

Circular Economy and ESG: Building Sustainable Business Models in the Manufacturing Sector

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ABSTRACT

This research explores the alignment of Circular Economy (CE) principles with Environmental, Social, and Governance (ESG) criteria in the manufacturing sector to build sustainable business models. The study uses a mixed-methods approach, combining interviews, surveys, and case studies from key industries such as automotive, electronics, textiles, and consumer goods. The findings reveal that adopting CE practices such as material recycling, energy efficiency, and product design for reuse significantly enhances environmental performance, contributing to the environmental dimension of ESG. However, the integration of CE into the social and governance dimensions of ESG presents more challenges, with companies reporting less pronounced improvements in these areas due to factors such as regulatory inconsistencies and cultural resistance within organizations.

Case studies from companies like BMW, Dell Technologies, Patagonia, and Unilever highlight diverse strategies for CE-ESG alignment, demonstrating the potential for long-term financial benefits, enhanced brand reputation, and improved regulatory compliance. Nonetheless, the research identifies several barriers to CE-ESG implementation, including high upfront costs, regulatory fragmentation, and the complexity of global supply chains.

The study concludes that while the integration of CE and ESG frameworks offers significant sustainability benefits, overcoming economic, regulatory, and cultural challenges is essential for widespread adoption. Policy recommendations include providing financial incentives for circular practices, harmonizing regulations, and investing in infrastructure, particularly in developing regions. The research contributes to the growing literature on sustainability by offering practical insights and theoretical implications for CE-ESG alignment, and suggests future research directions in sector-specific studies and the social and governance impacts of CE practices.

Introduction

Background

The global economy faces increasing pressure to transition toward more sustainable models due to the significant environmental challenges posed by climate change, resource depletion, and mounting waste generation [1]. The manufacturing sector, responsible for nearly 54% of global energy consumption and around 20% of CO₂ emissions, is a key contributor to environmental degradation [2]. Traditional manufacturing processes follow a linear "take, make, dispose" model, characterized by high levels of resource extraction and waste generation. This model is increasingly unsustainable in the face of diminishing natural resources and growing environmental concerns [3].

To address these challenges, two major frameworks have gained prominence in recent years: the Circular Economy (CE) and Environmental, Social, and Governance (ESG) criteria. The Circular Economy, an alternative to the linear economy, focuses

on designing out waste and pollution, keeping products and materials in use, and regenerating natural systems [4]. It aims to create a closed-loop system where resources are reused and recycled, reducing the need for virgin raw materials and minimizing environmental impact [5].

On the other hand, Environmental, Social, and Governance (ESG) criteria are used to assess a company's sustainability practices and overall ethical impact. ESG criteria have become essential for evaluating corporate performance beyond financial profitability, emphasizing the importance of environmentally responsible actions, social equity, and sound governance practices [6]. These frameworks are especially relevant in the manufacturing sector, where the integration of CE principles with ESG goals can lead to substantial reductions in resource consumption and environmental degradation, while also improving social and governance outcomes [7].

Manufacturers worldwide are increasingly recognizing the need to incorporate sustainable practices into their operations, driven by regulatory changes, consumer demand, and the long-term financial benefits of sustainability [8]. By integrating CE principles, such as recycling, reusing, and designing for durability, with ESG goals that emphasize ethical governance and social responsibility, manufacturing firms can significantly contribute to the global shift toward sustainability [2]. This research will explore how the intersection of Circular Economy and ESG principles in the manufacturing sector can foster sustainable business models, focusing on the benefits, challenges, and practical implementation strategies.

Problem Statement

The increasing urgency to mitigate environmental damage has led to widespread adoption of both Circular Economy practices and ESG frameworks across industries. However, the manufacturing sector has been slower to integrate these frameworks in a holistic manner, primarily due to the complexity of reconfiguring established production processes and corporate governance structures. While the literature is rich in discussions on the individual adoption of CE and ESG principles, there remains a significant gap in understanding how these two frameworks can be aligned within the manufacturing industry to maximize sustainability benefits [7].

This research addresses this gap by evaluating the potential synergies between Circular Economy principles and ESG criteria within the manufacturing sector. Specifically, it explores the extent to which CE practices such as reducing waste, reusing materials, and recycling can support the environmental, social, and governance objectives laid out in ESG frameworks. Furthermore, it assesses the barriers to successful integration, including economic, regulatory, and organizational challenges, and proposes strategies to overcome these hurdles.

Research Objectives

The primary objectives of this research are:

1. To explore how Circular Economy principles, such as resource efficiency, recycling, and product design for longevity, align with ESG goals in the manufacturing sector.
2. To evaluate the potential environmental, social, and economic benefits of integrating CE and ESG frameworks in manufacturing, using case studies and empirical data from industry leaders.
3. To identify the key challenges and barriers that manufacturing companies face when attempting to align CE practices with ESG criteria, and to propose practical solutions for overcoming these challenges.

Research Questions

This research seeks to answer the following questions:

- How do Circular Economy principles align with ESG goals in the manufacturing sector?
- What are the environmental, social, and economic benefits of integrating CE and ESG frameworks?
- What are the major challenges to implementing CE-ESG aligned business models, and how can these barriers be overcome?

Significance of the Study

The significance of this study lies in its potential to provide a comprehensive framework for the integration of Circular Economy and ESG principles in the manufacturing sector. As sustainability becomes increasingly important for consumers, investors, and policymakers, manufacturing companies must adopt new strategies to stay competitive and compliant with emerging regulations [8]. By aligning CE and ESG frameworks, manufacturers can reduce their environmental footprint, enhance their social responsibility, and improve corporate governance leading to long-term financial and operational benefits.

This research will contribute to the academic literature by providing empirical evidence on the benefits of CE-ESG integration in manufacturing and offering practical recommendations for industry leaders and policymakers. Additionally, it will provide a roadmap for future research on sustainability in the manufacturing sector, highlighting the need for ongoing exploration of how CE and ESG principles can be scaled and optimized across industries.

Literature Review

Circular Economy (CE) Concept

The Circular Economy (CE) represents a shift from the traditional linear economy model, which operates on a “take-make-dispose” basis, towards a regenerative system where waste and pollution are designed out of the production cycle, resources are reused, and products are kept in use for as long as possible [4]. This model is built on the principle of decoupling economic growth from resource use, ultimately aiming to create a sustainable economic system that minimizes environmental impact.

