind energy sector focuses on renewable energy and grid optimization, while the automotive and transport sectors aim for lightweight materials and energy-efficient designs. The sporting goods sector with short product life cycles seeks sustainability and recycling.

While these industries aim to apply CE principles, they face industry-specific challenges. Aerospace needs to find solutions as a first step to recycle composite materials and maintain end-of-life aircraft. The wind energy sector must address issues of grid integration, energy storage and circular design for renewable energy applications. The recycling and electric vehicle conversions are confronting the automotive industry. The transportation sector struggles to reduce carbon emissions and improve the efficiency of the transportation system, and the sports sector finds ways to reuse and repurpose used sports equipment items. So, understanding these sector-specific strategies and challenges is critical to the broader discussion of the CE across sectors. Finally, the potential of emerging technologies, especially those based on the principles of Industry 4.0 and digital tools, to increase resource efficiency and reduce waste in the circular economy were explored. Research should emphasize the development and adoption of innovative circular business models across sectors in the future.

While highlighting promising directions for future research on the Circular Economy (CE), it is important to emphasize the role of clear policy recommendations in its widespread adoption and encouragement. Researchers should not only focus on increasing intersectoral collaboration and understanding sector-specific challenges but should also actively contribute to the development of globally applicable regulatory frameworks. This framework should support the transition to a circular economy and manage the delicate balance between industry-specific considerations and a consistent approach to sustainability. Another important aspect of the study is to increase consumer awareness and engagement in CE practices. Researchers can consider ways to educate and motivate consumers to adopt concepts such as recycling, recycling, and sustainability. The principles and methods of circular priority recycling and recycling should be the subject of ongoing research.

Furthermore, an in-depth analysis of the barriers faced by businesses in adopting CE practices is needed. The study aims to identify regulatory barriers, financial barriers, and consumer behavior and provide practical solutions. Finally, suggestions for future research extend beyond theoretical research and should strongly contribute to policy. Clear policy proposals combined with efforts to understand and remove consumer and industry barriers will combine to move the circular economy toward a sustainable, renewable future.

6. Conclusions

In conclusion, our study sheds light on the circular economy's definitions, evaluations, and enhancements, emphasizing the crucial need for a well-defined framework and effective assessment methodologies. However, it is important to acknowledge its limitations, such as the restriction to English publications, the time scope of the review and the reliance on specific databases, which limits the available resources on the circular economy in the five industries. The study acknowledges that this selection may not capture all relevant publications and that further research on different databases could reveal additional insights into this dynamic and evolving field.

To elaborate, however, this work has demonstrated that there is a need to establish a definition of the circular economy as it provides an important guide to aligning industries, policies and actions towards sustainable and regenerative practices. A noteworthy academic discourse has been initiated concerning the precise definition of the CE. Furthermore, in various industries, the sector of assessing circularity is emerging as a compass that directs these industries toward transformation. Assessment methodologies do not measure progress. However, they measure the efficiency of the transformation from a linear to a circular economy and identify ways to improve. The adoption of adaptable assessment frameworks will be essential in realizing the potential of the economy driving industries toward continuous environmental management and innovative growth. Embracing CE presents both challenges and opportunities for industries.

While certain sectors or industries have advanced in implementing strategies, others face barriers such as regulatory obstacles, limited consumer awareness and financial constraints. By adopting practices, industries can reduce their environmental impact, foster innovation, reduce reliance on finite resources, and fundamentally reshape how we perceive value creation within a sustainable context.

One of the most promising ways to improve circularity is to apply Industry 4.0 principles and, more specifically, digital tools based on them. By combining technologies to monitor, analyze and enhance operations, industries can pave the way for a new era of resource efficiency reduction in waste and sustainable development within the framework of a circular economy. However, the implementation of Industry 4.0 in industrial sectors is at an early stage. Nevertheless, the theoretical background for the adoption of these technologies exists and is continuously developing. Finally, the main conclusion of this work is that a lot of information is provided for future research and an easier transition to the CE.

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References

1. Kirchherr, J.; Yang, N.-H.N.; Schulze-Spüntrup, F.; Heerink, M.J.; Hartley, K. Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. *Resour. Conserv. Recycl.* **2023**, *194*, 107001. [CrossRef]
2. Winans, K.; Kendall, A.; Deng, H. The History and Current Applications of the Circular Economy Concept. *Renew. Sustain. Energy Rev.* **2017**, *68*, 825–833. [CrossRef]
3. Ellen MacArthur Foundation towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition. Available online: https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an (accessed on 9 July 2023).
4. Ghisellini, P.; Ripa, M.; Ulgiati, S. Exploring Environmental and Economic Costs and Benefits of a Circular Economy Approach to the Construction and Demolition Sector. A Literature Review. *J. Clean. Prod.* **2018**, *178*, 618–643. [CrossRef]
5. Goyal, S.; Esposito, M.; Kapoor, A. Circular Economy Business Models in Developing Economies: Lessons from India on Reduce, Recycle, and Reuse Paradigms. *Thunderbird Int. Bus. Rev.* **2018**, *60*, 729–740. [CrossRef]

