

Systematic Review

Integrating Circular Economy Practices into Renewable Energy in the Manufacturing Sector: A Systematic Review of the Literature

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Abstract

The primary aim of this paper is to survey the literature's coverage of integrating circular economy practices with renewable energy sources in the manufacturing sector. A systematic review of 107 peer-reviewed articles published between 2018 and 2023 in journals within the Web of Science and Scopus databases was conducted. The review documented CE and RE applications in emerging economies across Africa, Asia, and South America, assessing the overall characteristics of the research, its methodological rigour, and the barriers to or facilitators of CE and RE integration. Integration refers to the implementation of at least one CE practice, as well as one or more RE sources, in a single context, like manufacturing. A total of 14 practices were included in this analysis because they were mentioned at least 10 times by varying authors. The practice list includes recycling (mentioned in 74 articles), reducing materials (57), remanufacturing (53), the reuse of materials (51), waste minimisation (48), renewable energy use (43), consumer awareness (38), repurposing (35), refuse (33), education and training (28), environmentally friendly design (22), environmental criteria for supplier selection (17), reverse logistics (16), and stakeholder collaboration (14). Recycling, life cycle assessment, and end-of-life management were the most common CE practices in the literature. Additionally, solar power and bioenergy emerged as the most frequently recurring areas of integration for CE practices within the RE realms. Governmental support, incentives, research and development, and strong environmental legislation were found to be the most frequently recurring facilitators of effective CE and RE integration. Organisational resistance, bureaucratic red tape, lack of human capital, limited stakeholder involvement, and insufficient collaboration were found to be important barriers to effective integration between CE and RE.

Keywords: circular economy; renewable energy; transition; sustainability; systematic literature review; emerging economies

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1. Introduction

The circular economy (CE) aims to reduce waste while improving financial returns and environmental protection [1,2]. By 2030, the CE will reduce primary material consumption (i.e., construction and manufacturing materials, land, fertilizers and pesticides, water use, fuels, and non-renewable energy) by 32% [3,4]. Additionally, the CE will accelerate the rate of primary material recycling tenfold if it is implemented in extraction, production, and consumption processes in the future [5,6].

The CE refers to the reduction, reuse, and recycling of resources in production or service provision, shifting away from the “take, make, and dispose” model [7]. The framework transforms the concept of linear production by introducing a circular system [8–14]. The concept developed with the rise of industrial ecology, which aimed to optimise the location of manufacturing facilities throughout the 1950s and 1960s [15]. Industrial ecologists desired prime locations for facilities to minimise the time and resources needed for the transfer and processing of raw materials [16,17]. An increasingly popular practice among circular economy advocates is the expanding role of renewable energy [18–20].

Renewable energy is the production of power using natural, replenishable sources [20–22]. The production of electricity using wind, water, or solar power is not a new phenomenon [23]. For centuries, electricity has been generated to power many industrial applications using renewable energy sources across the world [24,25]. The implementation of the circular economy, therefore, necessarily incorporates renewable energy production [26–28]. The concept of renewable energy as part of sustainability advocacy gained momentum during the oil crisis in the 1970s [15]. On the one hand, the idea of soft energy paths emphasising energy efficiency emerged in North America and Western Europe in the late 1960s [20,21]. On the other hand, the rise of the Green Movement cemented its position within political spheres across many countries in the 1980s. Renewable energy sources have shown tremendous progress in decreasing greenhouse gas emissions and increasing environmental quality around the world [24,26].

In line with the CE model, renewable energy transitions have emerged as lucrative, sustainable, and efficient models that assist in the implementation of the CE in achieving its goals [29]. Similarly, CE practices like recycling contribute to renewable energy transitions by turning waste like compost into energy used in production, thereby minimising resource utilisation [30]. Therefore, integrating CE practices with renewable energy production leads to long-term financial savings for the private sector and the achievement of sustainable development goals from the public sector perspective, and, most importantly, it decreases negative environmental impacts [31]. The simultaneous implementation of CE practices within renewable energy transitions reduces the amount of waste, enhances efficient production, improves optimal process alignment, and encourages social corporate responsibility initiatives [32,33].

While authors in the literature have not unanimously agreed on a specific list of principles, a number of shared principles recur across various studies. The list of common CE principles includes reduce, reuse, recycle, refurbish, repair, remanufacture, repurpose, recover, rethink, and refuse. The application of CE practices within renewable energy is multifaceted. On the one hand, recycling and reuse have been applied to extend the lifespan of solar panels and wind turbines. On the other hand, Waste-to-Energy facilities reduce the amount of waste while enhancing clean energy production in manufacturing facilities. Over the past decade, an increasing industrial interest in integrating renewable energy and the circular economy in manufacturing has emerged across various contexts around the globe [34]. Governments have passed several environmental legislations aimed at decreasing carbon emissions in manufacturing, with an emphasis on the increasing role of renewable energy [35]. The literature is interdisciplinary and spans many fields and applications. The current research attempts to synthesise the empirical literature on integration. Furthermore, learning about successful cases of integration guides government policymakers in drafting effective energy policies, helping them make strides toward achieving sustainable development [36,37].

The purpose of this research is to present a comprehensive overview of the literature on integrating CE practices with renewable energy. The driving research question for this study is as follows: How have researchers examined the integration of CE practices and

renewable energy? To achieve this objective, the present research follows a systematic literature review (SLR) methodology. In other words, the present study provides the number of peer-reviewed articles published in the Web of Science and Scopus databases between 2018 and 2023. There are several objectives underlying this review to fulfil the purpose of the investigation. First, this research provides readers with a thorough description of the published literature on the integration of the circular economy and renewable energy. Second, this review demonstrates the research rigour by displaying the quality of journals publishing the examined literature. Third, an analysis of the content of the published research is conducted to generate an overview of the barriers and facilitators facing the integration of the circular economy and renewable energy in both advanced and emerging economies.

2. Methods

This research utilised a systematic literature review (SLR) approach to examine the common patterns, trends, themes, research limitations, and opportunities in scholarly writing on renewable energy and circular economy. SLRs are distinguishable from other types of reviews with respect to their design, implementation, organisation, and presentation [38,39]. Unlike exploratory literature reviews that answer one or more research questions without delving into the quality of the research and the characteristics of the research itself, SLRs describe a collection of research attributes surrounding the research question prior to the interpretation of the literature's main arguments on the primary inquiry [36,40]. The description of the quality of CE and RE literature preceded discussions on the relationship between the different RE types and various CE practices in the Section 3 of this investigation. SLRs, for instance, present the number of papers, journals, authors, and keywords used in the scholarship on a topic. While such information is helpful in contextualising the setting around the presented research, it is not essential in the provision of succinct answers to proposed questions. Like any methodology, SLRs are not free from limits [41–44]. SLRs tend to be more comprehensive, covering more variables about a research question compared to scoping, exploratory, and non-systematic reviews [45,46]. They are celebrated as the most comprehensive, transparent, and replicated types of reviews in the scientific community [47,48].

Regardless of the variety in SLRs implementation across disciplines, five essential steps must be completed to fully satisfy the output warranted by SLRs [49,50]. First, researchers need to identify one or more research questions. In this study, the primary question driving the research was how have researchers examined the integration of renewable energy and the circular economy in the past five years across all disciplines? The answer to this question is presented in the Section 3 using descriptive statistics and thematic analysis. A specific focus was awarded to Saudi Arabia, the case study for further research in this project. Second, SLRs proceed with an elaborate strategy in identifying relevant studies to answer the research question [51,52]. In this research, the identification procedures are detailed below in this section. Third, SLRs need to evaluate the quality of the research used to answer the research question [53,54].

In this study, the variety of journals, their impact factors, and the number of citations are used to assess the trustworthiness and authenticity levels of the research reviewed. Such metrics have been recommended by many experts in the evaluation of research quality. The impact factor is used as a metric of journals' importance and ranking [55]. One study noted that "impact simply reflects the ability of the journals and editors to attract the best paper available," leading to more reliable and trustworthy studies being utilised by the publication [56] (p. 123). Authors prefer to publish their research in journals featuring high-impact factors because of the perception that journals with high-impact factors are

superior to journals with no or lower scores. Similarly, journals with a high-impact factor tend to be well-established as reputable sources of information within their disciplines. Simultaneously, the number of citations per article represents the attractiveness, reliability, and strength of the published manuscripts [57,58].

Fourth, SLRs identify the common themes in the results surrounding the research question [59,60]. In this analysis, the main barriers and facilitators of the integration of renewable energy and the circular economy were reported as part of the literature's summary. Further, the themes of the main findings were integrated into a few meaningful themes to aid readers in understanding the highly interdisciplinary nature of the findings. Fifth, SLRs feature interpretive remarks concerning the evidence reported or summarised throughout the analysis [61,62]. In this study, theoretical and practical implications, coupled with Section 4.4, were included to better situate the findings in the study.

Figure 1 represents the five distinct phases taken to complete the SLR on renewable energy and circular economy integration. Each phase has distinct objectives, and a set of primary tasks completed to fulfil the goals. The five phases were crafting the review scope and direction, preparing for the review, conducting the review, preparing the preparation of review analysis and findings, and the write-up of the final report. Each phase was completed separately to ensure the transparency and quality of the procedure to generate the best possible results for the research. The arrows indicate the logical flow and connections between the stages, objectives, and tasks.

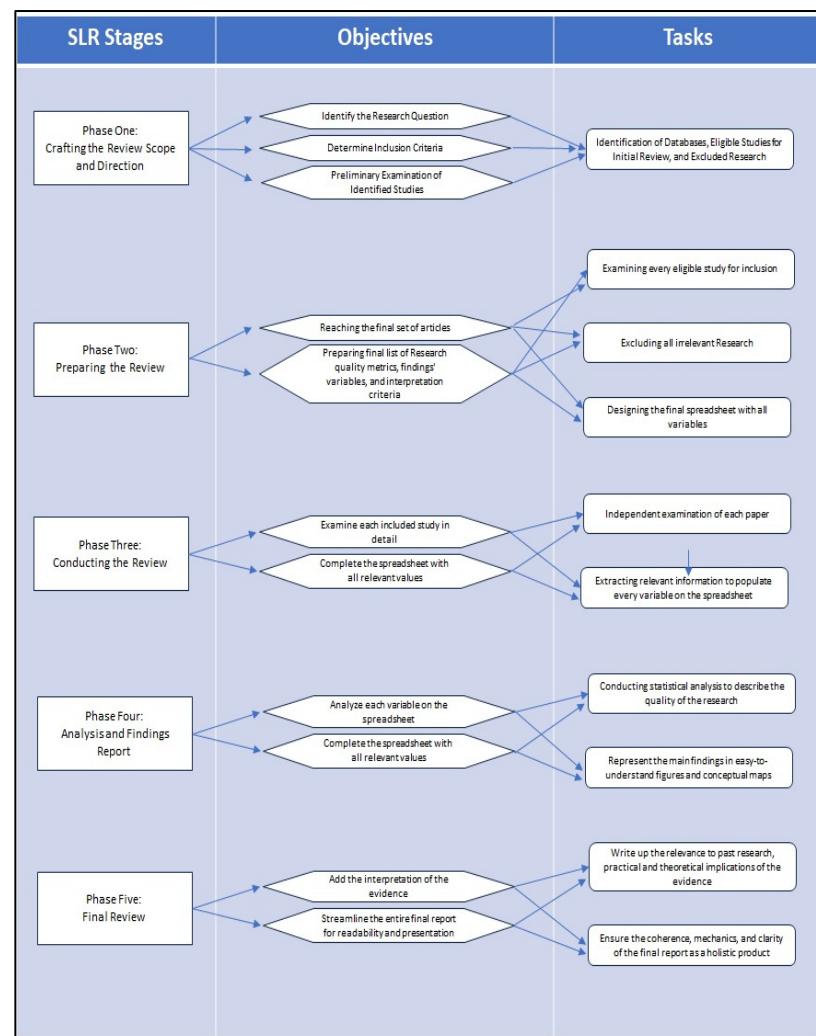


Figure 1. Systematic Literature Review (SLR) Phases.

2.1. Phase 1: Crafting the Review's Scope and Direction

The first step in the SLR is to prepare a specific research question. The primary research question in this review is how have researchers examined renewable energy and circular economy integration in the past five years across all disciplines? The main component determining the scope of this review is the integration element. The question covers all types of renewable energy and all practices of the circular economy. The integration simply refers to combining at least one type of renewable energy with one or more practices of the circular economy in a research paper. The five-year metric ensures the inclusion of the most recent research in the field. Given the growth of the integration research in renewable energy and circular economy, coupled with the high level of interdisciplinary nature of the topic, the five-year mark constitutes a criterion that captures the most recent developments in the field. Similarly, all disciplines' scope guarantees that studies from science, technology, engineering, and mathematics, business or economics, as well as public policy or environmental studies, are included. The direction of the research is to summarise the literature without regard to a parochial context, like certain industries or economic models.

Integration varies from one setting to another. At the very least, a simple integration combines at least one CE practice with one RE source. For instance, food and beverage manufacturers may introduce reuse (CE practice) through transforming compost into fuel in an anaerobic digestion unit to generate clean energy (biogas). The level of integration increases as the number of CE practices and RE sources is combined. For example, when a large oil company like Saudi Aramco integrates solar and wind power to supply energy for Waste-to-Energy facilities to decrease waste, one may consider such a setting a more advanced integration pattern.