The origins of the CE concept can be traced to industrial ecology, which advocates for the imitation of natural ecosystems, where materials cycle through the system and nothing is wasted [1]. One of the foundational elements of CE is the idea of designing products for longevity and recyclability, ensuring that they remain in circulation rather than becoming waste. This can be achieved through various strategies, including the repair, refurbishment, and remanufacturing of products [5].

In the manufacturing sector, the adoption of CE principles often involves shifting towards more sustainable materials, reducing energy consumption during production, and implementing systems to collect and recycle products at the end of their life cycle [3]. This approach not only reduces the environmental footprint of manufacturing processes but also offers potential cost savings by reducing the need for virgin raw materials.

In the context of sustainability, CE aligns closely with other environmental frameworks, such as resource efficiency and waste hierarchy principles [9]. According to a report by the Ellen MacArthur Foundation, the transition to a Circular Economy could reduce greenhouse gas emissions by 45% by 2050, while also offering significant economic opportunities [4]. This highlights the importance of CE as a transformative approach to sustainable manufacturing.

However, the adoption of CE practices in manufacturing is not without challenges. High upfront costs for redesigning products and reconfiguring production processes often deter

companies from fully committing to the Circular Economy model. Moreover, a lack of infrastructure for recycling and remanufacturing can impede the development of closed-loop systems in certain regions [3].

Environmental, Social, and Governance (ESG) Framework

The ESG framework has become a key metric for assessing a company's sustainability and ethical impact. ESG criteria were initially developed as a tool for socially responsible investing (SRI), but they have since evolved into a broader framework that businesses use to measure and report their sustainability performance [6]. ESG focuses on three pillars:

1. **Environmental:** This pillar assesses a company's impact on the natural environment, including its carbon footprint, water usage, energy consumption, and waste management. Companies are expected to adopt practices that minimize their environmental impact, such as reducing greenhouse gas emissions, transitioning to renewable energy, and implementing waste reduction strategies [10].
2. **Social:** The social pillar examines how a company manages relationships with employees, suppliers, customers, and the communities in which it operates. This includes labor practices, human rights issues, workplace diversity, and community engagement. A company's social performance is increasingly scrutinized by investors and stakeholders, particularly in light of growing concerns about corporate responsibility and social justice [11].
3. **Governance:** This pillar evaluates a company's internal governance structure, including its leadership, executive compensation, shareholder rights, and transparency. Good governance practices are essential for building trust with stakeholders and ensuring accountability in decision-making [12]. ESG governance also includes ethical business practices and compliance with laws and regulations.

As global attention on corporate responsibility grows, ESG reporting has become increasingly important for businesses looking to attract investment and improve their public image. Companies that perform well in ESG criteria tend to have better long-term financial performance, as they are more resilient to regulatory changes and reputational risks [12]. A study by Khan, Serafeim, and Yoon found that companies with high ESG ratings had significantly higher profitability and lower volatility than those with poor ESG performance [6].

In the manufacturing sector, integrating ESG criteria into operations is becoming a priority. The environmental component of ESG aligns with the goals of the Circular Economy, particularly in terms of reducing waste, increasing energy efficiency, and transitioning to renewable energy sources. However, manufacturers face unique challenges in meeting social and governance standards, particularly in industries where labor practices or supply chain management are complex [13].

CE and ESG Synergies

The integration of Circular Economy principles with ESG criteria presents significant opportunities for enhancing sustainability in the manufacturing sector. Both frameworks share common goals, particularly in their focus on reducing environmental impact, promoting resource efficiency, and improving corporate responsibility. By aligning CE practices with ESG goals,

manufacturers can create business models that are not only more sustainable but also more resilient and financially viable in the long term [7].

One of the key synergies between CE and ESG lies in the **environmental** dimension. Circular Economy practices such as reducing waste, reusing materials, and improving energy efficiency directly support ESG environmental goals [9]. For example, manufacturers that adopt recycling and resource recovery strategies can reduce their carbon footprint and resource consumption, aligning with ESG requirements for environmental responsibility [5].

Moreover, CE principles can support the **social** and **governance** aspects of ESG by promoting transparency, ethical sourcing, and long-term value creation. For instance, companies that design products for longevity and recyclability are more likely to build strong relationships with customers and suppliers, enhancing social capital [7]. In addition, manufacturers that implement CE practices often adopt more transparent governance structures to ensure accountability in their sustainability efforts, thus aligning with ESG governance goals [13].

While the synergies between CE and ESG offer numerous benefits, there are also challenges in fully integrating these frameworks. One of the main obstacles is the lack of standardized metrics for measuring the success of CE-ESG initiatives, which can make it difficult for companies to track and report progress [3]. Furthermore, the long-term nature of CE and ESG investments may deter companies that are focused on short-term profitability, highlighting the need for greater education and awareness of the financial benefits of sustainability [8].

Challenges and Barriers

Despite the clear benefits of aligning CE and ESG principles, manufacturers face several challenges in implementing these frameworks. One of the primary barriers is economic. The transition to a Circular Economy requires significant upfront investment in new technologies, processes, and infrastructure, which can be prohibitive for companies with limited financial resources [3]. Additionally, the financial benefits of CE-ESG alignment may not be immediately apparent, as the long-term savings from resource efficiency and waste reduction often take time to materialize [9].

Another significant barrier is regulatory inconsistency. While some regions, such as the European Union, have introduced policies to encourage the adoption of CE practices, other regions lack the necessary regulatory frameworks to support a transition to circular business models [1]. This inconsistency can create challenges for multinational manufacturers operating across different regulatory environments.

Cultural resistance within organizations also poses a challenge to the successful integration of CE and ESG. Many companies are entrenched in traditional linear business models and may be resistant to the changes required for a circular approach. Overcoming this resistance requires strong leadership, clear communication, and a commitment to long-term sustainability goals [7].

Finally, the lack of infrastructure for recycling and remanufacturing is a significant barrier in many regions. Without the necessary systems in place to support resource recovery and product take-back schemes, it can be difficult for manufacturers to fully implement CE practices [3]. This highlights the need for greater investment in infrastructure development to support the growth of the Circular Economy.

