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# Policy Instruments for Circular Economy Transition in the Manufacturing Sector

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**ABSTRACT:** This study assesses the efficiency of policy measures - regulatory, economic, informational, and voluntary in supporting the circular economy initiatives in the manufacturing industry. Through a qualitative lens, it leverages sustainability transitions theory, institutional theory, and policy implementation theory to implement a comprehensive theoretical framework. Through this systematic literature review and analysis of eleven cases drawn from various manufacturing contexts, the study finds that integrated policy mixes, especially those comprising of regulatory and economic instruments, improve the implementation of circular practices. Also, the study identifies implementation challenges that include global supply chain complexities and potential rebound effects. In view of these findings, it is imperative that sectoral policies should be formulated with a view to removing various barriers and encouraging international collaboration. Overall, the research includes an array of strategic suggestions for the use of digital technologies and the promotion of new circular economy business models, hence offering a wealth of information relevant to policymakers designing the appropriate circular economy strategies for boosting sustainability in manufacturing. Furthermore, the study also reveals potential opportunities for innovative policy approaches and growth, more specifically in leveraging digital technologies and supporting new circular business models. Consequently, the study provides recommendations to various players across the manufacturing landscape, with recommendations for policymakers including the development of comprehensive policy packages, addressing sector-specific barriers, and fostering international cooperation. Holistically, this study contributes to the growing body of knowledge on circular economy implementation across manufacturing industries, and provides practical insights for policy design and implementation.

**KEYWORDS:** Circular economy, policy instruments, manufacturing, sustainability, regulatory frameworks, economic incentives, digital technologies.

## I. LITERATURE REVIEW

### 1.1 The Circular Economy Concept

The circular economy (CE) exists as a sustainable replacement to the more well-known 'take-make-dispose' linear economy (LE) model, which has championed economic growth, albeit posing significant environmental threat (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2013). The CE model's aim is to alienate resource use from economic activity, fostering reuse, recycling, and waste moderation. As Korhonen et al. (2018) astutely observed, the CE concept is fundamentally rooted in several schools of thought, namely industrial ecology, cradle-to-cradle design, and biomimicry. In the context of manufacturing, CE principles serve as a contrary position to the traditional linear model of production and consumption, suggesting an opposing system that prioritizes the longevity, reuse, and recycling of materials and products.

Interestingly, despite CE's continuous acceptance amongst critics and professionals alike, its practical implementation in manufacturing remains a thing of scattered fragments, not gaining the necessary implementation. A comprehensive study by Kristensen and Mosgaard (2020) reveals that while many manufacturers express interest in CE principles, the actual adoption of circular practices often falls short of aspirations. Their work suggests that there exists a gap between interest and implementation, further establishing that the gap actually may be due to complexities between factors like technological, economic, and regulatory factors.

Also, it has been established that the application of CE in manufacturing varies across subsectors. In their groundbreaking analysis, Kalmykova et al. (2018) demonstrated how CE strategies exhibit significantly different characteristics between industries, for example, the electronics and textile sectors. In this heterogeneity, a unique

challenge exists that make implementation difficult for policymakers who aim to devise holistic instruments that may be applicable for CE transition.

### 1.2 Policy Instruments for Circular Economy

Policy instruments, within the scope of circular economy transition, may be broadly categorized into four types, namely:

- Regulatory
- Economic
- Informational
- Voluntary

The aforementioned categorization, first proposed by Bemelmans-Videc et al. (2011) and later adapted for CE by Milios (2018), serves an astute framework for understanding the tools policymakers make use of.

- Regulatory instruments, often referred to as "command-and-control" measures, are means of establishing direct regulations through laws and standards. In the more specific context of CE, regulatory instruments may include mandates for recycled content in products, bans on certain single-use items, etc.
- Economic instruments, on the other hand, employ financial incentives or disincentives to craft behavioral regulations. It may include taxes on virgin materials, subsidies for recycling infrastructure, and more.
- Informational instruments, in their own categorization, primarily uses education, enlightenment, and raising awareness as tools to influence behavior. Their examples may include labeling schemes, public information campaigns about CE practices, use of social media for CE promotional campaigns, etc.
- Voluntary instruments use the willingness of businesses to exceed regulatory requirements, often in exchange for recognition or other non-financial benefits.