Eligibility Criteria

The inclusion criteria for studies in this research were specified as follows. First, each study must be published in a peer-reviewed journal. This excludes all non-peer-reviewed publications like dissertations or theses. Second, all papers must be published in an English-language journal between 2018 and 2023. Most importantly, each included study must exhibit the integration of at least one type of renewable energy with one or more practices of the circular economy. Notice that a pre-specified set of renewable energy sources or circular economy practices was not prepared to avoid bias in the selection of studies. The initial predetermination criteria for included studies were the use of renewable energy and circular economy phrases in the title of the paper. Note that each subsequently included paper went through rigorous abstract assessments to ensure that the integration of CE and RE exists with at least one type of each. The phrases “sustainable development” and “sustainability” were also used with the circular economy as another term for renewable energy in order to increase the studies potentially eligible for the review. Past research in the CE and RE integration literature demonstrated that many authors use the terms “sustainability” or “sustainable development,” implying the use of RE in manufacturing [63–65].

2.2. Phase 2: Preparing the Review

2.2.1. Information Sources

Prior to conducting the initial search for studies to fulfil the SLR's objectives, the researchers must determine the relevant databases and keywords for mining the archives to identify relevant research. In this research, the Clarivate Web of Science platform and Elsevier's Scopus database constituted the main archives for relevant research on renewable energy and circular economy. Each outlet features several dedicated journals covering renewable energy, sustainable development, and circular economy. Both platforms

regularly update their listings of journals. More importantly, Clarivate and Elsevier ensure that any journal in their databases adheres to certain quality criteria, guaranteeing better research to be included in this review.

2.2.2. Search Strategy

Within each of the two databases, three combinations of keywords were used to generate the initial pool of studies. These were (1) “renewable energy” AND “circular economy”, (2) “sustainable development” AND “circular economy”, and (3) “sustainability” AND “circular economy.” Figure 2 represents the search methodology followed in this research. The common denominator connecting the Web of Science and Scopus databases is the quality of research that both platforms put forward. In addition, the difference between the two databases is that Scopus hosts more emerging and newer journals in comparison with Web of Science, which presents more established outlets.

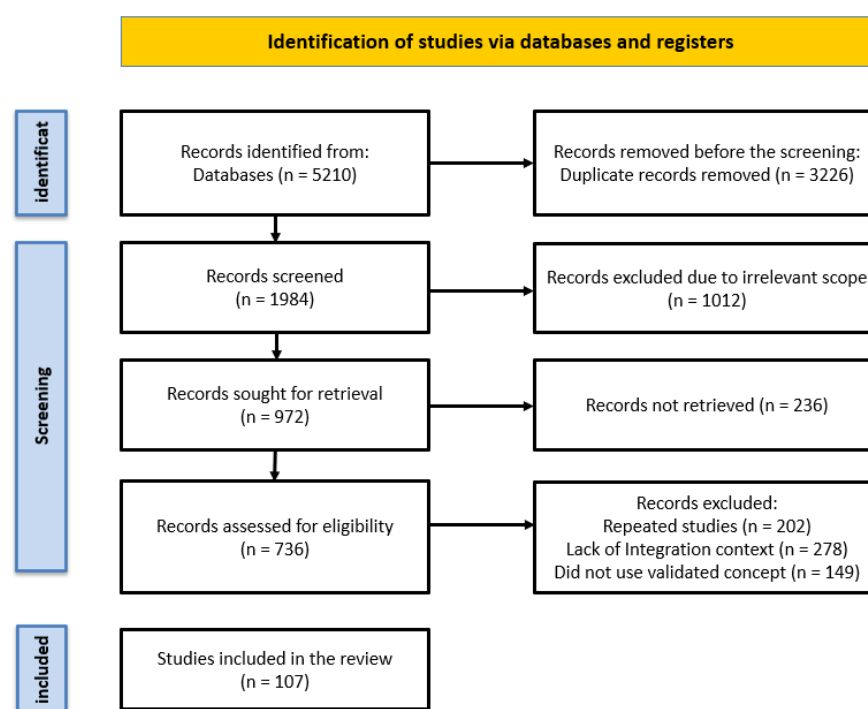


Figure 2. Articles selection (PRISMA flow diagram).

2.2.3. Selection Process

Once all eligible studies were identified, a closer reading of each of them was conducted to make a final determination on whether they would remain included or not. The procedure involved the reading of the title, keywords, and the abstract. This process resulted in the exclusion of many studies that failed to specify an integration pattern or context between at least one specific renewable energy type and one circular economy practice.

2.2.4. Data Collection Process

The initial pool of all eligible studies was 736, but 629 records were excluded because of repetition, lack of integration, and not using a validated concept (see Figure 2). After closely examining all articles and excluding repeated titles, the final set of included studies in the review was composed of 107 peer-reviewed articles. A closer examination of all studies after selecting eligible studies resulted in further elimination of articles. A total of 278 studies did not specify a particular integration pattern or a context where at least one CE practice is implemented within a renewable energy concept. Likewise, 149 articles did

not apply validated CE concepts in the literature. Validated concepts refer to commonly agreed-upon labels among scholars. Thus, unique labels referring to CE practices, while not consistent with the CE literature, were excluded. Another 202 articles were deleted because they were duplicates.

2.2.5. Data Items

To examine the hypothesis that RE and CE integration is a theme only pertinent to industrial nations, the first author's country affiliation was analysed. Note that the first authors' country affiliation was analysed to examine whether the research was produced in developing or advanced countries. Despite the fact that this assessment approach may be inaccurate in some instances, past researchers have concluded that the first author is often from the country hosting his or her work institution [66,67]. The logic behind this step stems from an overall belief that CE and RE integration is a topic discussed in advanced economies.

2.3. Phase 3: Conducting the Review

Once all included studies were identified, they were inserted into an Excel spreadsheet. This step prepared the articles for the coding procedure. Prior to the examination of each paper in detail, a number of variables describing each paper were constructed to provide a holistic overview of each manuscript's characteristics, quality, and content. The first author's last name, year of publication, name of the journal, and the affiliated country of the first author were all prepared to help understand the context of each study. Examining the name of the journal informs readers about the specific domain or approximate application of the CE and RE integration. Combining the country and the journal then reveals potential trends in the literature about the directions of advanced or developing countries concerning integration patterns.

Effect Measures

On the quality front, the number of citations, as well as the journal's impact factor, were included in the coding process. Relatedly, the research design, data level, research type, and data analysis methods used in each paper were constructed. Such metrics provide readers with better information on the methodological rigour of the research as recommended by many analysts [68,69]. Concerning the content, each paper was reviewed carefully to extract the barriers and facilitators of renewable energy integration with the circular economy. Additionally, the main finding of each research manuscript was written to be used as input for a thematic analysis summarising the main findings in the literature. The examination of each study featured the careful reading of each paper separately to extract all the information featured in the Excel sheet. On many occasions, the researcher needed to re-read the manuscripts to ensure that all information inserted was accurate and consistent. This approach is highly recommended in SLR research to guarantee reliable and valid data [70,71].

2.4. Phase 4: Analysis and Findings

Synthesis Methods

The analysis of the information collected through the close readings of each paper featured the use of descriptive statistics, multivariate distribution graphing, and qualitative thematic analysis. Numeric variables like the journal's impact factor or articles' citations were analysed using histograms, boxplots, and area charts. Further, in many cases, three variables' graphs (multivariate) were employed to better understand the relationships between variables. Additionally, frequency distributions and summary statistics were used to describe central tendency and variability trends in quantitative metrics. This approach

is consistent with prior SLR's research that encourages analysts to describe all collected information numerically and qualitatively [72].

For categorical variables, qualitative thematic analysis was used to present the common themes observed in the findings. Thematic analysis begins with coding each unique textual piece as a barrier with a unique identifier. Once all textual elements are coded, the collapsing of similar points occurs. The final product of a thematic analysis is a set of interesting, meaningful dimensions that summarise the idiosyncrasies within the data. Prior SLR research recommended the use of thematic analysis for describing string-level variables [73,74].

2.5. Phase 5: Final Review

The final phase of the SLR procedure is to prepare the final report. In this step, the researcher ensures that all necessary elements of the report are included. The conventional wisdom in SLR research is to provide readers with the study's limitations, theoretical contributions, practical implications, and future research directions. Also, the discussion of the findings must relate to prior research. In a similar fashion, the researcher also checks the presence of all elements recommended by experts, such as compliance with PRISMA criteria. Once a final reading is made for readability and cohesion, the researcher prepares the final version of this study.

3. Results and Analysis

3.1. Descriptive Statistical Analysis

Figure 3 displays the geographic distribution of studies examining renewable energy transition with circular economy frameworks. Darker colors in the map correspond to higher proportions of studies in the literature. For example, Saudi Arabia is one of the darkest countries on the map as a result of contributing 13 or more studies to the review. Note that Saudi Arabia, China, the United States, and Italy are the top-producing countries for research on renewable energy and circular economy integration. Western Europe enjoys the largest share of studies if one considers regional distribution. More specifically, Italy, Poland, Spain, Finland, and the United Kingdom combined account for a significant number of reviewed studies. Developed industrial economies like Canada, Australia, South Korea, and the United Arab Emirates generated a larger proportion of studies compared to developing economies. The research on renewable energy and circular economy integration, however, is not confined to the advanced industrial world. Studies from Iraq, Egypt, Iran, and Togo emerged as equally compelling and important. The variety of renewable energy resources, the plethora of circular economic practices, and the affordability of several technologies make the integration of renewable energy and circular economy within the reach of any nation, regardless of their level of development. The rapid expansion of global technologies has rendered CE and RE integration accessible to advanced as well as developing nations.

Figure 4 demonstrates the distribution of publications reviewed in this analysis over time. One noticeable trend is that interest in renewable energy and circular economy integration literature has increased greatly since 2018. The year 2021 marked the highest number of peer-reviewed papers on renewable energy integration with the circular economy. Nevertheless, the following two years did not significantly differ with respect to the frequency of publications. In sum, researchers from all over the globe have been awarding further attention to the study of renewable energy and circular economy integration.

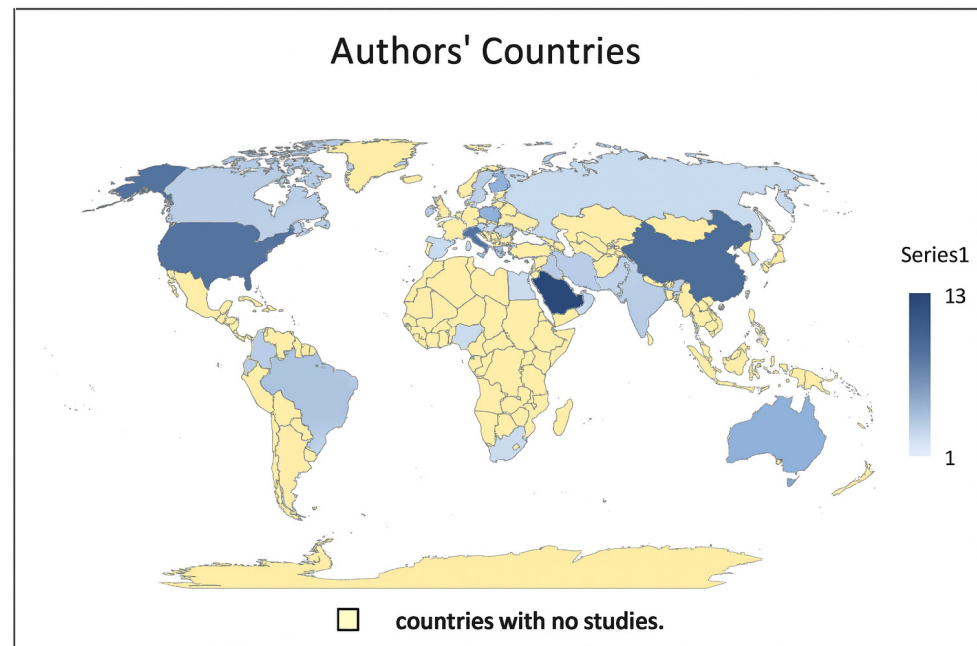


Figure 3. Worldwide distribution of scholars.

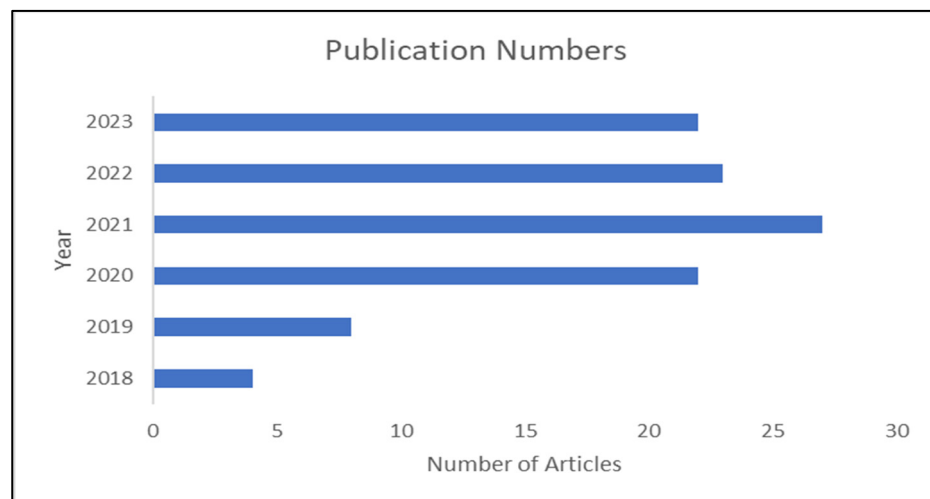


Figure 4. Publications reviewed from 2018 to 2023.

Table 1 presents the worldwide distribution of scholars contributing to the reviewed articles. The results reveal that research on CE and RE integration is geographically diverse, with contributions from both developed and developing countries. The largest share of scholars comes from Saudi Arabia (12), China (10), the United States (11), and Italy (9), highlighting these nations as leading hubs in this research domain. Other countries such as Brazil, Finland, South Korea, Spain, and Poland also show notable representation. Meanwhile, several countries—including Austria, Denmark, Egypt, and Switzerland—are represented by a single scholar, indicating more limited engagement. Overall, the data illustrate the global and interdisciplinary nature of CE and RE research, while also reflecting regional differences in the intensity of academic participation.