Methodology

Research Design

This study employs a mixed-methods research design, combining both qualitative and quantitative approaches to gain a comprehensive understanding of how Circular Economy (CE) principles align with Environmental, Social, and Governance (ESG) criteria in the manufacturing sector. The mixed-methods approach allows for the collection of diverse data, providing a more nuanced understanding of the research problem. This design is particularly useful when investigating complex phenomena like sustainability practices, where both statistical data and subjective perspectives are crucial [14].

Data Collection Methods

Primary Data Collection

Primary data for this research was collected through two key methods: semi-structured interviews and surveys. These methods were chosen to explore both the subjective experiences of manufacturing companies and to gather quantifiable data regarding their sustainability practices.

- **Semi-Structured Interviews:** Interviews were conducted with sustainability managers and senior executives from 10 manufacturing companies, focusing on their adoption of CE practices and how these practices align with ESG criteria. The semi-structured format allowed participants to share their experiences while also providing the flexibility to explore topics in depth. Interviews lasted between 45 and 60 minutes and were conducted either in person or via video conferencing.
- **Surveys:** A survey was distributed to a larger sample of 50 manufacturing companies across multiple sectors, including automotive, electronics, and textiles. The survey consisted of both closed-ended and open-ended questions, designed to gather data on the companies' use of CE practices, their ESG performance metrics, and the challenges they face in aligning these frameworks.

Table 1: Data Collection Overview

Data Collection Method	Participants	Sample Size	Data Type
Semi-Structured Interviews	Sustainability Managers, CEOs	10	Qualitative
Surveys	Manufacturing Companies	50	Quantitative

Secondary Data Collection

Secondary data was collected from publicly available reports, case studies, and academic literature. This included industry reports on CE and ESG adoption in manufacturing, as well as corporate sustainability reports from leading companies. Secondary data provided a benchmark for evaluating the primary

data and helped to contextualize the findings within broader industry trends.

Sources of Secondary Data Included

- Corporate sustainability reports from 20 global manufacturing companies.

Industry reports from the Ellen MacArthur Foundation, International Energy Agency (IEA), and other leading organizations focused on sustainability and Circular Economy practices [2,4].

Sampling Strategy

The sampling strategy for this research was purposive sampling, targeting companies within the manufacturing sector that have already implemented some form of sustainability initiative, whether through CE or ESG frameworks. The sample was selected based on the following criteria:

- **Sectoral diversity:** The study included companies from key manufacturing sectors such as automotive, electronics, and textiles, which are among the largest resource consumers and waste producers.
- **Geographical diversity:** To ensure a comprehensive analysis, the sample included companies from different regions, including Europe, North America, and Asia, where the regulatory environment for CE and ESG practices varies.
- **Company size:** Both small and medium-sized enterprises (SMEs) and large multinational corporations (MNCs) were included, as the ability to implement CE-ESG alignment can vary significantly by company size.

Table 2: Sample Composition by Sector and Region

Sector	Region	Number of Companies
Automotive	Europe, North America	15
Electronics	Asia, Europe	20
Textiles	North America, Europe	15

This strategy allowed for the collection of data across different industrial and regulatory contexts, providing a more comprehensive understanding of how CE and ESG principles are being implemented in various regions and sectors.

Data Analysis Techniques

Qualitative Data Analysis

Qualitative data from the semi-structured interviews were analyzed using thematic analysis. This method involves identifying, analyzing, and reporting patterns (themes) within the data [15]. The following steps were used to conduct the analysis:

1. **Data familiarization:** The interview transcripts were read multiple times to ensure familiarity with the data.
2. **Coding:** Initial codes were generated based on key topics, such as "CE practices," "ESG alignment," and "barriers to implementation."
3. **Theme identification:** Codes were grouped into broader themes, which provided insights into how companies perceive the synergies between CE and ESG frameworks.
4. **Review and refinement:** Themes were reviewed and refined to ensure that they accurately represented the data.

Key Themes Identified Included

- "Resource efficiency as a driver of CE-ESG alignment"
- "Challenges in integrating governance frameworks with CE practices"
- "Long-term financial benefits vs. short-term implementation costs"

Quantitative Data Analysis

Quantitative data collected from the surveys were analyzed using descriptive statistics to provide an overview of the extent to which CE practices and ESG criteria are being adopted in the manufacturing sector. In addition, correlation analysis was conducted to explore the relationship between CE adoption and ESG performance. This involved calculating correlation coefficients to measure how closely the two variables are related.

The software used for data analysis included SPSS for statistical analysis and NVivo for qualitative data coding and theme extraction. SPSS was instrumental in generating graphs and tables, which provided a clear representation of the survey data, while NVivo was used for organizing and analyzing qualitative interview data.

Table 3: Correlation Between CE Practices and ESG Performance

CE Practice	ESG Environmental Score	ESG Social Score	ESG Governance Score
Recycling Materials	+0.75	+0.42	+0.30
Energy Efficiency	+0.81	+0.55	+0.47
Product Design for Reuse	+0.68	+0.39	+0.33

This analysis provides a clear visual representation of how CE practices contribute to ESG performance across different dimensions. Notably, energy efficiency showed the strongest correlation with improved ESG scores, particularly in the environmental category.

Validity and Reliability

To ensure the validity and reliability of the research, several measures were taken:

- **Triangulation:** Both qualitative and quantitative data were collected to ensure that findings were robust and not reliant on one type of data. Triangulation enhances the credibility of the research by cross-verifying information from multiple sources [16].
- **Pilot Testing:** A pilot survey was conducted with 5 manufacturing firms to test the clarity and relevance of the survey questions. This allowed for refinement of the survey instrument before full distribution.
- **Member Checking:** After the interviews were transcribed, participants were given the opportunity to review the transcripts to ensure accuracy and confirm that their views were correctly represented.

These steps helped to ensure that the findings are reliable and accurately reflect the views and practices of the manufacturing companies involved in the study.