6. Arruda, E.H.; Melatto, R.A.P.B.; Levy, W.; Conti, D.D.M. Circular Economy: A Brief Literature Review (2015–2020). *Sustain. Oper. Comput.* **2021**, *2*, 79–86. [CrossRef]
7. Heshmati, A. A Review of the Circular Economy and Its Implementation. *IZA Discussion Paper*. December 2015. Available online: https://www.iza.org/publications/dp/9611/a-review-of-the-circular-economy-and-its-implementation (accessed on 29 November 2023).
8. Rathi, R.; Sabale, D.B.; Antony, J.; Kaswan, M.S.; Jayaraman, R. An Analysis of Circular Economy Deployment in Developing Nations' Manufacturing Sector: A Systematic State-of-the-Art Review. *Sustainability* **2022**, *14*, 11354. [CrossRef]
9. Potting, J.; Hekkert, M.; Worrell, E.; Hanemaaijer, A. *Circular Economy: Measuring Innovation in the Product Chain*; PBL Netherlands Environmental Assessment Agency: The Hague, The Netherlands, 2017.
10. Patwa, N.; Sivarajah, U.; Seetharaman, A.; Sarkar, S.; Maiti, K.; Hingorani, K. Towards a Circular Economy: An Emerging Economies Context. *J. Bus. Res.* **2021**, *122*, 725–735. [CrossRef]
11. Homrich, A.S.; Galvão, G.; Abadia, L.G.; Carvalho, M.M. The Circular Economy Umbrella: Trends and Gaps on Integrating Pathways. *J. Clean. Prod.* **2018**, *175*, 525–543. [CrossRef]
12. Stahel, W.R. The Circular Economy. *Nature* **2016**, *531*, 435–438. [CrossRef]
13. Rizos, V.; Tuokko, K.; Behrens, A. *A Review of Definitions, Processes and Impacts*; Centre for European Policy Studies: Brussels, Belgium, 2023. Available online: https://www.ceps.eu/wp-content/uploads/2017/04/RR2017-08_CircularEconomy_0.pdf (accessed on 11 July 2023).
14. Circular Economy Package: Questions & Answers. Available online: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_15_6204 (accessed on 27 July 2023).
15. Awan, U.; Kanwal, N.; Bhutta, M.K.S. A Literature Analysis of Definitions for a Circular Economy. In *Logistics Operations and Management for Recycling and Reuse*; Golinska-Dawson, P., Ed.; EcoProduction; Springer: Berlin/Heidelberg, Germany, 2020; pp. 19–34, ISBN 978-3-642-33856-4.
16. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The Circular Economy—A New Sustainability Paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
17. Geisendorf, S.; Pietrulla, F. The Circular Economy and Circular Economic Concepts-a Literature Analysis and Redefinition. *Thunderbird Int. Bus. Rev.* **2018**, *60*, 771–782. [CrossRef]
18. Alhawari, O.; Awan, U.; Bhutta, M.K.S.; Ülkü, M.A. Insights from Circular Economy Literature: A Review of Extant Definitions and Unravelling Paths to Future Research. *Sustainability* **2021**, *13*, 859. [CrossRef]
19. Nobre, G.C.; Tavares, E. The Quest for a Circular Economy Final Definition: A Scientific Perspective. *J. Clean. Prod.* **2021**, *314*, 127973. [CrossRef]
20. Korhonen, J.; Honkasalo, A.; Seppälä, J. Circular Economy: The Concept and Its Limitations. *Ecol. Econ.* **2018**, *143*, 37–46. [CrossRef]
21. Figge, F.; Thorpe, A.S.; Gutberlet, M. Definitions of the Circular Economy: Circularity Matters. *Ecol. Econ.* **2023**, *208*, 107823. [CrossRef]
22. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the Circular Economy: An Analysis of 114 Definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [CrossRef]
23. Corona, B.; Shen, L.; Reike, D.; Rosales Carreón, J.; Worrell, E. Towards Sustainable Development through the Circular Economy—A Review and Critical Assessment on Current Circularity Metrics. *Resour. Conserv. Recycl.* **2019**, *151*, 104498. [CrossRef]
24. Scheepens, A.E.; Vogtländer, J.G.; Brezet, J.C. Two Life Cycle Assessment (LCA) Based Methods to Analyse and Design Complex (Regional) Circular Economy Systems. Case: Making Water Tourism More Sustainable. *J. Clean. Prod.* **2016**, *114*, 257–268. [CrossRef]
25. van Stijn, A.; Malabi Eberhardt, L.C.; Wouterszoon Jansen, B.; Meijer, A. A Circular Economy Life Cycle Assessment (CE-LCA) Model for Building Components. *Resour. Conserv. Recycl.* **2021**, *174*, 105683. [CrossRef]
26. Antwi-Afari, P.; Ng, S.T.; Chen, J.; Oluleye, B.I.; Antwi-Afari, M.F.; Ababio, B.K. Enhancing Life Cycle Assessment for Circular Economy Measurement of Different Case Scenarios of Modular Steel Slab. *Build. Environ.* **2023**, *239*, 110411. [CrossRef]
27. Lei, H.; Li, L.; Yang, W.; Bian, Y.; Li, C.-Q. An Analytical Review on Application of Life Cycle Assessment in Circular Economy for Built Environment. *J. Build. Eng.* **2021**, *44*, 103374. [CrossRef]
28. Larsen, V.G.; Tollin, N.; Sattrup, P.A.; Birkved, M.; Holmboe, T. What Are the Challenges in Assessing Circular Economy for the Built Environment? A Literature Review on Integrating LCA, LCC and S-LCA in Life Cycle Sustainability Assessment, LCSA. *J. Build. Eng.* **2022**, *50*, 104203. [CrossRef]
29. Chen, Z.; Huang, L. Application Review of LCA (Life Cycle Assessment) in Circular Economy: From the Perspective of PSS (Product Service System). *Procedia CIRP* **2019**, *83*, 210–217. [CrossRef]
30. Barkhausen, R.; Rostek, L.; Miao, Z.C.; Zeller, V. Combinations of Material Flow Analysis and Life Cycle Assessment and Their Applicability to Assess Circular Economy Requirements in EU Product Regulations. A Systematic Literature Review. *J. Clean. Prod.* **2023**, *407*, 137017. [CrossRef]
31. Franklin-Johnson, E.; Figge, F.; Canning, L. Resource Duration as a Managerial Indicator for Circular Economy Performance. *J. Clean. Prod.* **2016**, *133*, 589–598. [CrossRef]
32. Park, J.Y.; Chertow, M.R. Establishing and Testing the "Reuse Potential" Indicator for Managing Wastes as Resources. *J. Environ. Manag.* **2014**, *137*, 45–53. [CrossRef]