Table 1. Worldwide distribution of scholars.

Country	Frequency	Country	Frequency	Frequency	Frequency
Australia	4	Hungary	1	Russia	1
Austria	1	India	3	Saudi Arabia	12
Brazil	4	Iran	1	Scotland	1
Canada	2	Iraq	1	Slovakia	1
China	10	Ireland	1	South Africa	1
Colombia	1	Italy	9	South Korea	4
Croatia	1	Kuwait	1	Spain	3
Cyprus	1	Latvia	1	Switzerland	1
Denmark	1	Nigeria	1	Taiwan	1
Ecuador	1	Oman	1	Thailand	1
Egypt	1	Pakistan	2	Togo	1
England	2	Poland	6	UAE	3
Finland	4	Qatar	1	United States	11
Greece	3	Romania	1		

Table 2 represents the single, bigram, and trigram keyword frequencies in the analysed articles. Bigrams refer to two keyword combinations, and trigrams represent three keyword combinations. The consideration of three types of frequencies allows for a richer examination of the patterns concerning the common themes across articles. With respect to the single words' frequency, energy, economy, circular, CE (circular economy), renewable, and sustainable enjoyed the largest share of keywords, with each being mentioned more than 20 times across all keywords' lists in all articles. Sustainable development, circular economy, and renewable energy featured the most frequent bigrams in keywords' lists across all articles, with each being mentioned more than ten times. With respect to the trigrams (three-word keywords), sustainable development goals, life cycle assessment, and municipal solid waste were the most recurring terms across the articles. While the initial terms searched in this investigation were CE, RE, sustainability, and sustainable development, the researcher did not specify particular RE types or CE practices. Therefore, the choice of terms in the initial phase of the review minimally affected the observed frequencies in Table 2 (especially the trigram). One potential explanation for the domination of such bigrams and trigrams is the popularity of such concepts across multiple disciplines. Environmental, energy, and social scientists all concentrated on the circular economy, renewable energy, and sustainability development goals. Such concepts apply broadly across many fields.

The terms in Table 2 display several associations in the CE and RE integration research. First, authors tend to emphasise one or two CE practices as well as one type of RE. For instance, the use of end-of-life CE practice is common among solar energy studies. Second, authors tended to add at least one keyword, indicative of sustainability, in the CE and RE combination of terms. An illustration of this pattern is the recurring use of sustainable development or sustainable development goals.

Table 2. Articles' keywords frequencies.

Single Word	Frequency	Bigram	Frequency	Trigram	Frequency
Energy	60	Circular Economy	46	Sustainable Development Goals	4
Economy	54	Renewable Energy	22	Life Cycle Assessment	3
Circular	49	Sustainable Development	15	Energy Circular Economy	3
Waste	26	Waste Management	9	Municipal Solid Waste	3
Renewable	22	Life Cycle	6	Economic Sustainable Development	3
Sustainable	22	Energy Transition	6	Solar Energy Sustainability	3
Sustainability	19	Saudi Arabia	6	Circular Renewable Economy	2
Development	17	Economy Circular	5	Economy Renewable Energy	2
Recycling	14	Solid Waste	5	Consumption of Renewable Energy	2
Solar	14	Economy Sustainability	5	Life Cycle Analysis	2
Management	12	Cycle Assessment	4	Energy Water Environment	2
Green	10	Business Model	4	End of Life	2
Analysis	8	Energy Circular	4		
Environmental	8	Power Plant	4		
Transition	8	Development Goals	4		
Life	8	Solar Panels	4		
Cycle	8	Energy Sustainability	4		
Assessment	8	Reverse Logistics	4		
Model	8	Nuclear Energy	3		

Figure 5 shows the co-occurrence of important terms in the papers included in the analysis. Important terms included keywords, titles, and abstracts. Note that such terms covered a wide range of circular economy practices, as well as renewable energy sources.

Figure 6 represents the bibliographic co-citations pattern across the papers included in the analysis. Note that papers published a few years ago featured more connections to current papers. Additionally, authors in North America and Western Europe were cited more than authors in the Middle East, Eastern Europe, and Africa. By the same token, case studies appear to have lower citation frequencies compared to reviews of the literature.

When one closely examines the keywords, solar and nuclear energy emerge as dominant themes in the analysis of renewable energy and circular economy integration. Further, solid waste transition into renewable energy features as a recurring topic in the literature. With respect to the circular economy, life cycle assessment or analysis, and end of life emerge as recurring practices in the analysed literature. Despite this ascendancy, however, recycling is the most frequently studied circular economy practice. Authors, nevertheless, have not explicitly written recycling in the keyword lists. One potential explanation could be the authors' implicit understanding that readers would consider recycling when discussions take on renewable energy and circular economy integration [75–77].

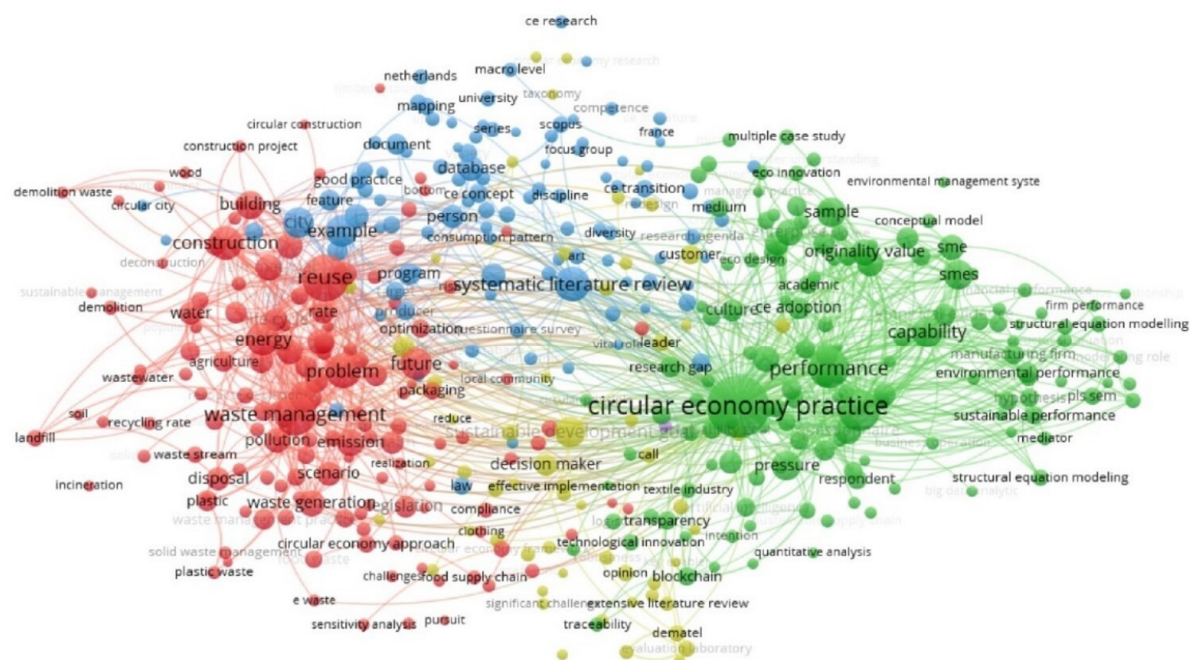


Figure 5. Distribution of important terms co-occurrence.

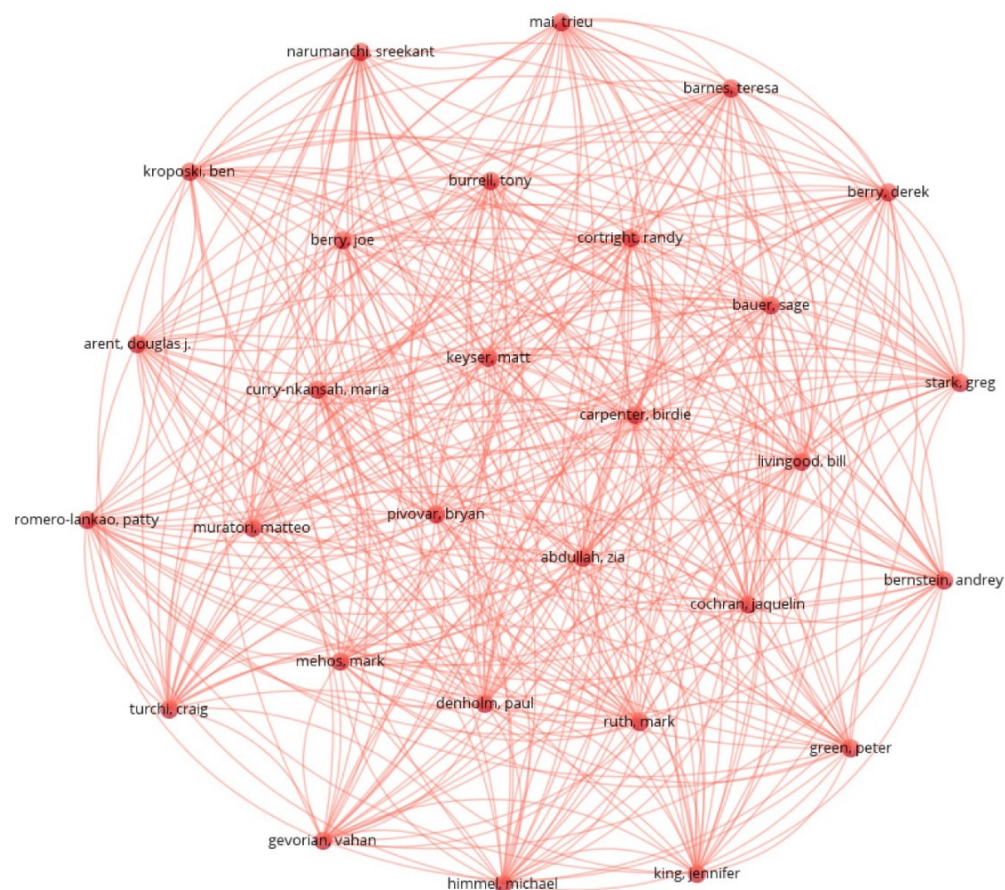


Figure 6. Distribution of co-author citations.

Figure 7 demonstrates the distribution of studies based on their analytical type. Empirical studies feature the most typical research type, with 30.29% (as seen in the pie chart) of the entire research reviewed. Empirical research included both quantitative and qualitative analysis. Additionally, empirical research featured a variety of analytical methods, including statistical analysis, simulations, system modelling, and life cycle assessment estimation approaches.

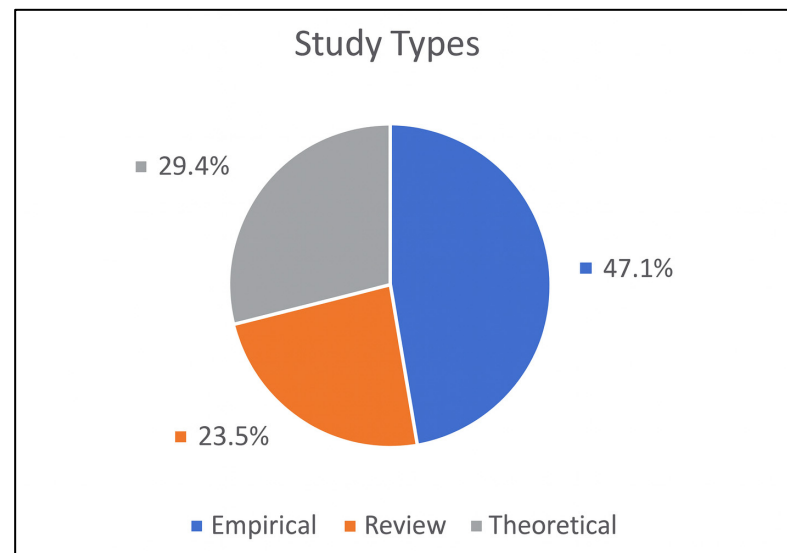


Figure 7. Distribution of studies based on their analytical type.

On the qualitative side, empirical research also featured thematic, narrative, and document analyses. One study examined the viability of two circular economic practices: lifetime extension assessment and closed-loop recycling in reducing waste potentials generated from the high demand for solar panels in the US. The authors utilised simulation and system modelling techniques with a life cycle assessment framework to empirically evaluate the different circular economic practices' impact on solar renewable energy waste management for panels [78].

The next most frequently used data type in the renewable energy transition research, with a focus on the circular economy, is the multi-level data category. Researchers utilised country-level data coupled with sectoral, firm, individual, or institutional levels of data in the same paper. Therefore, the use of many data levels suggested the preference of many researchers to utilise multi-level data [79–82].

Researchers also resorted to the use of reviews to examine RE and CE integration. Analysts conducted systematic literature reviews, scoping reviews, and literature reviews (without following a specific method) to summarise common themes. Reviews comprised 24.24% (as seen in the pie chart) of the entire literature examined in this study. Theoretical studies also demonstrated consumable popularity among interested researchers by featuring 48.47% of the entire research reviewed. Theoretical research featured the proposition of various recommendations for existing practices. Additionally, theoretical analyses focused on the development of new systems that should be adopted to maximise the benefits obtained from circular economy integration with renewable energy.

3.2. Analysis Related to Methodological Rigour

Figure 8 displays the number of citations and average impact factor per year since 2018 for all papers included in this review. Note that citations have decreased over the past five years. Understandably, recent years will feature fewer citations given the shorter period between their publication and the most recent research. Nevertheless, in 2018, the average citations increased to 212. On the other hand, the average impact factor has slightly improved from 2018 to 2023. The increase, however, is still less than a full point on the impact factor scale, moving from 5.57 to 6.16 in a five-year period. In 2020, the average impact factor was at its highest, reaching 8. The variety, quality, and disciplinary nature of journals publishing on renewable energy and circular economy integration have increased in the past five years. The impact factor serves as a measure of research quality assessment, with higher averages corresponding to better quality. Note that journals with higher impact factors tend to publish more rigorous analyses because of their heightened peer review processes.