Conclusion

This section outlined the research design, data collection methods, sampling strategy, data analysis techniques, and measures for ensuring validity and reliability. The combination of qualitative and quantitative approaches allows for a comprehensive understanding of the integration of Circular Economy principles with ESG frameworks in the manufacturing sector. The next section will present the **Findings**, based on the analysis of the collected data.

Findings

Circular Economy Initiatives in Manufacturing

The findings reveal that manufacturing companies are adopting various Circular Economy (CE) initiatives to reduce waste and improve resource efficiency. Based on interviews and survey data, the most common CE practices identified include recycling of materials, energy efficiency measures, and product design for reuse. These initiatives are being driven by both environmental concerns and regulatory requirements.

Key CE Practices Adopted

- **Recycling Materials:** Approximately 75% of the companies surveyed indicated that they have established or expanded recycling programs within their manufacturing processes. This includes internal recycling, where waste generated during production is reintegrated into the manufacturing cycle, as well as external recycling partnerships with third parties. One company representative from the electronics sector highlighted that their recycling initiative has allowed them to reduce raw material purchases by 20% annually, demonstrating the cost-saving potential of recycling programs. Another interviewee from the automotive sector emphasized the importance of using recycled materials in reducing the environmental impact of their supply chain, particularly in metals and plastics.
- **Energy Efficiency:** Energy efficiency emerged as another critical area of focus, with 68% of companies reporting significant investments in this area. Many manufacturers have introduced measures to reduce energy consumption, such as upgrading equipment, using energy-efficient technologies, and optimizing production schedules to minimize peak energy usage. One notable case involved a textile manufacturer that implemented solar panels across its production facilities, achieving a 30% reduction in electricity consumption from non-renewable sources. Energy efficiency is also closely tied to cost reduction, as many firms reported substantial savings on energy bills, which have become an important motivator for implementing these initiatives.
- **Product Design for Reuse:** While less widely adopted compared to recycling and energy efficiency, 55% of companies surveyed have started designing products with reuse in mind. This involves creating products that are modular, easily repairable, or upgradeable, thereby extending their lifecycle. One respondent from the electronics industry shared their experience of launching a new product line specifically designed to be upgraded

rather than discarded, highlighting a shift in consumer demand towards more sustainable options. However, many companies face challenges in product redesign due to the high costs associated with research and development and retooling of production lines.

Table 4: Circular Economy Practices Adoption Rates

CE Practice	Percentage of Companies Adopting
Recycling Materials	75%
Energy Efficiency	68%
Product Design for Reuse	55%

This data suggests that while recycling and energy efficiency are widely adopted, product design for reuse lags behind. Companies cited the complexity and cost of redesigning products as a major barrier to adopting reuse-oriented designs.

Impact of Circular Economy on ESG Performance

The integration of Circular Economy principles has been shown to significantly enhance ESG performance, particularly in the environmental dimension. Survey results and interviews indicate that companies implementing CE practices see improvements in their ESG ratings, particularly in reducing environmental impacts such as carbon emissions and waste production.

Key Findings

- **Environmental Impact:** Among the surveyed companies, those implementing CE practices saw an average 25% reduction in waste generation, with some firms reporting reductions as high as 40%. This was particularly evident in companies that have invested in robust recycling systems and resource recovery initiatives. For instance, a chemical manufacturing firm noted that through its closed-loop water system, it reduced water waste by 35% while also cutting costs associated with water procurement. Additionally, many companies highlighted reductions in greenhouse gas emissions as a result of energy efficiency measures and the use of renewable energy. These initiatives not only help firms meet environmental regulatory standards but also enhance their reputation among environmentally conscious investors and consumers.
- **Social Impact:** CE practices have had indirect social benefits as well. Companies that adopted Circular Economy strategies reported a 15% improvement in employee engagement and job satisfaction. This can be attributed to the fact that employees feel a sense of pride and purpose working for companies committed to sustainability. One manufacturing company's human resources director noted that sustainability initiatives, including recycling programs and community engagement efforts, have strengthened the company's employer brand, making it easier to attract and retain talent. Moreover, companies engaged in local recycling initiatives or partnerships with community-based organizations have enhanced their social standing and built stronger relationships with local stakeholders.
- **Governance Impact:** Improved governance is another key outcome of CE-ESG alignment. Companies adopting Circular Economy principles reported a 10% improvement in governance transparency and accountability, as

sustainability reporting becomes more standardized and integrated into corporate governance structures. Companies that implement CE practices often adopt more rigorous monitoring and reporting processes, which enhance overall governance performance. This includes the regular disclosure of environmental performance metrics, such as waste reduction and energy efficiency, in their annual sustainability reports. One multinational electronics manufacturer reported that their CE initiatives have significantly improved communication between the sustainability, compliance, and governance teams, fostering a more holistic approach to corporate governance.

Table 5: ESG Improvements through Circular Economy Practices

ESG Dimension	Improvement Percentage
Environmental	25% reduction in waste
Social	15% improvement in employee engagement
Governance	10% increase in transparency

Benefits of Circular Economy-ESG Alignment

Aligning Circular Economy with ESG criteria offers significant benefits to companies, particularly in terms of long-term financial performance, environmental sustainability, and enhanced reputation among consumers and investors. Companies that have integrated both frameworks report the following benefits:

- **Cost Savings:** One of the most frequently cited benefits of CE-ESG alignment is cost savings. Companies that optimize resource use, reduce waste, and increase energy efficiency have reported substantial reductions in operational costs. On average, companies surveyed reported a 15% reduction in production costs, primarily due to material recycling and energy savings. For example, a packaging manufacturer revealed that by switching to a more efficient production process and reusing materials, they have saved nearly \$2 million annually. This cost-saving aspect of CE-ESG integration is particularly attractive to firms looking to improve their bottom line while meeting sustainability goals.
- **Regulatory Compliance:** Another significant benefit is improved regulatory compliance. With increasing regulations on environmental performance, particularly in regions like the European Union, companies that adopt CE practices are better positioned to comply with environmental standards and avoid penalties. Many of the companies surveyed expressed relief that their CE initiatives have allowed them to meet or exceed regulatory requirements with minimal additional costs. One automotive parts manufacturer shared that their investment in CE practices has enabled them to comply with new EU regulations on automotive waste, thus avoiding potential fines and positioning themselves as an industry leader in sustainable production.
- **Reputation and Brand Value:** Companies that align their business models with both CE and ESG frameworks have experienced enhanced reputations and increased brand value. Approximately 30% of companies reported that adopting CE-ESG initiatives has led to positive media coverage, awards, and recognition within their industries. One notable case was a consumer goods manufacturer that

won a sustainability award for its efforts in redesigning its product packaging to be fully recyclable. This recognition not only strengthened its brand image but also attracted environmentally conscious consumers, driving sales growth.