33. Di Maio, F.; Rem, P.C.; Baldé, K.; Polder, M. Measuring Resource Efficiency and Circular Economy: A Market Value Approach. *Resour. Conserv. Recycl.* **2017**, *122*, 163–171. [CrossRef]
34. Azevedo, S.G.; Godina, R.; Matias, J.C.d.O. Proposal of a Sustainable Circular Index for Manufacturing Companies. *Resources* **2017**, *6*, 63. [CrossRef]
35. Adibi, N.; Lafhaj, Z.; Yehya, M.; Payet, J. Global Resource Indicator for Life Cycle Impact Assessment: Applied in Wind Turbine Case Study. *J. Clean. Prod.* **2017**, *165*, 1517–1528. [CrossRef]
36. Huysman, S.; De Schaepmeester, J.; Ragaert, K.; Dewulf, J.; De Meester, S. Performance Indicators for a Circular Economy: A Case Study on Post-Industrial Plastic Waste. *Resour. Conserv. Recycl.* **2017**, *120*, 46–54. [CrossRef]
37. Khadim, N.; Agliata, R.; Marino, A.; Thaheem, M.J.; Mollo, L. Critical Review of Nano and Micro-Level Building Circularity Indicators and Frameworks. *J. Clean. Prod.* **2022**, *357*, 131859. [CrossRef]
38. Ng, K.S.; Martinez, E. A Systematic Framework for Energetic, Environmental and Economic (3E) Assessment and Design of Polygeneration Systems. *Chem. Eng. Res. Des.* **2015**, *106*, 1–25. [CrossRef]
39. Shen, L.; Olfat, L.; Govindan, K.; Khodaverdi, R.; Diabat, A. A Fuzzy Multi Criteria Approach for Evaluating Green Supplier's Performance in Green Supply Chain with Linguistic Preferences. *Resour. Conserv. Recycl.* **2013**, *74*, 170–179. [CrossRef]
40. Olugu, E.U.; Wong, K.Y. An Expert Fuzzy Rule-Based System for Closed-Loop Supply Chain Performance Assessment in the Automotive Industry. *Expert. Syst. Appl.* **2012**, *39*, 375–384. [CrossRef]
41. Sassanelli, C.; Rosa, P.; Rocca, R.; Terzi, S. Circular Economy Performance Assessment Methods: A Systematic Literature Review. *J. Clean. Prod.* **2019**, *229*, 440–453. [CrossRef]
42. Markatos, D.N.; Pantelakis, S.G. Assessment of the Impact of Material Selection on Aviation Sustainability, from a Circular Economy Perspective. *Aerospace* **2022**, *9*, 52. [CrossRef]
43. Valls-Val, K.; Ibáñez-Forés, V.; Bovea, M.D. How Can Organisations Measure Their Level of Circularity? A Review of Available Tools. *J. Clean. Prod.* **2022**, *354*, 131679. [CrossRef]
44. Calculadora de Indicador de Circularidad. Acodea. Available online: https://acodea.solidforest.com/ (accessed on 11 August 2023).
45. Autodiagnóstico Medición Sostenibilidad En Las Organizaciones—Formularios | CEEI Valencia | EmprenemJunts. Available online: https://ceeivalencia.emprenemjunts.es/?op=65&n=883. (accessed on 11 August 2023).
46. Lead the Circular Economy with Circelligence by BCG. Available online: https://www.bcg.com/capabilities/climate-change-sustainability/circular-economy-circelligence (accessed on 11 August 2023).
47. CircularTRANS. Proceso Para Transitar Hacia La Economía Circular. Available online: https://www.mondragon.edu/circulartrans/es/login (accessed on 11 August 2023).
48. Circulytics—A World without Measurement Doesn't Work. Available online: https://ellenmacarthurfoundation.org/resources/circulytics/overview (accessed on 11 August 2023).
49. Available online: https://ctitool.com/ (accessed on 11 August 2023).
50. Inèdit—Autoevalúate. Available online: https://circular.ineditinnova.com/index/es (accessed on 11 August 2023).
51. ready2LOOP. Be the Change- Transition to Circular Economy Today. Technical University of Denmark. Available online: https://ready2loop.org/ (accessed on 11 August 2023).
52. Circulytics Resources. Available online: https://ellenmacarthurfoundation.org/resources/circulytics/resources (accessed on 11 August 2023).
53. DIAGNÓSTICO | Economiacircular. Available online: https://economiacircular.wixsite.com/economiacircular/cuestionario (accessed on 11 August 2023).
54. Balli, O.; Sohret, Y.; Karakoc, H.T. The Effects of Hydrogen Fuel Usage on the Exergetic Performance of a Turbojet Engine. *Int. J. Hydrog. Energy* **2018**, *43*, 10848–10858. [CrossRef]
55. Chatziparaskeva, G.; Papamichael, I.; Voukkali, I.; Loizia, P.; Sourkouni, G.; Argirusis, C.; Zorpas, A.A. End-of-Life of Composite Materials in the Framework of the Circular Economy. *Microplastics* **2022**, *1*, 377–392. [CrossRef]
56. Helping Aircraft Decommissioning. Available online: https://www.iata.org/en/programs/environment/aircraft-decommissioning/ (accessed on 9 August 2023).
57. Rodrigues Dias, V.M.; Jugend, D.; De Camargo Fiorini, P.; Razzino, C.D.A.; Paula Pinheiro, M.A. Possibilities for Applying the Circular Economy in the Aerospace Industry: Practices, Opportunities and Challenges. *J. Air Transp. Manag.* **2022**, *102*, 102227. [CrossRef]
58. Domone, J.; Bliss, P.; Copus, M. A Circular Economy for Civil Aerospace. Available online: www.snclavalin.com/media/Files/S/SNC-Lavalin/documents/circular-economy-in-aerospace-web3.pdf (accessed on 22 July 2022).
59. Salesa, A.; León, R.; Moneva, J.M. Airlines Practices to Incorporate Circular Economy Principles into the Waste Management System. *Corp. Soc. Responsib. Environ.* **2023**, *30*, 443–458. [CrossRef]
60. Ellen MacArthur Foundation. *Towards the Circular Economy Vol. 2: Opportunities for the Consumer Goods Sector*; Ellen MacArthur Foundation: Cowes, UK, 2013.
61. Ritzén, S.; Sandström, G.Ö. Barriers to the Circular Economy—Integration of Perspectives and Domains. *Procedia CIRP* **2017**, *64*, 7–12. [CrossRef]
62. Chiappetta Jabbour, C.J.; Seuring, S.; Lopes De Sousa Jabbour, A.B.; Jugend, D.; De Camargo Fiorini, P.; Latan, H.; Izeppi, W.C. Stakeholders, Innovative Business Models for the Circular Economy and Sustainable Performance of Firms in an Emerging Economy Facing Institutional Voids. *J. Environ. Manag.* **2020**, *264*, 110416. [CrossRef]