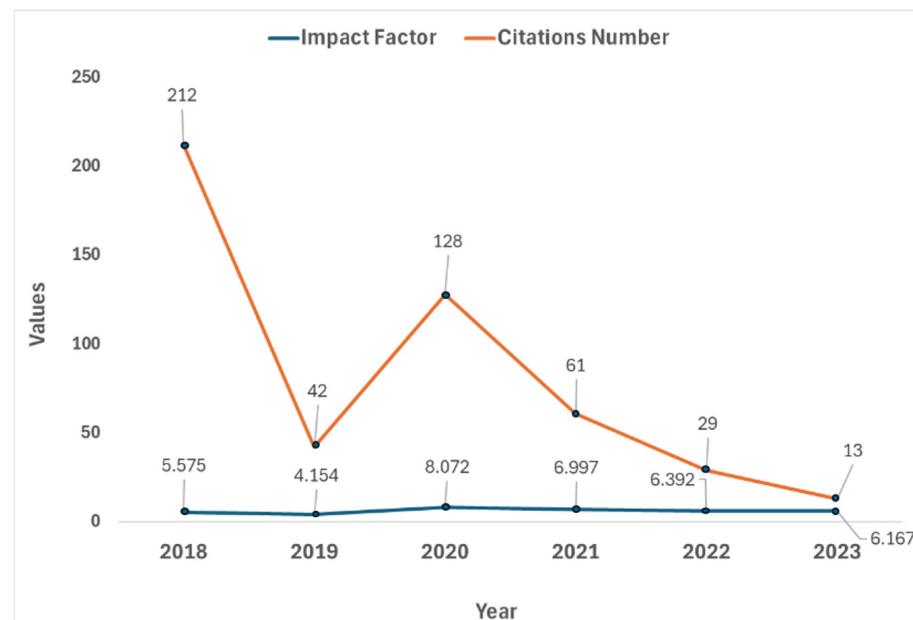


Figure 8. Number of citations and impact factors over time.

Figure 9 showcases the distribution of studies reviewed in the analysis based on the research methodology followed by the authors. This research follows the four types of methods that are considered to be possible categories that each study could take: (a) survey methods, (b) experimental designs, (c) secondary data analyses, and (d) case studies [83]. About two-thirds of all reviewed research was secondary data studies. They utilised quantitative and qualitative techniques. In some cases, secondary data research employed mixed methods of data collection and analysis. A large proportion of secondary data relied on simulation and system modelling. Authors utilise available data or estimate parameters based on a set of assumptions and then proceed to estimate values on their variables of interest. Additionally, secondary data featured the use of reviews.

One of the main findings concerning research rigour on CE and RE integration is the increasing quality of publications output. Taking impact factor as one metric of journals' quality, one finds that, on average, published articles appeared in relatively well-established quality journals since the average impact factor for each year was higher than four, reaching eight in a short period of time. While such a result could be collectively high for the entire scholarly body, the research suffers from numerous methodological issues. One common

problem is the reliance on single case studies to generate inferences about CE and RE integration patterns. Case studies suffer from weak external validity; thus, further large-n studies are needed to reach generalisable results.

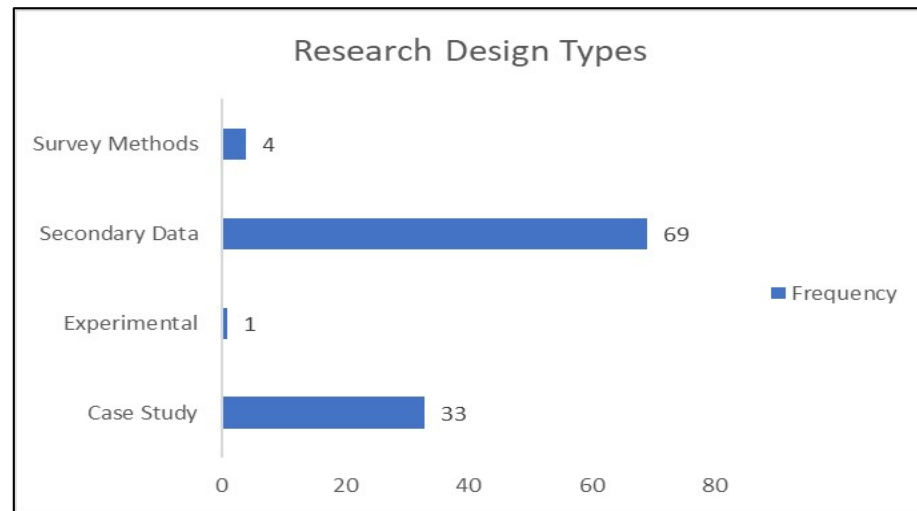


Figure 9. Distribution of studies based on the research methodology.

The second most recurring research methodology was the case study, which was present in about one-third of the research reviewed for this research. Most case studies are considered one country of interest and feature the use of both quantitative and qualitative data collection and analysis strategies. The use of survey methods and experimental designs was minimal. Only 4 studies out of the 107 total number of analyses utilised questionnaires or surveys. By the same token, experimental analysis was used in a single study. One of the interesting trends defining the renewable energy and circular economy literature is the interdisciplinary nature of the field. Many journals across the physical sciences, engineering, policy studies, and business or economics featured papers on various aspects linking renewable energy and circular economy integration. This review examined papers from 60 different journals.

Figure 10 displays the distribution of journals publishing peer-reviewed analyses on the topic. *Sustainability* enjoys the largest share of reviewed papers with 13 articles. *Renewable and Sustainable Energy Reviews* and *Energies* secured the second position on the top publishing list for the reviewed papers in this study, with six papers each. Then, *Science of the Total Environment* emerged as the fourth most published venue with four papers in the renewable energy and circular economy area.

Figure 11 showcases the distribution of impact factors of all journals reviewed in this research using a boxplot. The median impact factor of all journals used in the analysis was 5.20. The average (arithmetic mean) of all impact factors reported was 6.64. The highest impact factor was associated with *Renewable and Sustainable Energy Reviews* at 16.79. A few journals that published research on renewable energy and circular economy did not report information on their impact factor. Table A1 in Appendix A includes all the journals reviewed in this research, along with their impact factors. The above discussion notes the variability of journal impact factors, indicating different research quality levels.

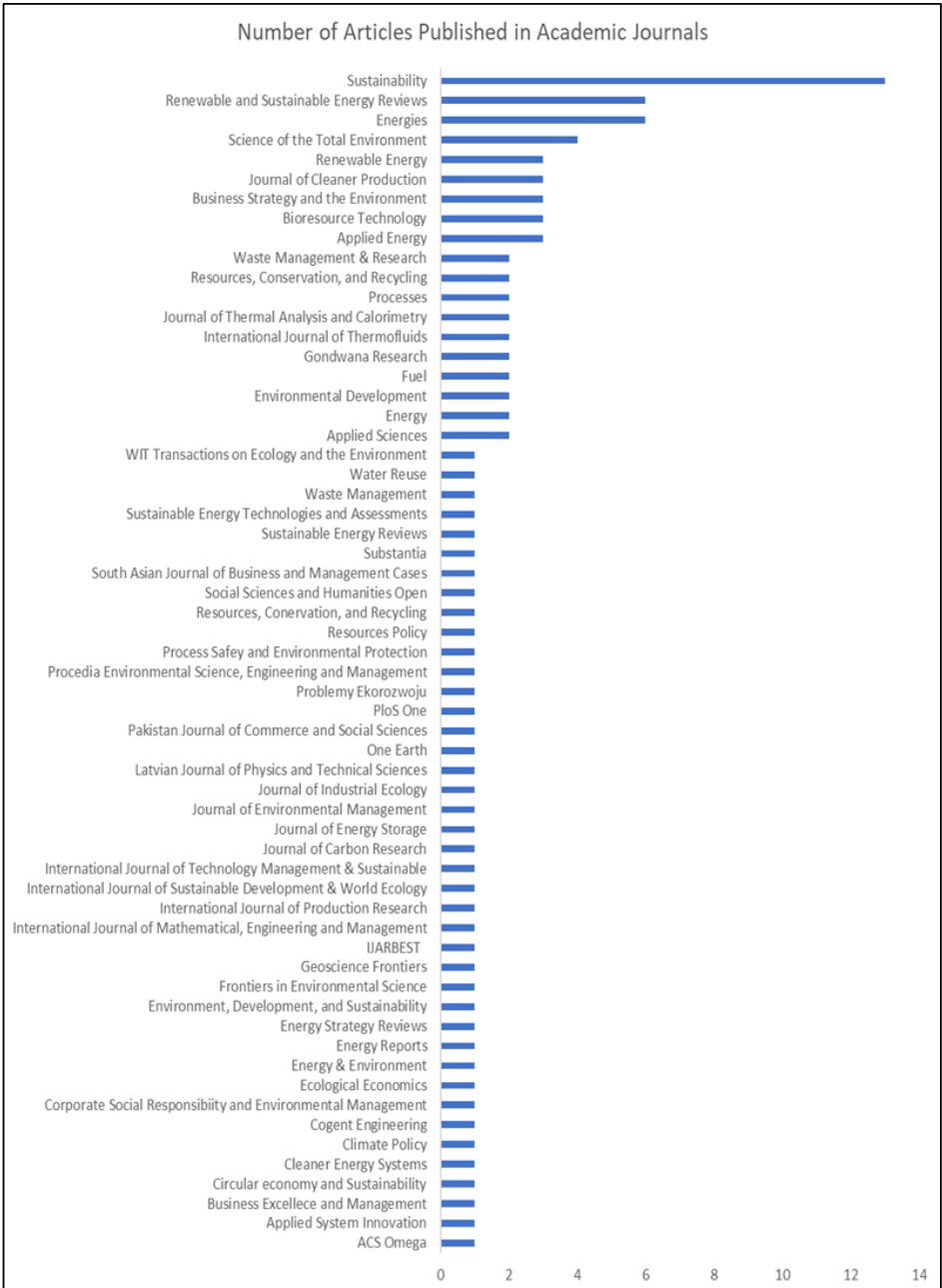


Figure 10. Distribution of peer-reviewed journals according to topic.

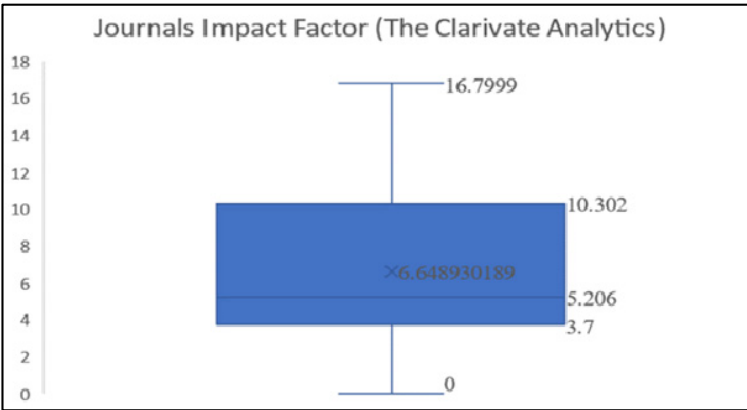


Figure 11. Distribution of impact factors of all journals.

3.3. Content or Qualitative Thematic Analysis

3.3.1. Circular Economy Practices

Figure 12 demonstrates the frequency of each circular economy practice mentioned in the reviewed studies. Note that each study explicitly mentioned at least one circular economy practice. More than 95% of all studies featured more than a single practice. On the one hand, the most frequently cited practices were the Rs' framework. Recycling, reducing, remanufacturing, and reusing materials appeared to be the most popular practices in the literature. On the other hand, human-centred practices like education training, stakeholder collaboration, and supplier selection based on environmental factors appeared to be the least emphasised practices within the literature. A total of 14 practices were included in this analysis because they were mentioned at least ten times by varying authors. The practices list includes recycle, reduce materials, remanufacturing, reuse of materials, waste minimisation, renewable energy use, consumer awareness, repurpose, refuse, education and training, environmentally friendly design, environmental criteria for supplier selection, reverse logistics, and stakeholders collaboration. Note that circular economy practices labels may differ from one paper to another. Therefore, the listed labels in the figure are consistent with the literature nomenclature [84–86].

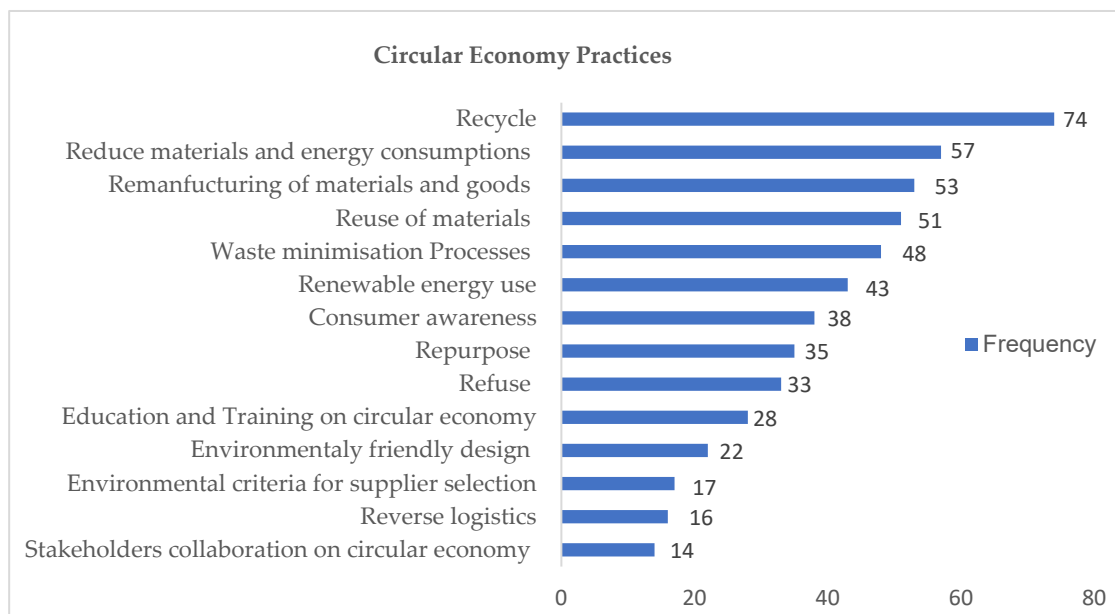


Figure 12. Circular economy practices reviewed in this analysis.