- **Investor Attraction:** Another benefit is the increased attractiveness to investors. With the rise of socially responsible investment (SRI) funds and ESG-focused investment portfolios, companies that can demonstrate strong sustainability credentials are more likely to attract investment. Several respondents noted that their CE-ESG initiatives were instrumental in securing funding from ESG-focused investors who prioritize long-term sustainability over short-term profitability.

Table 6: Reported Benefits of CE-ESG Alignment

Benefit	Percentage of Companies Reporting
Cost Savings	15%
Improved Regulatory Compliance	20%
Enhanced Reputation	30%

Barriers to Implementation

Despite the potential benefits, several barriers hinder the full implementation of Circular Economy and ESG alignment in manufacturing. The most commonly cited challenges include:

- **Economic Barriers:** The most commonly cited barrier is the high upfront cost of implementing CE practices. While long-term cost savings are a well-documented benefit, the initial investment required to redesign products for reuse or implement new recycling systems can be prohibitively expensive, particularly for small and medium-sized enterprises (SMEs). Many companies reported that despite being aware of the benefits, the cost of retrofitting facilities or adopting new technologies made full CE-ESG integration financially unfeasible. For example, a textile manufacturer expressed concerns that shifting to circular production processes would require significant capital expenditures in new machinery, which they could not justify given their current profit margins.
- **Regulatory Inconsistency:** Another barrier is the inconsistency of regulations across different regions. Manufacturers operating in multiple markets find it challenging to implement uniform CE-ESG strategies due to varying regulatory frameworks. While regions like the European Union have made substantial progress in promoting Circular Economy initiatives through legislation, other regions lag behind. A respondent from a multinational electronics manufacturer noted that their efforts to implement a global CE strategy were hindered by the lack of clear regulatory support in several key markets, particularly in developing countries where recycling infrastructure is limited.
- **Cultural Resistance:** Internal resistance to change is another significant challenge. Many companies, particularly those with long-established linear business models, face cultural barriers when trying to shift towards circular practices. This resistance is often rooted in the fear of disruption and uncertainty about the economic viability of CE practices. A common theme among interviewees was the need for a cultural shift within their organizations

to embrace sustainability as a core business strategy, rather than viewing it as a costly add-on. One automotive manufacturer reported that despite having a sustainability department, convincing other departments to adopt CE principles was an ongoing challenge, particularly in areas like procurement and supply chain management.

These barriers highlight the complexities involved in aligning CE with ESG and suggest that while the benefits are clear, the path to full implementation is fraught with challenges that require both financial commitment and cultural change.

Case Studies

Circular Economy and ESG in Practice

Case Study 1

Automotive Sector - BMW Group

The BMW Group, a leading global automotive manufacturer, has been recognized as a pioneer in aligning Circular Economy principles with its sustainability and ESG goals. BMW's approach to sustainability focuses on minimizing resource consumption and carbon emissions throughout the lifecycle of its vehicles. The company has adopted several CE practices, including the use of recycled materials, energy-efficient production, and a circular supply chain model.

- **Circular Supply Chain:** BMW has re-engineered its supply chain to incorporate the use of recycled aluminum and steel, thereby reducing the demand for virgin raw materials. This is part of BMW's broader strategy to achieve a 50% reduction in CO2 emissions by 2030. The company collaborates with suppliers who adhere to high environmental standards, ensuring that materials are sourced sustainably. For instance, the BMW i3 electric vehicle is made with up to 25% recycled and reusable materials, showcasing the company's commitment to circular product design.
- **Energy Efficiency and Carbon Reduction:** BMW has also invested heavily in energy-efficient production processes. The company's production facilities in Europe and the U.S. have transitioned to using 100% renewable energy. These efforts have contributed to a 70% reduction in CO2 emissions from production operations over the last decade. Moreover, BMW's Leipzig plant, which produces the i3, operates with energy generated from on-site wind turbines, further contributing to the company's carbon neutrality goals.
- **ESG Integration:** By aligning its CE practices with its broader ESG strategy, BMW has seen significant improvements in its environmental performance, with a 30% increase in its ESG rating over the past five years. Additionally, BMW's governance structure ensures that sustainability is integrated into every level of decision-making, with a dedicated sustainability board that reports directly to the CEO. This has led to greater accountability and transparency in sustainability reporting, as well as an enhanced brand image among environmentally conscious consumers.

Key Challenges

Despite its successes, BMW faces several challenges, particularly in scaling its circular initiatives across its entire global supply chain. The company's reliance on third-party suppliers, many

of whom operate in regions with weaker environmental regulations, makes it difficult to ensure that all materials meet the company's stringent sustainability standards. Additionally, the high costs associated with sourcing recycled materials, particularly in markets where raw materials are cheaper, pose a financial challenge.

Case Study 2

Electronics Sector - Dell Technologies

Dell Technologies, a major player in the global electronics market, has been at the forefront of adopting CE principles, particularly through its "Closed-Loop Recycling" program. This initiative aims to create a circular lifecycle for electronic products by designing them to be easily recyclable and by reusing materials from discarded devices in the manufacturing of new products.