Interestingly, a recent work by Domenech and Bahn-Walkowiak (2019) suggests an efficient policy approach. They opined that a mix of the four instrument types often provide the most efficient actions and results, when implemented with the specificity of industry and location. In their study, they specifically targeted CE policies across the EU, and they unearthed a trend that identifies integrated policy packages that combine multiple instrument types.

Table 1.1: Policy Instruments for Circular Economy Transition Across the Manufacturing Value Chain. This matrix is a comprehensive overview of regulatory, economic, information-based, and voluntary policy instruments applicable at different stages of the manufacturing process to promote circular economy principles.

Policy Type	Raw Material Extraction	Design	Production	Distribution	Use	End-of-Life
Regulatory Instruments	Resource extraction quotas	Eco-design regulations	Emission standards	Transportation regulations	Product safety standards	Waste management laws
Economic Instruments	Material taxes	R&D subsidies	Tax incentives for cleaner production	Carbon pricing for logistics	Tax breaks for repair services	Recycling subsidies
Information-based Instruments	Resource depletion indicators	LCA databases	Cleaner production guidelines	Carbon footprint labeling	Product use instructions	Recycling information
Voluntary Agreements	Sustainable sourcing commitments	Industry design standards	Green manufacturing alliances	Sustainable logistics initiatives	Product stewardship programs	Take-back programs

### 1.3 Challenges in Implementing Circular Economy Policies

The implementation of CE policies in manufacturing has been plagued with a number of challenges. One very significant challenge, as highlighted by Kirchherr et al. (2018), is the fact that many manufacturing supply chains are global in nature. In their work, it was revealed that some policies may be implemented in one jurisdiction and the same may be undermined in other parts of the supply chain, due to a lack of similar measures there.

Another notable challenge lies in the potential for unintended consequences of employed policies. A thought-provoking study by Zink and Geyer (2017) warns of the possibility of a "rebound effect," where improved resource efficiency may lead to increased consumption, potentially negating the environmental benefits of CE practices.

Notwithstanding, opportunities exist amidst these challenges, that may give room for innovative ideas that will promote growth in policy design. A good example may be identified in the work of Bocken and Short (2016) on "circular business models" which opines that the attainment of proactive transition to CE in manufacturing can be achieved through policies that support new forms of value creation and capture.

### 1.4 Theoretical Perspectives on Policy Effectiveness

This study's theoretical foundation is drawn from several integrated theories that offer a theoretical approach toward the analysis of circular economy policies in the manufacturing industry. Drawing on sustainability transitions, institutional theory, as well as policy implementation theory, the theoretical framework provides a comprehensive framework for analyzing circular economy initiatives.

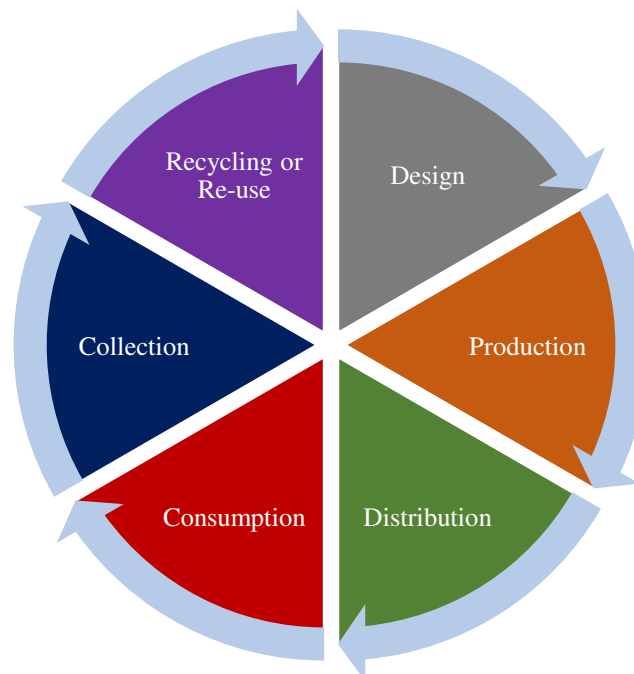
The primary paradigm that guides this research is the sustainability transitions theory, which show how transformation takes place in socio-technical systems to more sustainable pathways of production and consumption (Geels, 2011). The multi-level perspective (MLP) within this theory is particularly relevant, as it distinguishes between three levels of analysis: Innovations in niches, socio-technical regimes and landscape transformation (Geels & Schot, 2007). Within the context of circular economy in manufacturing, the concept of niche innovations means that circular innovations are new practices and technologies developed in protected environments (Köhler et al., 2019).