Table 3 demonstrates the distribution of CE practices and sectors based on geographic setting. One of the most common CE practices, regardless of regional variability, was recycling. Further, the integration of CE practices into manufacturing was frequent within the automotive, food and beverage, textile, and machinery industries across the globe. Advanced economies tended to feature integrations within heavy equipment sectors, whereas developing countries exhibited implementation in natural resources manufacturing settings, such as petroleum and gas generation and refineries.

Table 3. Distribution of CE practices based on geographic location.

Country Name	Top Three CE Practices	Most Representative Sectors
Australia	Recycle, Consumer Awareness, Environmental Criteria for Supplier Selection	Food and Beverage Manufacturing, Machinery and Equipment Manufacturing.
Austria	Recycle, Waste Minimisation, Remanufacture	Machinery and Equipment Manufacturing
Brazil	Recycle, Environmentally Friendly Design, Refuse	Automotive Industry, Chemical and Pharmaceutical Industry
Canada	Recycle, Consumer Awareness, Reuse	Food and Beverage Manufacturing, Transportation Equipment Manufacturing
China	Reuse, Waste Minimisation, Remanufacture	Automotive, Food Processing, Chemical Manufacturing, Machinery and Equipment
Colombia	Recycle, Consumer Awareness, Reuse	Textiles and Apparel
Croatia	Remanufacture, Education and Training, Recycle	Food and Beverage Industry
Cyprus	Recycle, Environmentally Friendly Design, Environmental Criteria for Supplier Selection	Food and Beverage Processing
Denmark	Recycle, Stakeholders Collaboration, Repurpose	Pharmaceuticals
Ecuador	Recycle, Waste Minimisation, Reuse	Food Processing
Egypt	Remanufacture, Repurpose, Renewable Energy Use	Textiles and Apparel
England	Recycle, Education and Training, Environmental Criteria for Supplier Selection	Automotive Manufacturing, Aerospace and Defence
Finland	Remanufacture, Repurpose, Renewable Energy Use	Metal Industry, Chemical Industry, Forest Industry
Greece	Recycle, Consumer Awareness, Renewable Energy Use	Food and Beverage Processing, Chemicals and Pharmaceuticals
Hungary	Remanufacture, Repurpose, Recycle	Automotive Industry, Electronics and Electrical Equipment, Pharmaceuticals and Chemicals
India	Recycle, Waste Minimisation, Reuse	Textiles and Apparel, Automotive Industry, Chemicals and Pharmaceuticals
Iran	Recycle, Environmentally Friendly Design, Environmental Criteria for Supplier Selection	Petrochemicals and Chemicals, Automotive Manufacturing, Food and Beverage Processing
Iraq	Recycle, Waste Minimisation, Reverse Logistics	Petroleum Refining Industry
Ireland	Recycle, Consumer Awareness, Waste Minimisation	Pharmaceuticals and Medical Devices, Food and Beverage Processing
Italy	Recycle, Stakeholders Collaboration, Repurpose	Machinery and Equipment Manufacturing, Automotive Industry, Food and Beverage Industry
Kuwait	Remanufacture, Repurpose, Recycle	Petrochemicals and Fertilizers, Cement and Construction Materials
Latvia	Recycle, Repurpose, Waste Minimisation	Engineering and Metalworking
Nigeria	Reuse, Waste Minimisation, Environmental Criteria for Supplier Selection	Food, Beverage, and Tobacco
Oman	Recycle, Environmentally Friendly Design, Repurpose	Petrochemicals and Basic Chemicals

Table 3. *Cont.*

Country Name	Top Three CE Practices	Most Representative Sectors
Pakistan	Recycle, Waste Minimisation, Remanufacture	Textile and Apparel Industry, Food and Beverage Processing
Poland	Recycle, Consumer Awareness, Environmentally Friendly Design	Automotive Industry, Electronics and Electrical Equipment, Furniture Manufacturing
Qatar	Reuse, Education and Training, Repurpose	Petrochemicals and Fertilizers
Romania	Recycle, Repurpose, Renewable Energy Use	Automotive Industry, Chemical and Petrochemical Industry
Russia	Reuse, Stakeholders Collaboration, Reverse Logistics	Defence and Aerospace Industry, Metallurgy and Metal Processing
Saudi Arabia	Recycle, Consumer Awareness, Waste Minimisation	Semiconductors and Electronics, Automotive Industry
Scotland	Recycle, Repurpose, Refuse	Food and Drink Manufacturing, Chemical Sciences, and Pharmaceuticals
Slovakia	Recycle, Education and Training, Reuse	Automotive Industry
South Korea	Recycle, Waste Minimisation, Environmentally Friendly Design	Semiconductors, Automotive Industry, Shipbuilding, and Heavy Industries
Spain	Recycle, Repurpose, Remanufacture	Automotive Industry, Food and Beverage Industry
Switzerland	Recycle, Stakeholders Collaboration, Reverse Logistics	Pharmaceutical and Life Sciences, Precision Instruments and Watches
Taiwan	Reuse, Waste Minimisation, Renewable Energy Use	Semiconductor Industry, Machinery and Machine Tools
Thailand	Recycle, Environmentally Friendly Design, Refuse	Automotive Industry, Electronics, and Electrical Appliances
Togo	Recycle, Waste Minimisation, Repurpose	Textiles and Garment Manufacturing
UAE	Recycle, Repurpose, Reuse	Petrochemicals and Chemicals
United States	Recycle, Education and Training, Renewable Energy Use	Computer, Electronics and Semiconductors, Automotive and Transportation Equipment, Chemical Manufacturing

3.3.2. Renewable Energy Type

Figure 13 displays the distribution of reviewed research based on the renewable energy type covered in the analysis. The most investigated renewable energy source in the circular economy integration literature is bioenergy, with 66 studies out of 283 (23.32%). Within bioenergy research, the study of food waste and compost featured high levels of importance.

Solar energy represented the second-highest renewable energy source in the circular economy framework, with life cycle assessment or end-of-life management of solar panel waste being dominant themes. On the other hand, hydroelectric energy scholarship focused on turning wastewater into an energy source that could be used as an asset in curbing reliance on fossil fuels or carbonised sources. One of the noteworthy observations in the recurrence of hydroelectric, wind, and geothermal energies together is the use of reviews in this research area. When authors review renewable energy integration with the circular economy, they study all types of renewable energy sources, focusing on the three sources [87].

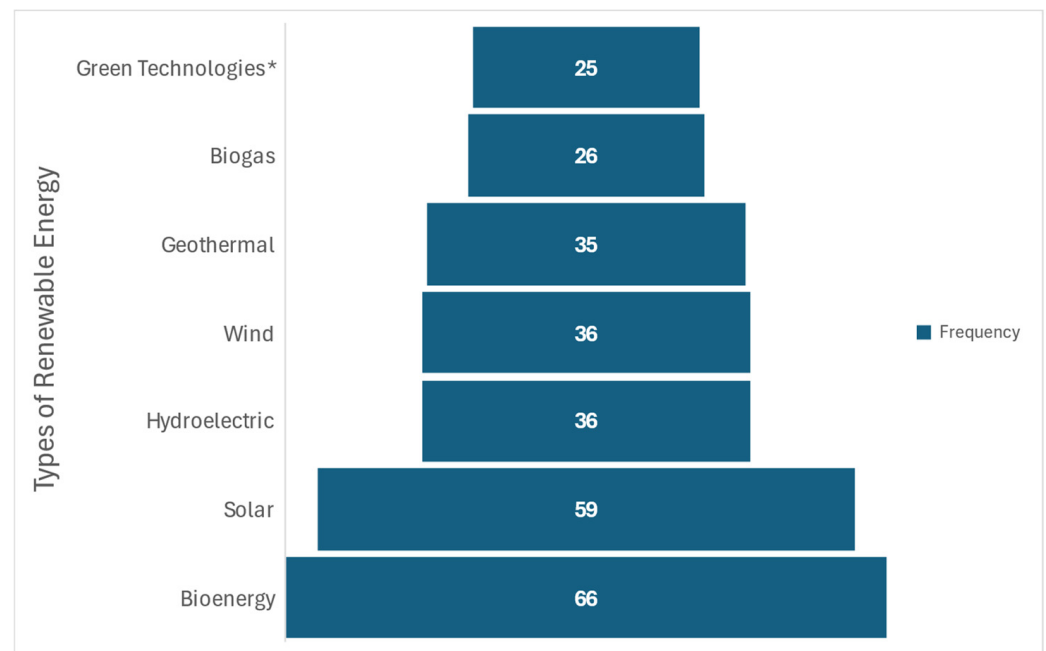


Figure 13. Distribution of studies based on the renewable energy types. * Note that green technologies are not considered renewable energy sources.

The least studied renewable energy source was biogas. A frequently studied context was the use of anaerobic digestion of food and animal waste to produce cleaner biogas for powering plants or residential areas. The production of methane from food compost or manure to provide electricity was a common theme across many analyses [88].

While a few authors consider green technologies like nuclear energy and green chemistry as renewable energy sources, many authors do not. Therefore, this research included both under the banner labelled green technologies, which is not considered to be renewable energy.

Within the nuclear energy literature, researchers focused on the potential of the source in generating power within double loops of economic contexts. With respect to green chemistry, researchers focused on the recycling of plastics or petrochemical materials. The general idea is that if specific optimisation methods are followed in the end-of-life management processing of waste, clean energy could be produced.

Table 4 demonstrates the intersection of renewable energy sources and circular economy practices in the literature. Each panel showcases the most frequent circular economy practices given each renewable energy source. For instance, solar power is integrated into several circular economy practices, including recycling, reducing, repurposing, remanufacturing, and refusing. Note that the listed practices represent the salient circular economy strategies linked to each of the renewable energy sources covered in this analysis.

Table 4. Circular economy and renewable energy integration.

Green Technologies *	Geothermal	Biogas	Wind
<ul style="list-style-type: none"> • Reduce (e.g., Bio-Based Plastic Production by Coca-Cola) • Waste Minimisation (Dyes from Supercritical CO₂ in Textile Manufacturing by Nike and DyeCoo) • Education and Training (Pfizer's Green Chemistry Program) • Reverse Logistics (Hewlett-Packard (HP)—Printer Cartridge Recycling and Remanufacturing) • Recycle (Interface—Carpet Tile Manufacturing) • Repurpose (TerraCycle—Waste Repurposing in Consumer Goods Manufacturing) 	<ul style="list-style-type: none"> • Stakeholders' Collaboration (Frito-Lay—PepsiCo) • Education and Training (Calera Corporation—Geothermal Energy and Education and Training in Manufacturing) • Consumer Awareness (Brew Dr. Kombucha—Geothermal Energy and Consumer Awareness in Manufacturing) 	<ul style="list-style-type: none"> • Remanufacture (BMW—Biogas and Remanufacturing at Leipzig Plant) • Reduce (Unilever—Biogas and Waste Reduction at Indaiaatuba Plant) • Waste Minimisation (Nestlé—Biogas and Waste Minimisation at the Moga Factory) 	<ul style="list-style-type: none"> • Recycle (Siemens Gamesa—Wind Energy and Recycling in Wind Turbine Manufacturing) • Reuse (Vestas—Wind Energy and Reuse in Manufacturing) • Environmental designs (GE Renewable Energy—Wind and Environmental Design in Manufacturing) • Remanufacture (Siemens Gamesa—Wind Energy and Remanufacturing in Wind Turbine Production)
Hydroelectric	Solar	Bioenergy	
<ul style="list-style-type: none"> • Environmental Criteria (Rio Tinto—Hydroelectric Power and Environmental Criteria in Aluminium Manufacturing) • Stakeholders' Collaboration (Norsk Hydro—Hydroelectric Power and Stakeholders' Collaboration in Aluminium Manufacturing) • Consumer Awareness (Apple and Elysis—Hydroelectric Power and Consumer Awareness in Aluminium Manufacturing) • Education and Training (Alcoa—Hydroelectric Power and Education and Training in Aluminium Manufacturing) 	<ul style="list-style-type: none"> • Recycle (Tesla Gigafactory—Solar Energy and Recycling in Manufacturing) • Reduce (First Solar Company—Solar Energy and Waste Reduction in Manufacturing) • Repurpose (SunPower—Solar Energy and Repurpose in Manufacturing) • Remanufacture (SunPower—Solar Energy and Remanufacturing in Solar Panel Production) • Refuse (Apple—Solar Energy and Refuse in Manufacturing) 	<ul style="list-style-type: none"> • Waste minimisation (POET Biorefining—Bioenergy and Waste Minimisation in Ethanol Manufacturing) • Reduce (LignoTech USA—Bioenergy and Reduce in Manufacturing) • Stakeholders' Collaboration (Drax Group—Bioenergy and Stakeholders' Collaboration in Power Generation and Manufacturing) • Consumer Awareness (Green Plains Inc.—Bioenergy and Consumer Awareness in Ethanol Manufacturing) 	

* Note that green technologies are not considered renewable energy sources.

3.3.3. Facilitators

The derivation of themes began with reading all the included articles. Each theme represents a collection of codes. A code refers to an idea. The ideas in each paper were derived by thoroughly reading each paper's Section 4. Each paper received a set of codes and ideas on facilitators and barriers. Some papers received three facilitators and/or three barriers, while others featured fewer or more, depending on the text.