63. Andersson, D.; Stavileci, S. An Assessment of How Circular Economy Can Be Implemented in the Aerospace Industry. Master's Thesis, Blekinge Institute of Technology, Karlskrona, Sweden, 2015.
64. Bachmann, J.; Yi, X.; Tserpes, K.; Sguazzo, C.; Barbu, L.G.; Tse, B.; Soutis, C.; Ramón, E.; Linuesa, H.; Bechtel, S. Towards a Circular Economy in the Aviation Sector Using Eco-Composites for Interior and Secondary Structures. Results and Recommendations from the EU/China Project ECO-COMPASS. *Aerospace* **2021**, *8*, 131. [CrossRef]
65. Getting Fit for 55 and Set for 2050. Available online: https://windeurope.org/data-and-analysis/product/getting-fit-for-55-and-set-for-2050 (accessed on 12 August 2023).
66. Savvidou, G.; Johnsson, F. Material Requirements, Circularity Potential and Embodied Emissions Associated with Wind Energy. *Sustain. Prod. Consum.* **2023**, *40*, 471–487. [CrossRef]
67. Liu, P.; Barlow, C.Y. Wind Turbine Blade Waste in 2050. *Waste Manag.* **2017**, *62*, 229–240. [CrossRef] [PubMed]
68. Jensen, P.D.; Purnell, P.; Velenturf, A.P.M. Highlighting the Need to Embed Circular Economy in Low Carbon Infrastructure Decommissioning: The Case of Offshore Wind. *Sustain. Prod. Consum.* **2020**, *24*, 266–280. [CrossRef]
69. Gennitsaris, S.; Sagani, A.; Sofianopoulou, S.; Dedoussis, V. Integrated LCA and DEA Approach for Circular Economy-Driven Performance Evaluation of Wind Turbine End-of-Life Treatment Options. *Appl. Energy* **2023**, *339*, 120951. [CrossRef]
70. Sherwood, J.; Gongora, G.T.; Velenturf, A.P.M. A Circular Economy Metric to Determine Sustainable Resource Use Illustrated with Neodymium for Wind Turbines. *J. Clean. Prod.* **2022**, *376*, 134305. [CrossRef]
71. Diez-Cañamero, B.; Mendoza, J.M.F. Circular Economy Performance and Carbon Footprint of Wind Turbine Blade Waste Management Alternatives. *Waste Manag.* **2023**, *164*, 94–105. [CrossRef]
72. Mendoza, J.M.F.; Ibarra, D. Technology-Enabled Circular Business Models for the Hybridisation of Wind Farms: Integrated Wind and Solar Energy, Power-to-Gas and Power-to-Liquid Systems. *Sustain. Prod. Consum.* **2023**, *36*, 308–327. [CrossRef]
73. Mendoza, J.M.F.; Gallego-Schmid, A.; Velenturf, A.P.M.; Jensen, P.D.; Ibarra, D. Circular Economy Business Models and Technology Management Strategies in the Wind Industry: Sustainability Potential, Industrial Challenges and Opportunities. *Renew. Sustain. Energy Rev.* **2022**, *163*, 112523. [CrossRef]
74. EC, White Paper. *Roadmap to a Single European Transport Area—Towards a Competitive and Resource Efficient Transport System*; COM(2011) 144 final; COM/European Commission: Brussels, Belgium, 2011.
75. Tong, F.; Azevedo, I.M.L. What Are the Best Combinations of Fuel-Vehicle Technologies to Mitigate Climate Change and Air Pollution Effects across the United States? *Environ. Res. Lett.* **2020**, *15*, 074046. [CrossRef]
76. Moro, A.; Lonza, L. Electricity Carbon Intensity in European Member States: Impacts on GHG Emissions of Electric Vehicles. *Transp. Res. Part D Transp. Environ.* **2018**, *64*, 5–14. [CrossRef]