In synergy with the sustainability transitions theory, the institutional theory, as opined by Scott (2008), focuses on how institutions shape behavior and decision-making. This theory is crucial for understanding the role of formal and informal institutions in facilitating or hindering the adoption of circular economy practices in manufacturing. Fuenfschilling and Truffer (2014) integrate institutional theory with the multi-level perspective, explaining how institutions shape socio-technical regimes.

The literature identifies the need for an integrated approach to CE policy implementation, considering sectoral and regional complexities. Building on these points, the study's methodology establishes how the systematic reviews of existing policies and case studies analyses provide targeted recommendations for manufacturing sectors. Despite the recorded advancements, existing research suggests that several challenges need to be addressed and further discoveries and implementations are still required to improve the integration of CE practices around world.

Figure 1.1: The Circular Economy in Manufacturing: A Paradigm Shift. The figure features two visuals representing the transition from the Linear Economy (LE) above to the Circular Economy (CE) below. The CE model emphasizes resource efficiency, waste reduction, and continuous material flows. Policy instruments (regulatory, economic, informational, and voluntary) play a crucial role in facilitating this transition, leading to benefits such as resource efficiency, waste reduction, economic growth, and innovation. Key benefits include Resource Efficiency, Waste Reduction, Economic Growth, and Innovation.





## **II.OBJECTIVES AND SIGNIFICANCE**

### **2.1 Study Objectives**

To facilitate and accelerate the proposed transition, policy instruments are important. Through these instruments, the right incentives can be created, barriers may be eliminated, and the regulatory landscape can be structured to support circular practices. Despite this, the manufacturing sector is rife with unique challenges for policy design and implementation due its complexities caused by its varying sub-sectors and global supply chains.

The aim of this study is to critically analyze the availability of policy instruments for the promotion of the transition to circular economy in the manufacturing sector. The objectives may be further highlighted within a threefold listing:

- To evaluate the effectiveness of different types of policy instruments – regulatory, economic, information-based, and voluntary – in promoting circular economy practices in manufacturing.
- To examine the challenges and opportunities in implementing these policy instruments, considering the specific characteristics of the manufacturing sector.
- To develop recommendations for a comprehensive policy mix that can effectively drive the transition to a circular economy in manufacturing.

By addressing these objectives, the study aims to provide a nuanced understanding of how policy instruments can be leveraged to achieve sustainability goals in the manufacturing sector.

### **2.2 Study Significance**

The significance of this study goes beyond mere academic enthusiasm or curiosity. Geissdoerfer et al. (2017) argues that circular economy can be identified as a conventional approach to conceptualize a sustainable unification between economic productivity and environmental wellbeing. Through a thorough scrutinization of the policy landscape, this study contributes to existing scholarly discourse, and even further adds to the growth and practicality of the global industrial sector.

Furthermore, this study comes at a critical moment when resource scarcity looms and environmental pressures surge. At this time, the need for effective circular economy policies is at its peak. By providing an illuminating path forward, this study hopes to expedite the transition to more sustainable manufacturing practices (Preston & Lehne, 2017). As

Stahel (2016) argues in Nature, the reinvention of the industrial system can be achieved through circular economy by carefully crafting policies that can navigate the complexities of global production systems while driving meaningful change. In essence, this research serves as a compass for navigating the complex terrain of circular economy policy in manufacturing. Although modest, it is a crucial step in the right direction, a move to redesigning our industrial future – one where “waste” is extinct, and circularity becomes the new norm.

In summary, this research has implications for developing a theoretical understanding of circular economy policy implementation in manufacturing contexts as well as real-world guidelines to support sustainable industrial transformation. Consequently, this research helps progress the overall objective of transitioning to a more sustainable and circular economy at the international level by closing the gap between policymaking and implementation.