Coding started with assigning a barrier or facilitator to each paragraph in the Section 4. If the text of the paragraph contained no discussion on facilitators or barriers, it did not receive a code. Simply put, a code is an idea that is written as a label. For instance, many authors referenced regulatory matters in many paragraphs, which made all such paragraphs refer to the regulation theme. Notice that the theme is a collection of related labels (codes). Thus, regulation, for instance, represented governmental support, strong environmental legislation, public–private partnerships, strong environmental regulations, green jobs legislation, and monitoring and audit systems.

Table 5 displays the facilitators' themes and their elements. An initial list of facilitators was generated per paper. Each paper reflected a set of facilitators. Final categorisation of facilitators was based on the similarities between the components of the initial list. These are regulation, science, finance, community, technology, and economy. All studies, without exception, noted the importance of more than a single facilitator. Additionally, many studies highlighted the importance of more than ten facilitators in making the integration of renewable energy and the circular economy more successful. Regulatory facilitators in the form of new legislation and rules appear to be the most frequent theme in the literature. Calling for further scientific research and development, as well as technical education, training, and preparation, appeared as the second most frequent category of facilitators. Financial backing, community support, technological innovation, and economic development comprised sizable proportions of the facilitators leading to optimal renewable energy integration with circular economy contexts. Figure 14 displays the overall rates for each facilitator's theme in the analysis.

Table 5. Facilitator themes.

Regulation	125	Science	114
• Governmental support	45	• Education and training	54
• Strong environmental legislation	22	• Research and development	39
• Public–private partnerships	24	• Knowledge sharing	15
• Strong environmental regulations	20	• Interdisciplinary collaboration	6
• Green jobs legislation	10		
• Monitoring and audit systems	4		
Finance	67	Community	39
• Fiscal incentives	30	• High stakeholder engagement	16
• Funding	30	• Community support	13
• Investments in the implementation of circular economy practices	4	• Establishment of global forums	8
• Cost–benefit analysis	3	• Public awareness and information campaigns	2
Technological investment	9	Economy	8
• Improved waste management systems	5	• Diversified economy	3
• Accurate data systems	2	• Initial development levels	3
• Improved life cycle assessment technology	2	• Incentivising corporate social responsibility	2

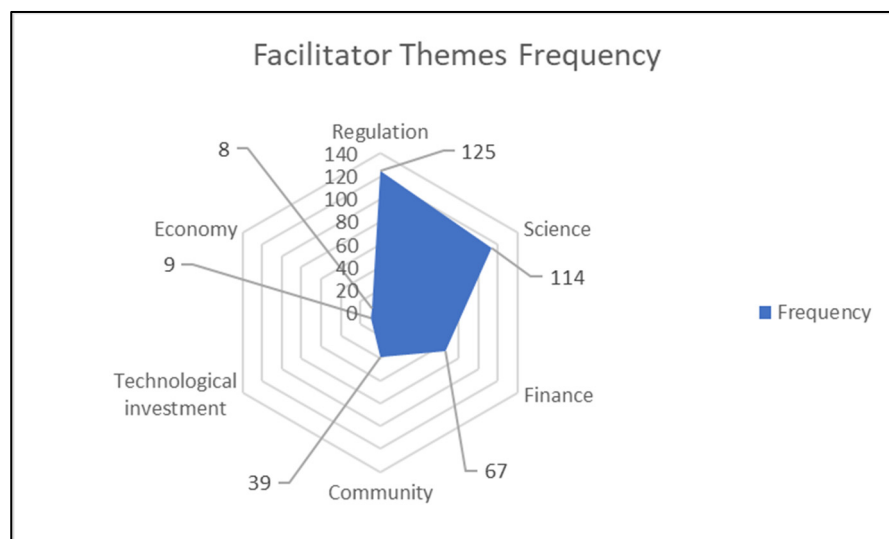


Figure 14. Frequency of each facilitator's theme in the analysis.

With respect to the regulation facilitators' theme, overall government support for the integration process seems to enjoy the highest emphasis among writers on the topic. Concerning science facilitators, researchers touched on various aspects of education and training. Many researchers have suggested the need for developing refined technologies for managing the end of life in the materials used in renewable energy to maximise the circular economy practice returns [87]. By the same token, new systems for recycling chemical materials to produce clean energy in closed-loop economic contexts were designed and tested [89]. Since renewable energy and circular economy integration could be domain or industry-specific, few studies have remarked on the need for improving interdisciplinary cooperation among scientists and practitioners [90]. Financial facilitators constituted an important segment of renewable energy and circular economy integration, critical success factors.

One of the significant facilitators emerging in the literature was community engagement. In Scotland and Finland, for instance, local residents need to buy into the use of renewable energy and circular economy practices to make any integration possible. When communities are on board with the government in the expansion of renewable energy transitions, the integration of such shifts with the circular economy becomes more probable. Public support is key to the success of any initiative. Therefore, the implementation of public awareness campaigns to educate citizens on the benefits of both renewable energy and the circular economy is needed [91]. A sizable proportion of studies emphasised the role of technology in fostering effective circular economies and renewable energy integration. One of the dominant themes is the repeated calls for improving waste management systems. Current data on renewable energy suffers from several limitations, such as unrealistic assumptions concerning consumer demand or real production [92]. Thus, new data platforms are recommended to be implemented to ease the scaling of the integration process.

Finally, economic factors were cited as facilitators for the integration of the circular economy and renewable energy. On the one hand, countries with high initial investment levels in green technologies, such as the nuclear sector, tend to possess more potential for integration [93]. The underlying logic is that when companies are incentivised to assist communities, they will be more likely to innovate energy and circular solutions, increasing the minimisation of waste and maximisation of clean energy production [94,95]. Additionally, when countries are endowed with diverse, sophisticated economic sectors, the integration of the circular economy into renewable energy becomes more frequent.

Thus, setting long-term economic development strategies for sectors or energy production seems to be a recurring pattern in discussions involving the facilitators of circular economy and renewable energy production [96–98].

3.3.4. Barriers

Table 6 displays the barriers to the circular economy and renewable energy integration. Seven themes of barriers were emphasised across the reviewed research. These were institutions, economy, regulations, technology, human capital, community, and politics. Each theme reflected a variety of interrelated barriers preventing successful integration across domains and sectors. Figure 15 displays the overall rates for each barrier's theme in the analysis.

Table 6. Barrier themes.

Institutions	66	Economy	56
• Lack of sectoral and agency collaboration	23	• Limited consumer interest	25
• Variation in structures, institutions, and infrastructure	18	• Inadequate scalability	19
• Organisational resistance	15	• Inadequate market cooperation	11
• Limited stakeholder interest	6	• Lack of consistent funding	1
• Development of standardised global assessments	4		
Regulation	34	Inaccessible Technology	31
• Lack of adequate regulatory framework	18	• Absence of innovative technological solutions	19
• Bureaucratic red tape	14	• Data availability	10
• Limited stakeholder engagement	2	• Unaffordable, inaccessible advanced technology for SMEs	2
Human Capital	23	Community	19
• Lack of technical expertise	16	• Fragmented public awareness and info campaigns	15
• Intellectual property violations	4	• Inadequate popular support	2
• Absence of interdisciplinary collaboration	2	• Lack of public awareness	2
• Absence of specific research	1		
Politics	12		
• Political feasibility	4		
• Environmental threats to physical and cyber systems	3		
• Political instability	3		
• Lack of international cooperation	1		
• Geopolitical concerns	1		

Institutional challenges comprised the most frequently cited barriers to successful integration. The absence of collaborative endeavours among stakeholders contributes to the limited scalable integration of CE practices and RE sources [99]. Cross-country analyses noted the stark variability in integration not only across countries but also within industries. European countries tended to exhibit similar legal and operational infrastructures regulating integration processes compared to other regions around the world. Further, internal institutional barriers to changing existing processes, such as managers tending to be resistant to transitions, are perceptible. Contemporary interest and awareness concerning

integration within the marketplace are still nascent, however, and require maturity to really bring tangible benefits [100].

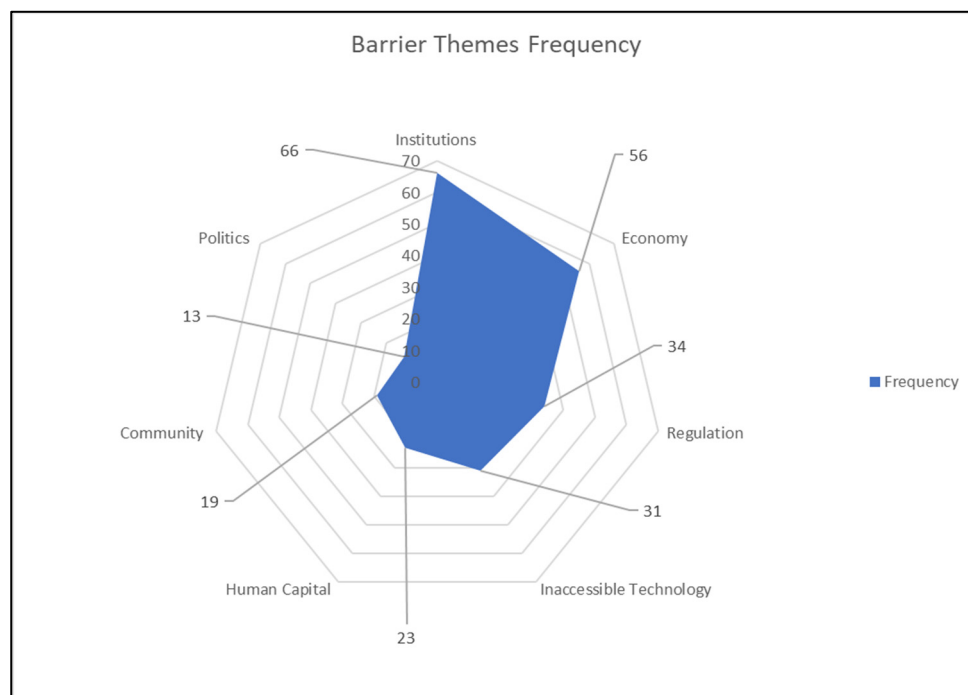


Figure 15. Frequency of each barrier's theme in the analysis.

Economic obstacles face governments, firms, and top leaders in adopting transitioning trajectories based on the circular economy and renewable energy. Stakeholders tend to be hesitant with respect to changing the entire business model [101]. There is limited scalability of renewable energy and circular economy integration in manufacturing, a situation generating limited consumer interest in the practical implementation of promising clean energy and circular economy. The economic atmosphere surrounding today's marketplace is best characterised as fragmented and inconsistent with regard to the funding levels available for improving renewable energy and circular economy integration [102].

The contemporary regulatory environment of renewable energy transition and circular economy implementation is incoherent. While many regulations aim to decarbonise the economy by increasing reliance on renewable energy, they are inadequate [103]. One of the chief reasons is the lack of enforcement mechanisms for the mandated targets by the law [104]. Similarly, regulatory bills address one or more symptoms of non-renewable energy production problems rather than the root causes related to the aggrandisement of renewable energy production. When change is on the horizon for better outcomes, bureaucratic red tape constrains the ability of pioneering firms to achieve real value [105].

Technical barriers also prevent governments and the marketplace from fully reaping the benefits of the circular economy and renewable energy integration. On the one hand, scalable technologies that help firms recycle materials or better manage the end of life for hard-to-process metals are simply inaccessible [106]. On the other hand, some existing technologies are incapable of addressing rising concerns like the management of expiring solar panels [107]. Simply put, companies and governments are ill-equipped to deal with the rising number of retiring photovoltaics [108]. Many scholars focused on the human capital element when describing the lack of preparedness of the marketplace for scalable integration between renewable energy and the circular economy. Studies noted the low levels of awareness among top leaders, as well as employees with regard to the benefits and outcomes of circular economy implementation [109]. Popular support for the integration

of renewable energy and the circular economy is fundamental for both frameworks to yield optimal results [110]. The reviewed analyses indicated low levels of popular support among the workforce for changing existing practices into innovative processes integrating the circular economy with renewable energy [111].

Figure 16 illustrates how CE practices and RE sources are integrated in the Saudi manufacturing sector. The representations serve as an elaboration of how the concepts presented in this analysis interact in a real-world setting. In Saudi Arabia, solar and wind power appear to be the most utilised RE sources because the government invested heavily in large-scale alternative energy projects, including the Sakaka PV Solar Power Plant, the Dumat Al Jandal Wind Power Plant, and the Sudair Solar PV Project. Recycling appears to be the most common CE practice in the manufacturing sector. Figure 16 also presents a number of examples of how companies integrate CE and RE simultaneously. For instance, Saudi Aramco reduces the amount of energy consumed in refineries by utilising solar panels. In another example, SABIC uses wind energy to supply power to its Waste-to-Energy facilities across the country.