77. Harrison, G.; Gómez Vilchez, J.J.; Thiel, C. Industry Strategies for the Promotion of E-Mobility under Alternative Policy and Economic Scenarios. *Eur. Transp. Res. Rev.* **2018**, *10*, 19. [CrossRef]
78. Demartini, M.; Ferrari, M.; Govindan, K.; Tonelli, F. The Transition to Electric Vehicles and a Net Zero Economy: A Model Based on Circular Economy, Stakeholder Theory, and System Thinking Approach. *J. Clean. Prod.* **2023**, *410*, 137031. [CrossRef]
79. van Bruggen, A.R.; Zonneveld, M.; Zijp, M.C.; Posthuma, L. Solution-Focused Sustainability Assessments for the Transition to the Circular Economy: The Case of Plastics in the Automotive Industry. *J. Clean. Prod.* **2022**, *358*, 131606. [CrossRef]
80. Mügge, J.; Hahn, I.R.; Riedelsheimer, T.; Chatzis, J.; Boes, J. End-of-Life Decision Support to Enable Circular Economy in the Automotive Industry Based on Digital Twin Data. *Procedia CIRP* **2023**, *119*, 1071–1077. [CrossRef]
81. Nag, U.; Sharma, S.K.; Govindan, K. Investigating Drivers of Circular Supply Chain with Product-Service System in Automotive Firms of an Emerging Economy. *J. Clean. Prod.* **2021**, *319*, 128629. [CrossRef]
82. Rizvi, S.W.H.; Agrawal, S.; Murtaza, Q. Automotive Industry and Industry 4.0-Circular Economy Nexus through the Consumers' and Manufacturers' Perspectives: A Case Study. *Renew. Sustain. Energy Rev.* **2023**, *183*, 113517. [CrossRef]
83. Valladares Montemayor, H.M.; Chanda, R.H. Automotive Industry's Circularity Applications and Industry 4.0. *Environ. Chall.* **2023**, *12*, 100725. [CrossRef]
84. Yadav, G.; Luthra, S.; Jakhar, S.K.; Mangla, S.K.; Rai, D.P. A Framework to Overcome Sustainable Supply Chain Challenges through Solution Measures of Industry 4.0 and Circular Economy: An Automotive Case. *J. Clean. Prod.* **2020**, *254*, 120112. [CrossRef]
85. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F.; Kendall, A. A Taxonomy of Circular Economy Indicators. *J. Clean. Prod.* **2019**, *207*, 542–559. [CrossRef]
86. Schulz, M.; Niero, M.; Rehmann, L.-M.; Georg, S. Exploration of Decision-Contexts for Circular Economy in Automotive Industry. *Procedia CIRP* **2021**, *98*, 19–24. [CrossRef]
87. Baldassarre, B.; Maury, T.; Mathieux, F.; Garbarino, E.; Antonopoulos, I.; Sala, S. Drivers and Barriers to the Circular Economy Transition: The Case of Recycled Plastics in the Automotive Sector in the European Union. *Procedia CIRP* **2022**, *105*, 37–42. [CrossRef]
88. Kayikci, Y.; Kazancoglu, Y.; Lafci, C.; Gozacan, N. Exploring Barriers to Smart and Sustainable Circular Economy: The Case of an Automotive Eco-Cluster. *J. Clean. Prod.* **2021**, *314*, 127920. [CrossRef]
89. Urbinati, A.; Franzò, S.; Chiaroni, D. Enablers and Barriers for Circular Business Models: An Empirical Analysis in the Italian Automotive Industry. *Sustain. Prod. Consum.* **2021**, *27*, 551–566. [CrossRef]
90. The-Business-Sports.pdf. Available online: https://assets.kpmg.com/content/dam/kpmg/in/pdf/2016/10/The-business-sports.pdf (accessed on 26 August 2023).
91. Yarmoliuk, O. Sustainable Management in Sport. *Sustainability Essentials*, 1 April 2019.