### **III. METHODOLOGY**

#### **3.1 Research Design**

In order to adequately examine policy instruments relevant to the transition from linear economy to circular economy in the manufacturing sector, considering the academic requirements of this study, a qualitative approach is employed. In situations rife with varying complex policies, qualitative methods exhibit adequate characteristics needed to critically explore policy complexities and challenges that abound therewith. Also, as Denzin and Lincoln (2018) write, qualitative methods are adequate when there is a need to establish contextually rich understanding of phenomena, and to reveal detailed perspectives. This study’s qualitative methodology has two primary constituents.

- Systematic Literature Review
- In order to obtain solid detailed understanding of the subject matter, the study conducted a systematic review of academic literature, policy documents, and industry reports. This was in accordance to the methodological outline proposed by Petticrew and Roberts (2006).
- Search Strategy:
- The study used specific search terms relevant to “circular economy” and “policy instruments” across databases such as Web of Science, Scopus, and Google Scholar, and also reviewed reports from key organizations like the Ellen MacArthur Foundation and the European Environment Agency (Fink, 2019).
- Inclusion Criteria:
- Research materials must be published between 2010 and 2024
- Resource materials include peer-reviewed articles, books, and high-quality grey literature
- Focus on policy instruments for circular economy in manufacturing
- Publications written fully in the English Language
- Data Extraction and Synthesis:
- Data obtained across the various credible sources were further extracted for synthesis. To do this, this study developed a standardized form to extract relevant data from each source, with emphasis on policy type, implementation context, reported outcomes, and methodological approach. The obtained data was subsequently synthesized using narrative techniques and thematic analysis.
- Case Study Analysis
- Aside obtaining generalized information from myriads of existing research literature, this study conducted an in-depth analysis of eleven relevant case studies, employing Yin's (2018) multiple-case study design. The eleven case studies are:
  - Germany’s Circular Economy Act (Kreislaufwirtschaftsgesetz)
  - The Netherlands - A Comprehensive Approach
  - China's Circular Economy Promotion Law
  - The European Union's Circular Economy Action Plan
  - Japan's Sound Material-Cycle Society
  - France’s Renault Remanufacturing Plant
  - Kalundborg Symbiosis (Denmark)
  - South Korea’s Resource Circulation Framework Act
  - India’s National Resource Efficiency Policy
  - Dell’s Circular Economy Initiatives (The USA)

➤ Canada's Circular Economy Leadership Coalition

This approach allows for rich, contextual understanding of policy implementation and outcomes.

- Case Selection Criteria
- Geographic diversity (cases from Europe, Asia, North America)
- Variety of policy instruments (regulatory, economic, information-based, voluntary)
- Availability of detailed implementation data and outcome measures
- Mix of successful and challenging implementations
- Relevance to the manufacturing sector

### 3.2 Data Collection

Data for these studies analyses were obtained through a comprehensive analysis of existing relevant research literature. This literature included policy documents, evaluation reports, and other forms of credible information.

#### 3.2.1 Data Collection Methods

- Document Analysis

The foundational credibility of this study is in its thorough review of relevant documents, and the expansive volume of the analyzed documents. The document selection process involved a purposive sampling approach, focusing on materials that provide rich, detailed information about circular economy policies in the manufacturing sector. As Bowen (2009) suggests, document analysis in qualitative research serves multiple purposes like providing context, suggesting questions relevant and appropriate, providing supplementary input to research data, identifying modifications and development, and verifying findings from other sources.

- Case Studies

Eleven in-depth case studies were developed to provide detailed examples of circular economy policy implementation in the manufacturing sector. The cases were selected using purposive sampling to ensure diversity in geographical location, manufacturing sub-sectors, and policy approaches. Data for the case studies were collected through a combination of qualitative document analysis techniques. Each case study focused on providing a holistic view of the policy context, implementation process, challenges encountered, and outcomes achieved. This multiple case study approach follows Stake's (2006) collective case study design, allowing for both within-case and cross-case analysis.