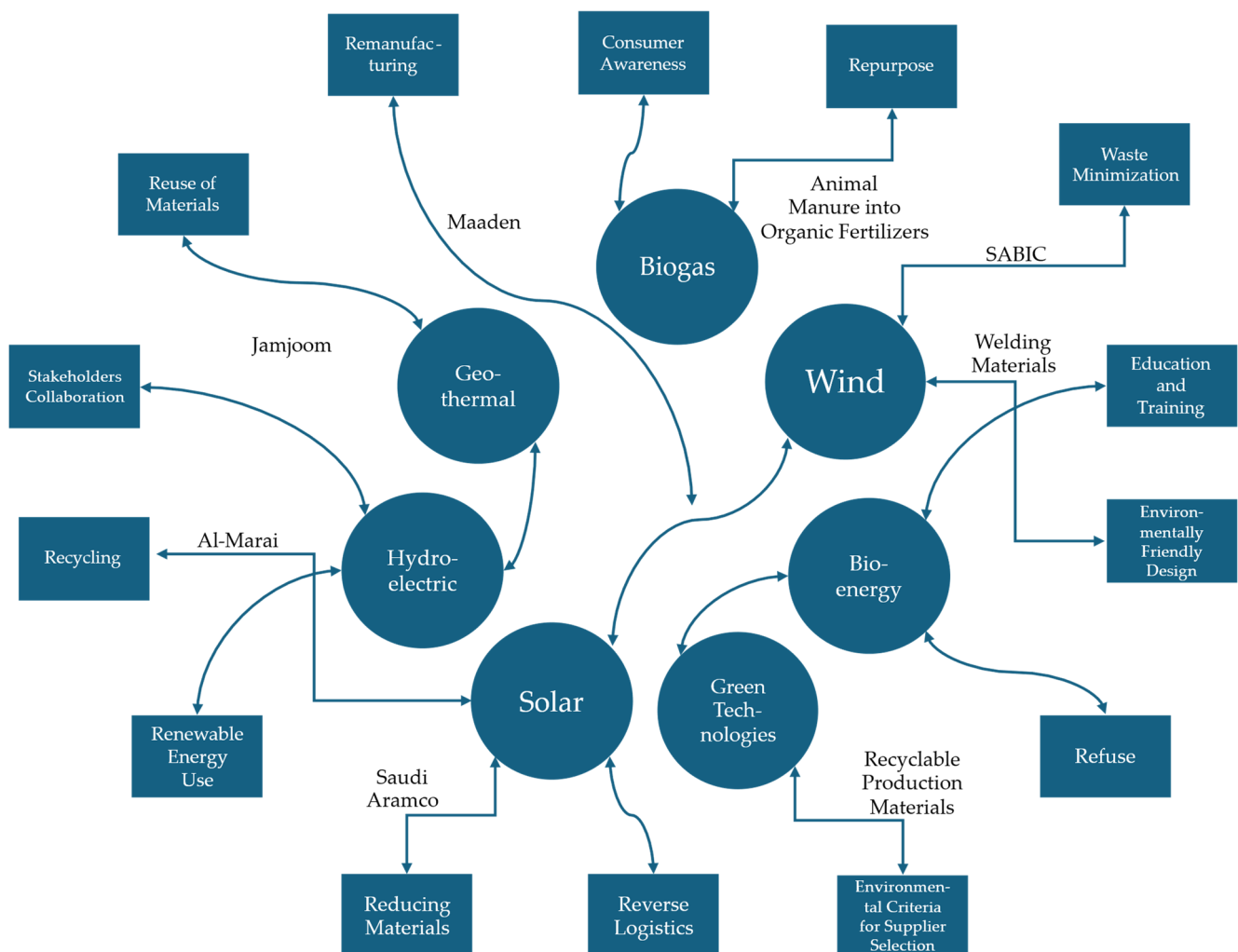


Figure 16. Integration of circular economy practices with renewable energy sources in the Saudi manufacturing sector.

4. Discussion

4.1. Relevance to Prior Research and Key Findings

The current research partly supports earlier studies' findings concerning the geographic distribution of renewable energy and circular economy integration analyses. Like previous studies, this research establishes the fact that Western Europe is home to the highest number of publications on the topic compared to other regions around the globe [112]. Dissimilar to prior reviews, however, the present research found the topic to be of interest to researchers from all around the world. Specifically, countries like Saudi Arabia, endowed with a great deal of natural resources, have generated a considerable amount of research on green economies and clean energy [113]. In the same vein, unlike past researchers who concluded that countries with low economic development exhibit limited interest in renewable energy and circular economy integration, this study reported results from sub-Saharan African developing economies, as well as countries outside of the Organisation for Economic Cooperation and Development (OECD).

One contradictory finding reported throughout this research to past reviews on related topics is the quality of research regardless of the context, industry, or country. The present manuscript concluded that research originating from North America and Western Europe is equal in quality to that published from Eastern European, Middle Eastern, and Latin American countries. This pattern is evident in the fact that many authors published their work in the same journals as *Sustainability* or *Energies*. As a matter of fact, the publishing firm MDPI contributes the highest proportion of all studies integrating circular economy and renewable research. The open access premise of MDPI attracts many authors from all over the world, regardless of their field or locale. Past researchers have also concluded that the quality of research of authors within countries endowed with little to no renewable energy sectors is inferior to the research produced in the developed industrial world [75,114,115]. The current manuscript does not support such a finding, given the fact that all authors have published in similar journals in terms of impact factor rankings.

Consistent with prior reviews, this analysis demonstrated authors' interest in the expansion of green technology in the integration of the circular economy and renewable energy sectors. Research on integration has already moved away from awareness or early implementation explorations into proposing new alternative technologies for waste management and clean energy production [116]. The present analysis supports the authors' view given the rise of research on green chemistry and bioenergy [51]. A sizable number of articles focused on the improvement of existing anaerobic digestion frameworks to maximise the output obtained from such processes [117]. Similarly, researchers concentrated on the redesigning of materials used in the production of renewable energy surfaces like photovoltaics [118]. In PV studies, many researchers have called for immediate investments in new technologies capable of addressing the end-of-life crisis associated with solar panels in the coming decades.

The present study corroborates the need for further research and development in the technologies used to integrate the circular economy and renewable energy. For instance, one pioneering proposal to shorten the thermal cycle in the report using carbon fiber material that generates commercial value in the industry needs to be further tested and refined [119]. Other authors have also suggested numerous ways to recycle glass, plastics, and carbon fiber in ways that shift from traditional treatments to improve clean energy production while keeping the loops closed [120]. Therefore, this research joins others in calling for experimental studies aiming to enhance the redesign, refurbishment, repressing, and reuse of materials used in clean production and the circular economy. In this review, one research study was conducted in a lab testing numerous conditions on how glass in PVs

would react if subjected to varying circumstances [121]. Thus, a serious need for further research and development arises to scale innovative solutions in the recycling industries.

The findings in this study are consistent with the rising interest in end-of-life recycling and reuse of consumer products across the globe. One study suggested that the biomass recycling industry must innovate methods of separating fossil fuel-related processes from the circular economic treatment of compost or waste at the end-of-life stages [122]. Conforming to this call is the apparent concentration on the improvement of anaerobic digestion and fertilizer production techniques using clean energy [123]. By the same token, researchers have disproportionately concentrated on biomass, bioenergy, and biogas compared to other renewable energy sources like wind or hydroelectric [124]. Therefore, this research also reported higher frequencies for research conducted in the food and beverage production contexts, as well as the fertilizers' manufacturing domain.

The ongoing research on renewable energy transitions and circular economy integration notes the difficulty in changing consumer behavior. One of the most important obstacles facing the industrial world in reaping the potential of Waste-to-Energy solutions in treating municipal waste is popular resistance [61]. This research documented that local community support, popular approval of integration methods, and stakeholders' engagement are all part of the transitioning process. Without securing the will of individuals to shift daily behavior from undesirable patterns to conducive trends, governments and firms are less likely to be successful in achieving strides in the integration domain [125,126]. Therefore, similar to earlier studies, this research documented the significance of public awareness campaigns in raising interest and grit among people, policymakers, and industry agents to adopt the change.

4.2. Potential Explanations for Observed Trends

A potential explanation for the widespread implementation of circular economy practices and renewable energy sources around the world is the relative access and affordability of technology, allowing nations and firms to apply innovative manufacturing methods [99,115]. Today, emerging economies in the Middle East, West Africa, and Latin America have access to a highly talented workforce, as well as advanced technical solutions from East Asia and the West, helping in integrating CE practices with renewable energy [82,108]. Globalisation has made the transfer of knowledge and resources across borders much easier compared to the Cold War era, accelerating integration in developing economies [81,97,98].

A probable explanation for the high frequency of theoretical research in the CE practices integration in renewable energy literature is the difficulty in measuring key concepts [52]. The proportion of all studies reviewed in this research that did not utilise real data was 72 percent. Such statistics confirm the difficulty in obtaining access to real-world cases like factories. Also, CE practices are difficult to capture in easy-to-understand quantitative metrics, making integration patterns harder to operationalise [94,108]. Thus, whenever empirical data is used, one finds researchers using a multitude of measures attempting to capture the multifaceted nature of integration [51,124].

One of the important explanations for the observation of the simultaneous implementation of more than a single CE practice is the intersectionality of the concept [113,116]. The implementation of CE entails the adoption of the framework or the strategy, which features more than a single practice by definition [69,120]. Thus, recycling and reduction go hand-in-hand when implemented, and it would be extremely difficult to separate both practices from each other. On the other hand, the integration pattern could feature a single renewable energy source [70,99]. In rare circumstances, more than a single renewable energy source is involved in an integration episode. Such a fact stems from the factory's

ability to access energy resources, which is often limited to one type, like solar or wind, depending on the location of the facility [89,122].

4.3. Implications

One of the practical implications emerging from this research is the importance of Extended Producer Responsibility (EPR) legislation. Governments mandate manufacturers to take responsibility for their products, like photovoltaics, when the end-of-life phase emerges. While most countries do not require manufacturers to install a robust collection system for their materials once dispensed to markets, stipulating that manufacturers do so compels them to create innovative solutions for recycling their produced materials. This investigation urges policymakers to seriously consider EPR frameworks to help in enhancing the integration of the circular economy and renewable energy.

An important implication emerging from this research is the potential power of circular economy integration with renewable energy in providing a pathway for clean energy transitions for cities and municipalities around the world. Capturing surplus heat and the electrification of key processes supply stakeholders with great avenues to shift from relying on traditional energy sources to clean, renewable sources. With the power of a circular economy, more resources like environmental assets are saved while already-in-use materials are recycled. Effective integration is capable of reducing the carbon footprint while increasing clean power generation.

While this review documented the plethora of uses of anaerobic digestion to produce biogas, capturing a plethora of economic capital, contemporary applications of the technology are still far from scalable or standardised. The extant literature documented the plethora of benefits of biogas in saving resources, reusing waste for economic value, and generating clean energy. The uses of technology are largely fragmented and fundamental. Scalability in anaerobic digestion is needed to help governments achieve their sustainability development goals in a timely manner. Additionally, further education and awareness campaigns on how to implement technology, especially in the agricultural industry context, must be elevated. This research notes the need for more concerted efforts from all stakeholders in making anaerobic digestion a regular staple in the renewable energy sector.

The public sector plays a crucial role in achieving sustainability at all levels. The passage of carbon taxes compels businesses to innovate by saving resources and increasing their circular economy implementation. Through the expansion of circular economy operations, businesses are able to generate further clean energy to run their manufacturing lines. Similarly, the evidence in this review suggests that the private sector is best incorporated through the use of positive incentives or taxation. Presenting opportunities may convince many businesses to scale their circular economy practices. Nevertheless, taxation also proved to be a useful business tool, pushing manufacturers to innovate. Therefore, government actors must be active in positively driving the implementation of a circular economy through economic policy tools.

A less emphasised, yet important, phenomenon in the circular economy and renewable energy integration literature is popular or community support for sustainability. While most studies ignore the attitudes, beliefs, and actions of consumers or stakeholders with respect to circular economy adoption, people make decisions based on their beliefs and experiences. Therefore, there is a serious need to invest in circular economy formal and informal education or learning. Private firms, as well as public agencies, are urged to design training workshops on the circular economy and how it is integrated within sustainability. The outcomes of such programs would likely increase the integration of a circular economy and clean energy across many contexts.

4.4. Limitations

One of the recurring limitations in the study of circular economy integration into renewable energy transitions is the failure to detail all the assumptions at play in the study context. Simulation, system modelling, and life cycle assessment estimation research suffer from a lack of clarity on the part of ensuring that readers are fully informed about the methods' limits used in their research. For instance, three studies all celebrated the gains of introducing circular economy practices into renewable energy sectors [127–129]. They, however, did not explain the characteristics of their data, models' specifications, and the suitability of such techniques to the information used in their analyses adequately. Testing the appropriateness of the data is an essential step prior to any modelling procedure that was performed by many authors [130]. Therefore, the observed values and estimates from such models could suffer from reliability and validity concerns.

Another limitation facing this research and earlier reviews on similar topics is coverage [131]. In this specific review, studies published in the English language within the past five years and in peer-reviewed journals were included. Such stringent criteria exclude many types of research that are relevant to the subject under investigation. A broader review with longer time frames, and those that include government reports, dissertations, theses, and conference papers could have generated different results. As was apparent in the relevance to the Section 4.1 above, this review found support for some important key findings in the literature. On the other hand, the review contradicted another set of findings. Simply put, the number and type of studies fed into the review determine part of the results observed, which is a limitation facing any review regardless of its methodological rigour.

Another common limitation to reviews that is often neglected or not disclosed by authors is the subjectivity of every decision along the way in the research journey. The selection criteria set forth prior to examining analyses generate different sets of studies compared to distinct criteria, causing differences in the findings [132]. Similarly, the decision on what variables need to be coded, and how such variables are labelled or the number of values they have are all specific critical points that lead the research in varying directions if conducted by various researchers. The selection of analysis methods, like descriptive statistics or thematic analysis, to present the findings of the review is also a subjective decision made by the researcher. Since researchers prefer varying methods of data organisation or analysis, the findings reported will indeed differ even if the same data is used [133]. Therefore, readers must be aware of the subjectivity that takes place when conducting a review like the present research.

Systematic reviews present a few challenges to practitioners. This research is no exception to the barrier of incorporating conclusions into practical solutions [134]. While the present study offered several findings describing the types, quality, and content of research on circular economy and renewable energy, its results are mostly conceptual. Practice-based recommendations or policy implications originating from systematic reviews are open to serious investigation. Therefore, like any review, this research presented a set of findings without attempting to influence a specific industry or practice. This is a limiting characteristic of all review types [135–137]. Readers need to be cautious when interpreting results by not generalising the findings to specific contexts or domains.