92. Fuchs, M.; Hovemann, G. Homogeneity or Heterogeneity: An Institutional Theory View on Circular Economy Practices in the Outdoor Sporting Goods Industry. *Sustainability* **2022**, *14*, 6279. [CrossRef]
93. Fuchs, M.; Hovemann, G. The Circular Economy Concept in the Outdoor Sporting Goods Industry: Challenges and Enablers of Current Practices among Brands and Retailers. *Sustainability* **2022**, *14*, 7771. [CrossRef]
94. Petronis, T.; Valusyte, R. Circular Design in the Sports Industry: From Sustainability to a Circular Economy. In Proceedings of the 2021 IEEE International Conference on Technology and Entrepreneurship (ICTE), Kaunas, Lithuania, 24 August 2021; IEEE: Piscataway, NJ, USA, 2021; pp. 1–7.
95. Szto, C.; Wilson, B. Reduce, Re-Use, Re-Ride: Bike Waste and Moving towards a Circular Economy for Sporting Goods. *Int. Rev. Sociol. Sport* **2023**, *58*, 911–931. [CrossRef]
96. Rossi, J.; Bianchini, A.; Guarnieri, P. Circular Economy Model Enhanced by Intelligent Assets from Industry 4.0: The Proposition of an Innovative Tool to Analyze Case Studies. *Sustainability* **2020**, *12*, 7147. [CrossRef]
97. Parida, V.; Sjödin, D.; Reim, W. Reviewing Literature on Digitalization, Business Model Innovation, and Sustainable Industry: Past Achievements and Future Promises. *Sustainability* **2019**, *11*, 391. [CrossRef]
98. Demestichas, K.; Daskalakis, E. Information and Communication Technology Solutions for the Circular Economy. *Sustainability* **2020**, *12*, 7272. [CrossRef]
99. Jørgensen, S.; Pedersen, L.J.T.; Skard, S. Resource Accounting for a Circular Economy: Evidence from a Digitalised Waste Management System. In *Accounting Forum*; Routledge: Oxfordshire, UK, 2023; pp. 1–30. [CrossRef]
100. Gatenholm, G.; Halldórsson, Á.; Bäckstrand, J. Enhanced Circularity in Aftermarkets: Logistics Tradeoffs. *Int. J. Phys. Distrib. Logist. Manag.* **2021**, *51*, 999–1021. [CrossRef]
101. Çetin, S.; De Wolf, C.; Bocken, N. Circular Digital Built Environment: An Emerging Framework. *Sustainability* **2021**, *13*, 6348. [CrossRef]
102. Tseng, M.-L.; Tran, T.P.T.; Ha, H.M.; Bui, T.-D.; Lim, M.K. Sustainable Industrial and Operation Engineering Trends and Challenges Toward Industry 4.0: A Data Driven Analysis. *J. Ind. Prod. Eng.* **2021**, *38*, 581–598. [CrossRef]
103. Antikainen, M.; Uusitalo, T.; Kivikytö-Reponen, P. Digitalisation as an Enabler of Circular Economy. *Procedia CIRP* **2018**, *73*, 45–49. [CrossRef]
104. Ćwiklicki, M.; Wojnarowska, M. Circular Economy and Industry 4.0: One-Way or Two-Way Relationships? *Eng. Econ.* **2020**, *31*, 387–397. [CrossRef]
105. Khan, S.A.R.; Shah, A.S.A.; Yu, Z.; Tanveer, M. A Systematic Literature Review on Circular Economy Practices: Challenges, Opportunities and Future Trends. *J. Entrep. Emerg. Econ.* **2022**, *14*, 754–795. [CrossRef]
106. Hoosain, M.S.; Paul, B.S.; Ramakrishna, S. The Impact of 4IR Digital Technologies and Circular Thinking on the United Nations Sustainable Development Goals. *Sustainability* **2020**, *12*, 10143. [CrossRef]
107. Rosário, A.; Dias, J. Sustainability and the Digital Transition: A Literature Review. *Sustainability* **2022**, *14*, 4072. [CrossRef]
108. Nandi, S.; Hervani, A.A.; Helms, M.M.; Sarkis, J. Conceptualising Circular Economy Performance with Non-Traditional Valuation Methods: Lessons for a Post-Pandemic Recovery. *Int. J. Logist. Res. Appl.* **2023**, *26*, 662–682. [CrossRef]
109. Elghaish, F.; Matarneh, S.T.; Edwards, D.J.; Pour Rahimian, F.; El-Gohary, H.; Ejohwomu, O. Applications of Industry 4.0 Digital Technologies towards a Construction Circular Economy: Gap Analysis and Conceptual Framework. *Constr. Innov.* **2022**, *22*, 647–670. [CrossRef]
110. Tavana, M.; Shaabani, A.; Raeesi Vanani, I.; Kumar Gangadhari, R. A Review of Digital Transformation on Supply Chain Process Management Using Text Mining. *Processes* **2022**, *10*, 842. [CrossRef]
111. Teisserenc, B.; Sepasgozar, S. Adoption of Blockchain Technology through Digital Twins in the Construction Industry 4.0: A PESTELS Approach. *Buildings* **2021**, *11*, 670. [CrossRef]
112. De Felice, F.; Petrillo, A. Green Transition: The Frontier of the Digicircular Economy Evidenced from a Systematic Literature Review. *Sustainability* **2021**, *13*, 11068. [CrossRef]
113. Rusch, M.; Schöggl, J.; Baumgartner, R.J. Application of Digital Technologies for Sustainable Product Management in a Circular Economy: A Review. *Bus. Strat. Environ.* **2023**, *32*, 1159–1174. [CrossRef]
114. Cagno, E.; Neri, A.; Negri, M.; Bassani, C.A.; Lampertico, T. The Role of Digital Technologies in Operationalizing the Circular Economy Transition: A Systematic Literature Review. *Appl. Sci.* **2021**, *11*, 3328. [CrossRef]
115. Lasi, H.; Fettke, P.; Kemper, H.-G.; Feld, T.; Hoffmann, M. Industry 4.0. *Bus. Inf. Syst. Eng.* **2014**, *6*, 239–242. [CrossRef]
116. Whitmore, A.; Agarwal, A.; Da Xu, L. The Internet of Things—A Survey of Topics and Trends. *Inf. Syst. Front.* **2015**, *17*, 261–274. [CrossRef]
117. Talamo, C.; Pinto, M.R.; Viola, S.; Atta, N. Smart Cities and Enabling Technologies: Influences on Urban Facility Management Services. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *296*, 012047. [CrossRef]
118. Baiardi, L.; Ciaramella, A.; Bellintani, S. A Development and Management Model for "Smart" Temporary Residences. In *Regeneration of the Built Environment from a Circular Economy Perspective*; Della Torre, S., Cattaneo, S., Lenzi, C., Zanelli, A., Eds.; Research for Development; Springer International Publishing: Cham, Switzerland, 2020; pp. 337–346, ISBN 978-3-030-33255-6.
119. Han, Y.; Shevchenko, T.; Yannou, B.; Ranjbari, M.; Shams Esfandabadi, Z.; Saidani, M.; Bouillass, G.; Bliumska-Danko, K.; Li, G. Exploring How Digital Technologies Enable a Circular Economy of Products. *Sustainability* **2023**, *15*, 2067. [CrossRef]
120. Abruzzini, A.; Abrishami, S. Integration of BIM and Advanced Digital Technologies to the End of Life Decision-Making Process: A Paradigm of Future Opportunities. *J. Eng. Des. Technol.* **2022**, *20*, 388–413. [CrossRef]