#### Data Analysis Approach

This study's analysis employs several qualitative techniques to ensure robust and meaningful results:

- Thematic Analysis: In order to obtain and establish objective facts, this study used Braun and Clarke's (2006) six-step approach to thematic analysis to identify key themes and patterns across the literature, case studies, and expert consultations.
- Content Analysis: The content of the various research literature and policy documents obtained in the study all underwent systematic analysis (Krippendorff, 2018). This systematic content analysis consisted of coding and categorization of information into themes such as policy types used, sectoral focus within manufacturing, implementation strategies, reported outcomes, and challenges.
- Critical Discourse Analysis (CDA): Adhering to Fairclough's (2013) approach, the study examined how language is used in policy documents and stakeholder interviews to construct meanings and power relations in circular economy discourse.
- Comparative Analysis: In a bid to highlight the similarities and differences between the case studies under critical review and analyses, a comparative analysis framework was developed (Hong & Munij, 2022). This framework considered policy instrument mix, sectoral focus, implementation timeline, reported effectiveness, challenges encountered, and corporate responses to policies.

Cross-case Synthesis: For a thoroughly critical approach, this study employed cross-case synthesis techniques (Yin, 2018) to identify common patterns and divergences across different policy implementations. The cross-case analysis acted as a complementary approach to the comparative analysis as a means to further establish patterns, similarities, and differences across multiple case studies (Miles et al., 2014).

### 3.2.2 Ensuring Rigor in Qualitative Research

Several strategies were enacted to ensure the credibility of findings obtained through this study, some of which are (Cresswell & Cresswell, 2017):

- Triangulation: Data was gathered through multiple sources and methods and the study cross checked this information (Patton, 2015).
- Peer Debriefing: Meeting with colleagues outside of the study aided in questioning and considering different perspectives on findings (Creswell & Poth, 2018).
- Audit Trail: To reduce biases and enhance the reliability of the study, notes of all research activities, decisions, and reflections were kept throughout the study process, as suggested by Schwandt and Halpern (1988).

These strategies align with Lincoln and Guba's (1985) criteria for establishing trustworthiness in qualitative research: credibility, transferability, dependability, and confirmability (Lemon & Hayes, 2020).

### Study Limitations

As much as this study has adopted a robust research methodology that makes it easy to analyze CE policy instruments in the manufacturing sector, there are some limitations. The reliance on secondary data may introduce bias or missing information, and the lack of direct interviews with policymakers and industry professionals limits the ability to capture first-hand perspectives. Moreover, only English articles were considered for inclusion, which could limit the scope of the results if some important articles were published in other languages.

The methodological approach adopted in this study – the systematic literature reviews together with the multiple case study analysis – encompasses an effective research design to assess the CE policy instruments concerning the manufacturing sector. Collecting numerous data sources and applying various analytical methods, the study seeks to provide policymakers, industry decision-makers, and scholars with the result to advance sustainable manufacturing pursuit.

## IV. RESULTS AND RECOMMENDATIONS

### Study Results

This analytical study of CE policies in the manufacturing, through a systematic literature review and eleven case studies across different geographical regions show the efficacy of different policy instruments: regulatory, economic, informational and voluntary and the issues and opportunities related to them. The results are organized into three main themes: the efficiency of policies and regulatory tools, prospects for utilizing policy tools, the difficulties of policy application and the impact of regional and sectoral specifics.

- Effectiveness of Policy Instruments: The impact of the policy instruments in enhancing CE practices also depends on the type of instrument being used; environment in which it is used; and the subsector of manufacturing activity involved. The outcomes also indicate that various policy combinations comprising regulatory, economic, informational, and voluntary measures policy instruments are more efficient in implementing circular behaviors than relying on single-policy strategies.
- Regulatory Instruments: Extended producer responsibility (EPR) schemes, minimum recycling requirements, and restrictions on selected single-use products have been effective in establishing tangible requirements for circularity. For instance, increased recycling rates and resource productivity have been attributable to Germany's Circular Economy Act and Japan's 3R policy (Destatis, 2021; Ministry of the Environment Japan, 2021). Nonetheless, enforcement of these regulatory instruments tends to be weak, especially in the regions featuring intricate supply chains and inconsistent levels of governance.
- Economic Instruments: Some measures which have shown positive effects towards encouraging innovation and investment in circular economy technologies include subsidies to recycling technologies, tax incentives and rebates for repair services, and carbon pricing policy. In particular, the Netherlands provides financial incentives for companies that implement CE practices, thereby causing a 20% increase in resource productivity between 2015 and 2020 (PBL Netherlands, 2021). However, the effectiveness of economic instruments depends on the market conditions and availability of technology, and the willingness of companies to fund circular economy solutions.
- Informational Instruments: Policy instruments like eco-labeling schemes, public awareness campaigns, and LCA database are relevant in persuading consumers and suppliers to embrace CE practices. The EU's Product