A classic critique of any systematic review, including the present research, is the reliance on a small number of databases, the use of few keywords, or the exclusion of large bodies of research based on the inclusion criteria. While this research attempted to remedy such limits by incorporating studies from the two largest academic databases, Web of Science and Scopus, it still excluded many others. Also, this research utilised the impact factor criterion as a justifiable metric for research quality, which has been critiqued on many occasions and across various fields. The logistical limits placed on the author in

terms of time, resources, access to databases, costs associated with lengthy reviews, and the inability to hire assistants all restrict the realistic choices of any researcher. The only positive outcome from such a trap is making readers aware of every detail throughout the research process, adding further trustworthiness to the results observed.

One of the acknowledgements of the authors in this research is the shortcomings of the impact factor and the number of citations metrics as measures of research quality. Since measures of journals and articles quality vary depending on paradigms or views considered, the impact factor is only one of the metrics and should not be taken as the sole measure of quality. Likewise, the number of citations should not be considered the best quality research metric in evaluating research. Future researchers may consider other metrics in including studies on the subject.

4.5. Directions for Future Research

A recurring theme in this research is highlighting the positive effect of research and development in facilitating the integration of renewable energy and the circular economy. Despite this repeated emphasis, little estimation of how research and development truly impact integration has been performed. Future researchers could utilise simulation models to examine how specific research endeavours could impact circular economy adoption or integration, especially in renewable energy contexts [138,139]. For instance, the Saudi Investment Recycling Company (SIRC) funded the research and development of the Waste-to-Energy (WYE) facilities initiative. Today, many recycling facilities turn waste into energy as an integrated illustration of the circular economy and renewable energy in the oil and gas sector. Further, researchers are urged to specify the types of research and development activities. More importantly, adding realistic expectations would help readers better situate the available research and development options with respect to regional or country-level variations.

In this research, a comprehensive review of the literature was conducted to learn more about how the circular economy is integrated with renewable energy. While there are many benefits to documenting how researchers examined the integration phenomenon on a global level, each region or country around our beloved planet is endowed with varying levels of natural resources. Therefore, future researchers need to delve into the details of how geographic regions or specific countries have integrated or could integrate the circular economy with renewable energy [140,141]. More specifically, integration research could be even more specific, targeting one circular economy practice and renewable energy type. For example, Saudi Arabia has heavily invested in solar power and has not made proactive steps in developing geothermal power like the United States. Similarly, Nordic countries have greatly focused on hydropower rather than solar panels like Middle Eastern countries. Today, solar power fuels many large-scale manufacturing facilities in Saudi Arabia, thereby decreasing utility bills and carbon emissions.

On a methodological level, existing reviews or syntheses on circular economy and renewable energy suffer from a lack of documentation of authenticity, transferability, credibility, and confirmability. Reviews are full of subjective decision-making, like the determination of variables to be included and their measurement processes. Future researchers are encouraged to share as much detail as possible on how they selected their studies, coded them, and reached the results [102,142]. More importantly, researchers are called upon to show readers how they vetted their results. What processes have researchers implemented to ensure that the results obtained are transferable to other similar contexts? Literature reviews are largely qualitative in nature and therefore must adhere to the same principles of quality as any other type of analysis.

Much of the existing research on the circular economy or renewable energy relies on the English-language literature. Similarly, Web of Science and Scopus formulate the venues where most researchers, like this study, extract the materials for review. While such decisions are taken because of perceived or even actual rigour and accessibility, a large proportion of research is left out. For instance, government reports, published in any language on the topic, are less emphasised in the review literature. Similarly, unpublished papers like dissertations or theses are also excluded from most reviews. Future researchers are urged to search the non-English literature, as well as the unpublished bodies of scholarly writing on the topic [143,144].

One of the important future research endeavours is the construction of mediation studies that explain how circular economy practices foster the transition into renewable energy. Much of the existing research focuses on the strength and direction of these associations. Further, few investigations have been conducted examining how the circular economy explains changes in renewable energy transitions. For instance, authors may examine the mediation effects of stakeholders' collaboration on the link between recycling and the use of solar panels or wind energy [145].

Another significant future research direction is prioritising barriers and facilitators that are contingent upon industry type, the context of the application, and the environment of implementation [146,147]. Studies on the integration of the circular economy into renewable energies simply list barriers or facilitators without indicating the salient conditions necessary. Indeed, some facilitators are more relevant in some environments than others. Similarly, barriers would differ in their effects on integration depending on the environment or context involved.

The interdisciplinary scholarly area of CE and RE integration is an emerging frontier in the manufacturing engineering and industrial application literature. Well-developed theoretical frameworks guiding the integration of circular economic models with sustainable practices like renewable energy are still developing. The present research offers future researchers opportunities to explore further theoretical links in the integration movement rising within the manufacturing sector.

4.6. Research Gap

One of the gaps in the literature is an overemphasis on technological integration, with authors paying limited attention to the management, organisational, administrative, and economic elements of integration. For instance, three studies emphasised the need for revamping existing technologies in the production of renewable energy to maximise waste reduction and resource utilisation [148–150]. While technology offers valuable solutions to recycling or waste reduction, top management support and human capital are necessary for the achievement of effective integration. Lack of management support and resistance to change appear to be more frequent in the adoption of more advanced CE practices such as reverse logistics, as well as environmental designs [149,150]. The uncertain return on investment and high initial investment costs fuel managers' fears about the integration of CE practices, especially in developing countries, endowed with fewer resources dedicated to research and development or innovation [73,92].

Another problem in the CE and renewable energy literature is the dearth of analyses on the barriers and facilitators facing the integration shift. For instance, one study stated that “currently, no specific literature review journal addresses the barriers and challenges of implementing renewable energy in a circular economy, nor a future research agenda” [151] (p. 3). Integration of CE practices and renewable energy sources is a new research field with great potential for expansion [138]. Case studies documenting the phenomenon have not adequately investigated the technical or human hindrances for efficient and effective

integration [122,134]. For instance, manufacturing studies in emerging economies did not assess facilities' readiness nor personnel preparedness for the shift despite the presence of many methods of evaluation [140]. Such barriers are more likely to be present in developing markets, as well as in highly sophisticated integrations such as reverse logistics with any renewable energy source.

The present analysis supports earlier research on CE implementation in sustainability initiatives [152,153]. Similar to Pasqualotto et al. [153], the present study highlighted the impact of institutional, technological, and financial variables on CE implementation. For instance, cost, fiscal incentives, and subsidies affect integration in the manufacturing sector regardless of geography or domain. In Saudi Arabia, the public sector pioneered in incentivising CE and renewable energy implementation through the injection of colossal institutional support backed by large financial investments across many sectors [126,127,132]. Likewise, this study demonstrated the variability and complexity of CE integration with RE in manufacturing [154,155]. Geographic attributes, for instance, affected integration methods. Solar power served as the top source of clean energy in the Middle East, while wind power emerged as a key source in Western European markets [140].

A stark gap in the literature is negligence towards the developing world [156]. Most current research focuses on industrialised Western nations, paying inadequate attention to emerging economies such as Saudi Arabia when considering circular economy and renewable energy integration [157]. Case studies document the implementation of circular economy practices within renewable energy contexts in the Middle East, sub-Saharan Africa, and South Asia. Despite the multitude of research on energy policy, there has been an insufficient number of reviews written on policy interventions facilitating the effective integration of the circular economy and renewable energy. More specifically, the policy literature has little regard for the potentially different economic and political environments of developing countries like Saudi Arabia possess compared to advanced economies [154]. A synthesis of the policy literature on how integration across different contexts is successful as a warranted endeavour.

5. Conclusions

This investigation examined the integration of circular economy practices into renewable energy in the past five years. The research only focused on peer-reviewed English-language literature found in the Web of Science and Scopus databases. Overall, a tremendous interest in circular economy and renewable energy integration is noticeable in the literature, with 107 distinct papers reviewed in this study. Note that the inclusion criterion for this research was stringent, stipulating explicit integration. The literature is interdisciplinary and spans many contexts, including the fields of manufacturing, agriculture, business, and economics.

A total of 14 CE practices were represented, with each mentioned at least 10 times by distinct authors. The list of CE practices included recycling, reducing materials, remanufacturing, reuse of materials, waste minimisation, renewable energy use, consumer awareness, repurposing, refuse, education and training, environmentally friendly design, environmental criteria for supplier selection, reverse logistics, and stakeholders' collaboration. Studies represented 40 different countries, with recycling appearing to be the most representative CE practice. Additionally, biogas, geothermal, wind, hydroelectric, solar, and bioenergy renewable sources were identified throughout the research. The most recurring integration pattern was applying recycling with solar and wind energy in manufacturing facilities.

The investigation reported that recycling is the most popular circular economy practice integrated with renewable energy. Additionally, the review noted that solar energy is the highest recurring type of renewable energy, with a special focus on photovoltaic end-of-

life or life cycle assessment. Another increasing application of the circular economy and renewable energy is the use of anaerobic digestion to produce biogas used to generate power. Similarly, the extension of life for recyclable materials used in wind energy production appeared to be an increasingly popular integration context. The food and beverage, as well as the fertilizer industries, appeared to be the most recurring manufacturing contexts in the literature.

Contrary to conventional wisdom, this review documented many case studies of integration beyond the industrialised developed economies. Authors from the Middle East, sub-Saharan Africa, and South Asia noted the implementation of the circular economy within emerging sectors and how such implementations fostered ancillary environments for the adoption of renewable energy. This review concluded that the public sector plays a crucial role in facilitating the integration process. On the other hand, overcoming management, organisational, and bureaucratic barriers presents many opportunities for increasing the implementation of a circular economy.

The feasibility of CE and RE integration in developing countries is in question given the current barriers facing markets. Low investment levels in transitions from traditional energy sources into renewable energy across much of the developing world make the shift harder to realise. Limited consumer engagement and stakeholders' collaboration, coupled with meager public funding and private investment, all render transformations slow. All in all, this review concludes with the statement echoed by most authors in the literature, emphasising the positive role of circular economy and renewable energy in achieving long-term sustainability at all levels.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17167301/s1>, PRISMA 2020 Checklist [158].

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Appendix A

Table A1. List of journal impact factors analysed in this study.

Journal Name		Impact Factor
1.	<i>Energies</i>	3.2
2.	<i>Sustainability</i>	3.9
3.	<i>Pakistan Journal of Commerce and Social Sciences</i>	N/A
4.	<i>Applied System Innovation</i>	3.8
5.	<i>International Journal of Technology Management & Sustainable Development</i>	N/A
6.	<i>Renewable and Sustainable Energy Reviews</i>	16.7999
7.	<i>Renewable Energy</i>	8.634

Table A1. Cont.

	Journal Name	Impact Factor
8.	<i>Science of the Total Environment</i>	10.753
9.	<i>Business Excellence and Management</i>	N/A
10.	<i>Waste Management & Research</i>	3.9
11.	<i>Sustainable Energy Reviews</i>	15.9
12.	<i>Cleaner Energy Systems</i>	11.1
13.	<i>WIT Transactions on Ecology and the Environment</i>	0.173
14.	<i>Processes</i>	3.5
15.	<i>Frontiers in Environmental Science</i>	4.6
16.	<i>Geoscience Frontiers</i>	7.483
17.	<i>Corporate Social Responsibility and Environmental Management</i>	8.741
18.	<i>Social Sciences and Humanities Open</i>	1.9
19.	<i>Gondwana Research</i>	8.122
20.	<i>Problemy Ekorozwoju</i>	0.242
21.	<i>Energy & Environment</i>	2.945
22.	<i>PloS one</i>	3.7
23.	<i>Bioresource Technology</i>	11
24.	<i>International Journal of Sustainable Development & World Ecology</i>	3.716
25.	<i>ACS Omega</i>	4.1
26.	<i>Resources, Conservation and Recycling</i>	13.716
27.	<i>Applied Energy</i>	11.2
28.	<i>Applied Sciences</i>	2.7
29.	<i>Resources Policy</i>	10.2
30.	<i>Energy Strategy Reviews</i>	8.2
31.	<i>Waste Management</i>	8.1
32.	<i>Latvian Journal of Physics and Technical Sciences</i>	0.6
33.	<i>Climate Policy</i>	7.1
34.	<i>Process Safety and Environmental Protection</i>	7.8
35.	<i>Cogent Engineering</i>	1.9
36.	<i>Business Strategy and the Environment</i>	10.302
37.	<i>IJARBEST</i>	5.023
38.	<i>Journal of Environmental Management</i>	8.7
39.	<i>International Journal of Production Research</i>	9.2
40.	<i>Sustainable Energy Technologies and Assessments</i>	8
41.	<i>Journal of Cleaner Production</i>	11.1
42.	<i>Journal of Energy Storage</i>	9.4
43.	<i>Energy</i>	9
44.	<i>Journal of Thermal Analysis and Calorimetry</i>	4.755
45.	<i>Environmental Development</i>	5.4
46.	<i>International Journal of Thermofluids</i>	9.468
47.	<i>Water Reuse</i>	4.5
48.	<i>Fuel</i>	8.035
49.	<i>Environment, Development, and Sustainability</i>	4.9
50.	<i>Journal of Carbon Research</i>	4.1
51.	<i>Circular economy and Sustainability</i>	N/A
52.	<i>Environments</i>	3.7
53.	<i>Substantia</i>	N/A
54.	<i>Procedia Environmental Science, Engineering and Management</i>	N/A
55.	<i>One Earth</i>	N/A
56.	<i>International Journal of Mathematical, Engineering and Management Sciences</i>	N/A
57.	<i>Energy Reports</i>	4.937
58.	<i>Ecological Economics</i>	5.389
59.	<i>Journal of Industrial Ecology</i>	6.946
60.	<i>South Asian Journal of Business and Management Cases</i>	N/A

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