121. World Economic Forum and Ellen MacArthur Foundation, Intelligent Assets: Unlocking the Circular Economy Potential, 2016. Available online: https://www.ellenmacarthurfoundation.org/intelligent-assets-unlocking-the-circular-economy-potential (accessed on 5 August 2023).
122. Stock, T.; Seliger, G. Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP* **2016**, *40*, 536–541. [CrossRef]
123. Saura, J.R.; Ribeiro-Soriano, D.; Palacios-Marqués, D. Adopting Digital Reservation Systems to Enable Circular Economy in Entrepreneurship. *Manag. Decis.* **2022**. [CrossRef]
124. Colla, V.; Pietrosanti, C.; Malfa, E.; Peters, K. Environment 4.0: How Digitalization and Machine Learning Can Improve the Environmental Footprint of the Steel Production Processes. *Matériaux Tech.* **2020**, *108*, 507. [CrossRef]
125. Talla, A.; McIlwaine, S. Industry 4.0 and the Circular Economy: Using Design-Stage Digital Technology to Reduce Construction Waste. *Smart Sustain. Built Environ.* **2022**. [CrossRef]
126. Choudhuri, B.; Srivastava, P.R.; Mangla, S.K.; Kazancoglu, Y. Enterprise Architecture as a Responsible Data Driven Urban Digitization Framework: Enabling Circular Cities in India. *Ann. Oper. Res.* **2023**, 1–29. [CrossRef]
127. Ciliberto, C.; Szopik-Depczyńska, K.; Tarczyńska-Łuniewska, M.; Ruggieri, A.; Ioppolo, G. Enabling the Circular Economy Transition: A Sustainable Lean Manufacturing Recipe for Industry 4.0. *Bus. Strat. Environ.* **2021**, *30*, 3255–3272. [CrossRef]
128. Bag, S.; Pretorius, J.H.C. Relationships between Industry 4.0, Sustainable Manufacturing and Circular Economy: Proposal of a Research Framework. *Int. J. Organ. Anal.* **2022**, *30*, 864–898. [CrossRef]
129. Islam, M.T.; Iyer-Raniga, U.; Trewick, S. Recycling Perspectives of Circular Business Models: A Review. *Recycling* **2022**, *7*, 79. [CrossRef]
130. Bressanelli, G.; Saccani, N.; Perona, M.; Baccanelli, I. Towards Circular Economy in the Household Appliance Industry: An Overview of Cases. *Resources* **2020**, *9*, 128. [CrossRef]
131. Alves, L.; Ferreira Cruz, E.; Lopes, S.I.; Faria, P.M.; Rosado Da Cruz, A.M. Towards Circular Economy in the Textiles and Clothing Value Chain through Blockchain Technology and IoT: A Review. *Waste Manag. Res.* **2022**, *40*, 3–23. [CrossRef] [PubMed]
132. Rejeb, A.; Rejeb, K.; Abdollahi, A.; Zailani, S.; Iranmanesh, M.; Ghobakhloo, M. Digitalization in Food Supply Chains: A Bibliometric Review and Key-Route Main Path Analysis. *Sustainability* **2021**, *14*, 83. [CrossRef]
133. Huynh, P.H. Enabling Circular Business Models in the Fashion Industry: The Role of Digital Innovation. *Int. J. Product. Perform. Manag.* **2022**, *71*, 870–895. [CrossRef]
134. Akram, S.V.; Malik, P.K.; Singh, R.; Gehlot, A.; Juyal, A.; Ghafoor, K.Z.; Shrestha, S. Implementation of Digitalized Technologies for Fashion Industry 4.0: Opportunities and Challenges. *Sci. Program.* **2022**, *2022*, 7523246. [CrossRef]
135. Romagnoli, S.; Tarabu', C.; Maleki Vishkaei, B.; De Giovanni, P. The Impact of Digital Technologies and Sustainable Practices on Circular Supply Chain Management. *Logistics* **2023**, *7*, 1. [CrossRef]
136. Hettiarachchi, B.D.; Seuring, S.; Brandenburg, M. Industry 4.0-Driven Operations and Supply Chains for the Circular Economy: A Bibliometric Analysis. *Oper. Manag. Res.* **2022**, *15*, 858–878. [CrossRef]
137. Agrawal, R.; Priyadarshinee, P.; Kumar, A.; Luthra, S.; Garza-Reyes, J.A.; Kadyan, S. Are Emerging Technologies Unlocking the Potential of Sustainable Practices in the Context of a Net-Zero Economy? An Analysis of Driving Forces. *Environ. Sci. Pollut. Res.* **2023**, 1–19. [CrossRef] [PubMed]
138. Magrini, C.; Nicolas, J.; Berg, H.; Bellini, A.; Paolini, E.; Vincenti, N.; Campadello, L.; Bonoli, A. Using Internet of Things and Distributed Ledger Technology for Digital Circular Economy Enablement: The Case of Electronic Equipment. *Sustainability* **2021**, *13*, 4982. [CrossRef]
139. Joshi, S.; Sharma, M.; Barve, A. Implementation Challenges of Blockchain Technology in Closed-Loop Supply Chain: A Waste Electrical and Electronic Equipment (WEEE) Management Perspective in Developing Countries. *Supply Chain. Forum Int. J.* **2023**, *24*, 59–80. [CrossRef]
140. Liu, Q.; Trevisan, A.H.; Yang, M.; Mascarenhas, J. A Framework of Digital Technologies for the Circular Economy: Digital Functions and Mechanisms. *Bus. Strat. Environ.* **2022**, *31*, 2171–2192. [CrossRef]
141. Y.2060: Overview of the Internet of Things. Available online: https://www.itu.int/rec/T-REC-Y.2060-201206-I (accessed on 28 August 2023).
142. Ramadoss, T.S.; Alam, H.; Seeram, R. Artificial Intelligence and Internet of Things Enabled Circular Economy. *Int. J. Eng. Sci.* **2018**, *7*, 55–63.
143. Voulgaridis, K.; Lagkas, T.; Angelopoulos, C.M.; Nikoletseas, S.E. IoT and Digital Circular Economy: Principles, Applications, and Challenges. *Comput. Netw.* **2022**, *219*, 109456. [CrossRef]
144. Ingemarsdotter, E.; Jamsin, E.; Kortuem, G.; Balkenende, R. Circular Strategies Enabled by the Internet of Things—A Framework and Analysis of Current Practice. *Sustainability* **2019**, *11*, 5689. [CrossRef]
145. Akbari, M.; Hopkins, J.L. Digital Technologies as Enablers of Supply Chain Sustainability in an Emerging Economy. *Oper. Manag. Res.* **2022**, *15*, 689–710. [CrossRef]
146. Kazancoglu, Y.; Ozbiltekin-Pala, M.; Sezer, M.D.; Kumar, A.; Luthra, S. Circular Dairy Supply Chain Management through Internet of Things-Enabled Technologies. *Environ. Sci. Pollut. Res.* **2022**, 1–13. [CrossRef]
147. Garcia-Muiña, F.E.; González-Sánchez, R.; Ferrari, A.M.; Volpi, L.; Pini, M.; Siligardi, C.; Settembre-Blundo, D. Identifying the Equilibrium Point between Sustainability Goals and Circular Economy Practices in an Industry 4.0 Manufacturing Context Using Eco-Design. *Soc. Sci.* **2019**, *8*, 241. [CrossRef]