Environmental Footprint and Japan’s Top Runner also highlight the effectiveness of informational instruments to advance market transformation as it raises awareness and encourages consumers to make sustainable decisions (Saidani et al., 2019). However, the policies’ efficacies are limited by the varying level of awareness and outreach of the concerned stakeholders.

- Voluntary Instruments: Market mechanisms including sustainable certifications, green partnerships, product stewardship have also been useful in persuading the industries to do more beyond the practices set by law. For instance, Philips’ “Diamond Select” scheme of redistributing second-hand medical diagnostic equipment complies with the EU Circular Economy Action Plan since it supports goods, which are durable (European Commission, 2020). However, voluntary instruments are contingent upon the cooperation of the businesses and usually need support through the regulatory as well as economic measures.

Fig 4.1: Heatmap table showing the intensity of policy instrument usage (regulatory, economic, informational, voluntary) across different stages of manufacturing (e.g. design, production, end-of-life) in the case studies. Light blue indicates heavy use, while black indicates no use, highlighting where specific policies are most effective or underutilized.

Case Study	Regulatory	Economic	Informational	Voluntary
Germany	5	3	2	1
Netherlands	4	5	4	2
China	5	4	3	4
European Union	5	4	5	3
Japan	4	4	3	5
South Korea	5	3	2	2
India	3	3	4	2
USA (Dell case)	2	3	4	5
Canada	3	2	4	5

Intensity scale: 0 (Not used) to 5 (Heavily used)

#### 4.1 Challenges in Policy Implementation

From a thorough analysis, certain challenges have been identified to hinder the various implementations of circular economy policies. They are:

- Technological Barriers:
  - Difficulty in designing products for circularity.
  - Inadequacy of recycling technologies for complex materials.
- Economic Barriers:
  - To transition into circular business models, high capital is needed.
  - Volatility in recycled material markets.
- Institutional Barriers:
  - Disparities in departmental classifications
  - Resistance from industries grounded in linear economy

Others include the complexities that exist in global supply chain practices, as stated by Kirchherr et al. (2018), and the potentiality of rebound effects where improved resource efficiency causes increased consumption, potentially negating environmental benefits (Zink & Geyer, 2017).

#### **4.1.1 Influence of Regional and Sectoral Contexts**

The effectiveness of CE policies is influenced by regional economic conditions, institutional environments, and sector-specific characteristics:

- **Regional Differences**

The CE frameworks in developed countries like Germany, the Netherlands, and Japan, are more advanced due to their high levels of resource efficiency that is a result of stronger institutional environments and technological capabilities (Ghisellini et al., 2016). On the other hand, emerging economies like China and India find it harder to implement and enforce CE policies because of their under-developed infrastructure and regulatory frameworks (Mathews & Tan, 2016).

- **Sector-Specific Strategies**

The fact that CE strategies vary significantly across different manufacturing sub-sectors mean that the effectiveness of policy instruments also varies across different stages of the manufacturing value chain, from design and production to distribution and end-of-life management. For example, the electronics and automotive sectors are two different sectors with varying material compositions and lifecycle challenges, demanding that specific approaches are used put in place (Kalmykova et al., 2018).

#### **4.2 RECOMMENDATIONS**

Based on the comprehensive analysis of circular economy policies in the manufacturing sector, the following recommendations have been appositely suggested for an onward development. These recommendations are directed toward policymakers, industry leaders, and researchers.