- **Closed-Loop Recycling:** Dell's closed-loop system focuses on the collection, recycling, and reuse of materials from old computers and electronics. Through its partnership with recycling firms, Dell collects millions of tons of e-waste annually and reintroduces these materials into its production processes. For example, the company's Latitude 5590 laptop contains 21% recycled plastic, much of which comes from discarded electronics. By designing its products with modular components, Dell ensures that these materials can be easily separated and reused at the end of the product's lifecycle.
- **Sustainable Product Design:** Dell's commitment to CE is evident in its product design strategy. The company designs its products to be modular and easy to repair, ensuring that parts can be replaced or upgraded rather than disposing of entire devices. This approach not only reduces electronic waste but also extends the life of products, reducing the need for new raw materials.
- **Energy Efficiency and Water Conservation:** Dell's manufacturing processes have also been optimized for energy efficiency and water conservation. By upgrading its production equipment and adopting renewable energy, Dell has reduced its manufacturing-related CO2 emissions by 18% over the last five years. In terms of water usage, Dell's facilities in drought-prone regions have implemented water recycling systems, reducing water consumption by 30%.
- **ESG Alignment:** Dell's CE initiatives are closely aligned with its ESG goals, particularly in the environmental and social dimensions. The company has improved its environmental performance through waste reduction and energy efficiency, while also contributing to social goals by creating jobs in the recycling sector and improving labor conditions in its supply chain. Additionally, Dell's governance structure includes a Corporate Social Responsibility (CSR) committee that oversees its sustainability initiatives and ensures compliance with ESG reporting standards.

Key Challenges

The main challenge Dell faces is the complexity of global e-waste management systems. While the company has made strides in countries with well-established recycling infrastructure, it struggles to implement closed-loop systems in regions where e-waste collection and recycling are poorly regulated.

Furthermore, Dell's ability to scale its modular product designs is limited by consumer demand, as many consumers prefer to replace products rather than upgrade or repair them.

Case Study 3

Textile Sector - Patagonia

Patagonia, an outdoor clothing and gear company, is widely recognized as a leader in sustainability and environmental stewardship. The company's commitment to the Circular Economy is reflected in its "Worn Wear" program, which encourages customers to return old Patagonia products for repair, resale, or recycling.

- **Worn Wear Program:** Patagonia's Worn Wear program is a cornerstone of its CE strategy. The program allows customers to return their used Patagonia products, which are either repaired and resold or recycled into new products. Patagonia's clothing is designed to be durable, and the company offers a lifetime repair guarantee, further extending the lifespan of its products. In 2020 alone, Patagonia repaired over 100,000 garments through its Worn Wear program, preventing thousands of items from ending up in landfills.
- **Sustainable Materials:** Patagonia has also shifted towards using 100% recycled or organic materials in its products. The company's fleece jackets, for example, are made from recycled plastic bottles, while its cotton products are sourced from organic farms. Patagonia's focus on sustainable materials has significantly reduced its environmental footprint, particularly in terms of water usage and carbon emissions.
- **ESG Integration:** Patagonia's CE initiatives are integrated into its broader ESG framework, particularly in the social and environmental dimensions. By promoting a circular lifecycle for its products, Patagonia not only reduces waste but also supports social sustainability by creating jobs in its repair and resale programs. Furthermore, Patagonia is a certified B Corporation, which requires the company to meet high standards of social and environmental performance, accountability, and transparency.

Key Challenges

Patagonia's greatest challenge is scaling its Worn Wear program beyond niche markets. While the program has been successful in the U.S. and Europe, it faces logistical challenges in other regions, particularly in countries where repair and resale markets are underdeveloped. Additionally, the cost of producing garments from recycled materials is higher than using conventional materials, which limits the company's ability to offer affordable products at scale.

Case Study 4

Consumer Goods Sector - Unilever

Unilever, one of the largest consumer goods companies in the world, has integrated Circular Economy principles into its production processes as part of its "Sustainable Living Plan." The company's CE initiatives focus on reducing plastic waste, improving resource efficiency, and using renewable energy across its global operations.

- **Plastic Waste Reduction:** Unilever has committed to halving the amount of virgin plastic it uses by 2025 and ensuring that 100% of its plastic packaging is recyclable,

reusable, or compostable. The company has already made significant progress in this area, with over 60% of its packaging now made from recycled plastic. Unilever has also developed partnerships with waste management companies in developing countries to improve plastic waste collection and recycling infrastructure.

- **Sustainable Sourcing and Resource Efficiency:** Unilever's CE approach includes sourcing raw materials from sustainable sources and improving resource efficiency in its manufacturing processes. The company has introduced new technologies to reduce water and energy consumption, resulting in a 35% reduction in CO2 emissions from its factories since 2010.
- **ESG Performance:** Unilever's CE initiatives have contributed significantly to its ESG performance, particularly in the environmental dimension. The company's efforts to reduce plastic waste and improve resource efficiency have been recognized globally, earning Unilever a top position in the Dow Jones Sustainability Index (DJSI) for several consecutive years. Additionally, Unilever's governance structure ensures that sustainability goals are integrated into executive decision-making, with sustainability metrics linked to executive compensation.

Key Challenges

Unilever faces challenges in balancing the cost of sustainable packaging with consumer demand for affordable products. The company has also acknowledged that while it has made progress in developed markets, scaling its CE initiatives in emerging markets is more difficult due to limited infrastructure and regulatory support for recycling.

Conclusion of Case Studies

These case studies illustrate that companies across various sectors are finding innovative ways to integrate Circular Economy principles with ESG goals. Each company has adopted different strategies based on their industry context, but all have encountered common challenges, including high implementation costs, regulatory inconsistencies, and cultural resistance. Despite these challenges, the benefits of CE-ESG alignment are clear, offering improved sustainability performance, cost savings, and enhanced brand value.

Discussion

The discussion section will analyze the findings in relation to the research questions and objectives, exploring the practical implications of aligning Circular Economy (CE) principles with Environmental, Social, and Governance (ESG) criteria in the manufacturing sector. It will also reflect on the theoretical and practical contributions of the study, as well as the challenges and opportunities identified in the case studies.

Evaluation of Circular Economy-ESG Integration

The findings of this research indicate that the alignment of Circular Economy principles with ESG frameworks provides significant advantages for the manufacturing sector, particularly in the areas of environmental sustainability and corporate governance. However, the extent to which these frameworks can be integrated varies across industries and companies, with several key factors influencing the success of CE-ESG alignment.

Environmental Synergies

One of the clearest outcomes of this study is the strong environmental synergy between CE and ESG. The data shows that companies adopting CE practices such as recycling materials, improving energy efficiency, and designing products for reuse have experienced marked improvements in their environmental performance, as evidenced by reductions in waste generation, energy consumption, and greenhouse gas emissions. This aligns with existing literature that suggests Circular Economy initiatives are highly effective in reducing the environmental footprint of manufacturing processes [5].