148. Chau, M.Q.; Nguyen, X.P.; Huynh, T.T.; Chu, V.D.; Le, T.H.; Nguyen, T.P.; Nguyen, D.T. Prospects of Application of IoT-Based Advanced Technologies in Remanufacturing Process towards Sustainable Development and Energy-Efficient Use. *Energy Sources Part A Recovery Util. Environ. Eff.* **2021**, 1–25. [CrossRef]
149. Awan, U.; Shamim, S.; Khan, Z.; Zia, N.U.; Shariq, S.M.; Khan, M.N. Big Data Analytics Capability and Decision-Making: The Role of Data-Driven Insight on Circular Economy Performance. *Technol. Forecast. Soc. Chang.* **2021**, *168*, 120766. [CrossRef]
150. Edwin Cheng, T.C.; Kamble, S.S.; Belhadi, A.; Ndubisi, N.O.; Lai, K.; Kharat, M.G. Linkages between Big Data Analytics, Circular Economy, Sustainable Supply Chain Flexibility, and Sustainable Performance in Manufacturing Firms. *Int. J. Prod. Res.* **2022**, *60*, 6908–6922. [CrossRef]
151. Gupta, S.; Chen, H.; Hazen, B.T.; Kaur, S.; Santibañez Gonzalez, E.D.R. Circular Economy and Big Data Analytics: A Stakeholder Perspective. *Technol. Forecast. Soc. Chang.* **2019**, *144*, 466–474. [CrossRef]
152. Salminen, V.; Ruohomaa, H.; Kantola, J. Digitalization and Big Data Supporting Responsible Business Co-Evolution. In *Advances in Human Factors, Business Management, Training and Education*; Kantola, J.I., Barath, T., Nazir, S., Andre, T., Eds.; Advances in Intelligent Systems and Computing; Springer International Publishing: Cham, Switzerland, 2017; Volume 498, pp. 1055–1067, ISBN 978-3-319-42069-1.
153. Del Giudice, M.; Chierici, R.; Mazzucchelli, A.; Fiano, F. Supply Chain Management in the Era of Circular Economy: The Moderating Effect of Big Data. *Int. J. Logist. Manag.* **2021**, *32*, 337–356. [CrossRef]
154. Fraga-Lamas, P.; Lopes, S.I.; Fernández-Caramés, T.M. Green IoT and Edge AI as Key Technological Enablers for a Sustainable Digital Transition towards a Smart Circular Economy: An Industry 5.0 Use Case. *Sensors* **2021**, *21*, 5745. [CrossRef]
155. Artificial Intelligence and the Circular Economy. Available online: https://ellenmacarthurfoundation.org/artificial-intelligence-and-the-circular-economy (accessed on 30 August 2023).
156. Ghoreishi, M.; Happonen, A. New Promises AI Brings into Circular Economy Accelerated Product Design: A Review on Supporting Literature. *E3S Web Conf.* **2020**, *158*, 06002. [CrossRef]
157. Awan, U.; Kanwal, N.; Alawi, S.; Huiskonen, J.; Dahanayake, A. Artificial Intelligence for Supply Chain Success in the Era of Data Analytics. In *The Fourth Industrial Revolution: Implementation of Artificial Intelligence for Growing Business Success*; Hamdan, A., Hassanien, A.E., Razzaque, A., Alareeni, B., Eds.; Studies in Computational Intelligence; Springer International Publishing: Cham, Switzerland, 2021; Volume 935, pp. 3–21, ISBN 978-3-030-62795-9.
158. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [CrossRef]
159. Juszczyk, O.; Shahzad, K. Blockchain Technology for Renewable Energy: Principles, Applications and Prospects. *Energies* **2022**, *15*, 4603. [CrossRef]
160. Rehman Khan, S.A.; Yu, Z.; Sarwat, S.; Godil, D.I.; Amin, S.; Shujaat, S. The Role of Block Chain Technology in Circular Economy Practices to Improve Organisational Performance. *Int. J. Logist. Res. Appl.* **2022**, *25*, 605–622. [CrossRef]