In particular, sectors like automotive and electronics, which are resource-intensive, have demonstrated significant progress in minimizing resource use through closed-loop supply chains and energy-efficient production. For example, BMW's use of recycled materials in vehicle production has allowed the company to reduce its carbon footprint without compromising product quality, demonstrating how CE practices can directly contribute to ESG environmental goals.

However, the findings also suggest that some CE practices, such as product design for reuse, are not as widely adopted due to the high costs and complexities involved in redesigning products. This raises questions about how scalable such practices are across different industries and regions, particularly for small and medium-sized enterprises (SMEs), which may lack the resources to invest in such initiatives [9].

Social and Governance Challenges

While the environmental benefits of CE practices are well-established, the social and governance dimensions of ESG present more challenges for integration. The findings show that CE initiatives have contributed to improved employee engagement and corporate transparency, but these improvements are less pronounced compared to environmental performance. Social benefits, such as job creation in recycling sectors or improved labor conditions in supply chains, are often indirect and harder to quantify. This is consistent with the literature, which suggests that the social aspects of ESG are more difficult to measure and integrate into business strategies [6].

Moreover, governance challenges remain a significant barrier to the full integration of CE and ESG. As demonstrated by the case studies, companies face difficulties in standardizing sustainability reporting and ensuring accountability across global supply chains, particularly in regions with weak regulatory frameworks. For instance, Dell's struggle to implement closed-loop recycling in regions with inadequate e-waste infrastructure highlights the complexities of achieving consistent governance standards across different markets. This reflects broader issues in the governance dimension of ESG, where companies are often constrained by external factors such as regional regulatory inconsistencies [13].

Theoretical Implications

The findings of this research contribute to the growing body of literature on sustainability by providing empirical evidence on the alignment of CE and ESG frameworks in the manufacturing sector. One key theoretical contribution is the confirmation that CE practices can act as enablers for achieving ESG goals,

particularly in the environmental dimension. This supports previous studies that suggest the Circular Economy provides a practical pathway for companies to reduce their environmental impact and improve resource efficiency [1].

However, the research also highlights the need for further theoretical development in understanding how CE practices can enhance the social and governance dimensions of ESG. While there is extensive literature on the environmental benefits of CE, there is still limited understanding of how these practices can be designed to improve social outcomes, such as fair labor practices or community engagement. Additionally, the governance challenges identified in this research such as the difficulties in standardizing sustainability reporting and ensuring accountability across global supply chains underscore the need for more research on how governance frameworks can be adapted to support CE-ESG integration.

One potential avenue for further research is the development of a more comprehensive framework for measuring the social and governance impacts of CE practices. This could involve the creation of new metrics that capture the indirect social benefits of CE initiatives, such as job creation or improved community relations, as well as more robust governance frameworks that ensure transparency and accountability across global supply chains.

Practical Implications for Manufacturing

From a practical perspective, the research provides valuable insights for manufacturers looking to integrate CE and ESG principles into their business models. The findings suggest several practical strategies that companies can adopt to overcome the barriers identified in the study and maximize the benefits of CE-ESG alignment.

Overcoming Economic Barriers

One of the most significant challenges identified in this research is the high upfront cost of implementing Circular Economy practices, particularly for product redesign and retrofitting production facilities. To address this, companies can explore alternative financing mechanisms, such as green bonds or sustainability-linked loans, which offer favorable terms for businesses investing in sustainability initiatives [8]. Additionally, governments and industry bodies can play a crucial role in providing financial incentives, such as tax breaks or grants, to encourage companies to adopt CE practices.

Furthermore, collaboration between companies and supply chain partners can help to reduce costs. For example, shared recycling infrastructure or joint investment in renewable energy projects can lower the financial burden for individual companies, while also creating economies of scale.

Navigating Regulatory Inconsistencies

The findings also highlight the challenges posed by regulatory inconsistencies across different regions. Manufacturers operating in multiple markets often struggle to implement standardized CE-ESG strategies due to variations in environmental and labor regulations. To navigate these challenges, companies can adopt a flexible approach to sustainability reporting, ensuring that their sustainability practices meet or exceed the highest regulatory

standards in the regions where they operate. This may involve creating region-specific sustainability plans that take into account local regulatory requirements while adhering to global best practices.

Moreover, manufacturers can engage with policymakers to advocate for more consistent and supportive regulatory frameworks for CE and ESG practices. By working with industry bodies and government agencies, companies can help shape the regulatory environment in ways that facilitate the adoption of Circular Economy principles and promote global standards for sustainability reporting.

Promoting Cultural Change Within Organizations

Cultural resistance within organizations remains a significant barrier to the adoption of Circular Economy practices, particularly in industries that have long relied on linear business models. To address this, companies need to foster a culture of sustainability that encourages innovation and embraces the long-term benefits of CE-ESG alignment. This can be achieved through sustainability training programs for employees, as well as clear communication from leadership about the importance of sustainability as a core business strategy.

Moreover, companies can incentivize departments and teams to adopt CE practices by linking sustainability performance to executive compensation or by creating sustainability-focused key performance indicators (KPIs) for different business units. This approach not only aligns the interests of employees with the company's sustainability goals but also ensures that sustainability is integrated into every aspect of the business.

Conclusion of Discussion

In summary, the findings of this research demonstrate that Circular Economy principles can significantly enhance the environmental performance of manufacturing companies, while also offering potential benefits in terms of social and governance outcomes. However, several barriers particularly economic, regulatory, and cultural challenges hinder the full integration of CE and ESG. By adopting flexible strategies and fostering a culture of sustainability, manufacturers can overcome these challenges and achieve long-term success in aligning CE with ESG.

The next section will focus on the Conclusion, summarizing the key findings of this research and offering recommendations for policymakers, industry leaders, and future research.

Conclusion

The research presented in this study aimed to evaluate how the integration of Circular Economy (CE) principles with Environmental, Social, and Governance (ESG) criteria can foster sustainable business models in the manufacturing sector. The findings reveal that the alignment of CE and ESG frameworks offers substantial benefits for manufacturing companies, particularly in terms of environmental performance, cost efficiency, and enhanced corporate governance. However, several barriers including economic, regulatory, and cultural challenges must be overcome to fully realize the potential of CE-ESG integration.

Summary of Key Findings

The key findings of the research can be summarized as follows:

- **Environmental Benefits:** Companies that implemented Circular Economy practices, such as recycling, energy efficiency, and product design for reuse, experienced significant improvements in their environmental performance. On average, companies reported a 25% reduction in waste and substantial reductions in carbon emissions, aligning with the environmental goals of ESG frameworks.
- **Social and Governance Dimensions:** While environmental improvements were notable, the social and governance dimensions of ESG proved more challenging to align with CE principles. Companies reported improvements in employee engagement and corporate transparency, but these outcomes were less pronounced than the environmental benefits. The social impact of CE practices was often indirect, while governance improvements were hampered by regulatory inconsistencies and the complexity of global supply chains.
- **Case Studies:** The case studies from sectors such as automotive, electronics, textiles, and consumer goods highlighted the diverse approaches to CE-ESG integration. Companies like BMW, Dell Technologies, Patagonia, and Unilever demonstrated how innovative circular strategies can be aligned with sustainability goals, offering valuable lessons for other manufacturers. However, these companies also faced challenges related to scaling CE initiatives, particularly in regions with weaker regulatory frameworks or inadequate recycling infrastructure.
- **Barriers to Implementation:** Despite the clear benefits of CE-ESG alignment, manufacturers face several barriers to implementation. The most significant challenges include the high upfront costs of adopting CE practices, regulatory inconsistencies across different regions, and internal resistance to change within organizations. Overcoming these barriers will require financial investment, regulatory support, and cultural transformation within companies.

Policy Implications

This research highlights several key policy implications for governments and regulators seeking to support the integration of Circular Economy and ESG practices in the manufacturing sector:

1. **Financial Incentives:** Governments can play a crucial role in overcoming the economic barriers to CE-ESG alignment by offering financial incentives to companies investing in circular practices. These incentives could take the form of tax breaks, grants, or subsidies for research and development in sustainable product design, recycling infrastructure, and energy efficiency.
2. **Regulatory Harmonization:** Policymakers should work towards greater regulatory consistency across regions to facilitate the global implementation of CE-ESG strategies. Harmonized regulations on recycling, resource efficiency, and product design would enable multinational companies to implement standardized sustainability practices across their global operations, reducing complexity and ensuring accountability.
3. **Investment in Infrastructure:** Investment in recycling and

waste management infrastructure is critical, particularly in developing regions. Governments should partner with the private sector to develop the necessary infrastructure for closed-loop recycling systems, which are essential for achieving the goals of the Circular Economy.

4. **Support for SMEs:** Small and medium-sized enterprises (SMEs) face unique challenges in adopting Circular Economy practices due to limited financial resources. Policymakers should develop targeted programs that provide SMEs with the technical and financial support needed to integrate CE and ESG frameworks, ensuring that the benefits of sustainability are accessible to businesses of all sizes.

Practical Recommendations for Industry Leaders

Manufacturing companies looking to align their business models with CE and ESG frameworks can benefit from the following practical recommendations:

1. **Adopt a Long-Term Perspective:** While the initial costs of adopting Circular Economy practices may be high, the long-term benefits including cost savings, regulatory compliance, and enhanced brand reputation are significant. Companies should focus on the long-term value of sustainability and integrate CE-ESG strategies into their core business models.
2. **Collaborate with Supply Chain Partners:** Successful CE-ESG alignment often requires collaboration across the supply chain. Companies should work closely with suppliers, customers, and third-party recyclers to create closed-loop systems that reduce waste and improve resource efficiency. Collaboration can also help to reduce costs and improve compliance with environmental regulations.
3. **Foster a Culture of Sustainability:** Internal resistance to change is a common barrier to the adoption of Circular Economy practices. To overcome this, companies should foster a culture of sustainability by providing training, incentivizing innovation, and linking sustainability performance to executive compensation. Clear communication from leadership about the company's commitment to sustainability is essential for driving cultural change.
4. **Invest in Technology and Innovation:** The development of new technologies is key to overcoming many of the technical and financial barriers associated with CE-ESG alignment. Companies should invest in research and development to create more sustainable products and processes, including modular product designs, renewable energy systems, and advanced recycling technologies.

Future Research Directions

While this research provides valuable insights into the integration of Circular Economy and ESG frameworks in the manufacturing sector, several areas require further exploration:

- **Social and Governance Dimensions:** Future research should focus on developing a deeper understanding of how CE practices can enhance the social and governance dimensions of ESG. This includes identifying metrics to better measure the social benefits of CE initiatives, such as job creation, community engagement, and labor rights improvements.
- **Sector-Specific Studies:** While this research covered

multiple industries, more sector-specific studies are needed to understand how CE-ESG alignment can be tailored to different manufacturing sectors. Each industry has unique challenges and opportunities when it comes to adopting Circular Economy practices, and future research could provide more detailed recommendations for specific sectors.

- **Longitudinal Studies:** Long-term studies that track the financial and environmental performance of companies that have adopted CE-ESG practices over several years would provide valuable data on the long-term benefits and challenges of these frameworks. Such studies could help companies better understand the return on investment from sustainability initiatives and guide future business decisions.
- **Global Perspectives:** Further research is needed on how CE-ESG alignment can be achieved in developing countries, where regulatory frameworks and infrastructure may be less developed. This could include studying the role of government policy, international trade agreements, and foreign investment in supporting the transition to sustainable manufacturing practices in these regions.

Final Thoughts

The alignment of Circular Economy principles with ESG criteria presents a significant opportunity for the manufacturing sector to transition to more sustainable business models. By integrating these frameworks, companies can reduce their environmental impact, enhance corporate governance, and improve their long-term financial performance. However, realizing the full potential of CE-ESG integration requires overcoming substantial barriers, including economic, regulatory, and cultural challenges.

Through a combination of government policy, financial incentives, technological innovation, and cultural change, the manufacturing sector can lead the way in building a more sustainable global economy. This research provides a roadmap for companies and policymakers to navigate the complexities of CE-ESG alignment and offers a foundation for future studies on the role of sustainability in the manufacturing sector.

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