##### **4.2.1 For Policymakers**

- **Adopt a holistic policy approach:** Develop equal ratio of regulatory, economic, informational, and voluntary instruments to build an all-inclusive circular economy structure. This flexibility makes it possible to target various aspects of the circular economy and meet the needs of various stakeholders (Milios, 2018).
- **Tailor policies to local contexts:** With regard to the circular economy principles, key policy directions should take into account the economic development level, technological capabilities, and cultural characteristics of countries. This is due to the fact that what may have yielded positive results in one region may not be the same case for another. Before the initiation of policy implementation, they have to make comprehensive investigations of the local environments and the needs of the stakeholders (Schot & Steinmueller, 2018).
- **Promote international cooperation:** Promote the consistency in circular economy standards and policies across the geographical locations to increase the acceptance of the concept globally. This is particularly crucial in view of the fact that most manufacturing logistic networks go across the borders. Avail broad relations to exchange information and policy goals in bilateral and multilateral forums (McDowall et al., 2017).
- **Regularly review and update policies:** Implement strategies for policy review and update at regular intervals, in consideration to new technologies, market trends and societal expectations. This could involve creating committees of specialists or working groups that are responsible for tracking circular economy policy performance and identifying required modifications (Winans et al., 2017).
- **Strengthen enforcement mechanisms:** Policies and mechanisms need be put in place to track and check organization's adherence to circular economy practices. This includes expanding digital technologies for tracing the flows of materials through industries, increasing capabilities of environmental inspection bureaus, and increasing the severity of punishment for violations (Geng et al., 2019).
- **Support small and medium-sized enterprises (SMEs):** Design specific interventions for facilitating the shift towards circular economy by SMEs. This could involve supporting smaller manufacturers with technical know-how, funds and connections to aid overcome key barriers to circular economy transitions (Rizos et al., 2016).

#### 4.2.2 For Industry Leaders

- Embrace circular economy principles in product design: In the processes of product development, the principles of recyclability, reparability, and longevity need be inculcated. It may mean reevaluating existing design strategies, and implementing novel technologies and materials to support the circular economy (Bocken et al., 2016).
- Invest in circular economy technologies: Invest in the activities which could create and implement circular manufacturing technologies. This could include new recycling technologies, digital tools for tracking material flows and new sustainable materials (Lacy and Rutqvist, 2015).
- Collaborate across supply chains: A supply chain approach of engaging suppliers, customers, and even competitors to develop closed-loop technological ways of conducting business or enhancing resource utilization. This may mean setting up standardization processes such as set standards within the industry, a common platform for sharing infrastructure or carrying out collective research and development activities (Geissdoerfer et al., 2018).
- Engage in policy dialogues: Engage policymakers in dialogues on existing policies to ensure that impending policies are implementable and useful. Discuss experiences of the practical deployment of policies as well as dissemination of the data collected from the implementation process to shape the formation of the policies as well as their improvement (Katz-Gerro & López Sintas, 2019).

#### 4.2.3 For Researchers

- Develop standardized metrics: Develop a set of standard guidelines of tracking circular economy performance in manufacture that could be accepted globally. This would enable benchmarking activities, policy assessment, and cross-communal comparisons (Saidani et al., 2019).
- Conduct longitudinal studies: For a more enduring development, evaluate the effects of circular economy policies on resource consumption, economic indicators, and the environment over time. This will enable a comparison of the various policy measures that had been put in place in the past and seek to understand their performance of the present systems (Ghisellini et al., 2016).
- Explore interdisciplinary approaches: Incorporate a mix of economic, scientific, engineering, and social principles and perspectives to effectively solve circular economy problems. Such an approach can result in the development of more appropriate and efficient strategies (Kirchherr et al., 2017).
- Investigate emerging technologies: Study the roles of emerging technologies such as AI, Internet of Things, and block-chain in the implementation of circular economy in the manufacturing industries. Learn how these technologies could help improve the traceability, better the allocation of resources, and unlock new opportunities to embracing circular economy (Ellen MacArthur Foundation, 2019).

By implementing these recommendations, we can accelerate the transition to a circular economy in the manufacturing sector, leading to more sustainable and resilient industrial systems globally. It is crucial that all stakeholders work collaboratively to overcome the challenges and realize the full potential of the circular economy. Through the adoption of these recommendations, it is possible to expedite the transition to circularity in the manufacturing sector, toward attaining a more sustainable and robust industrial systems globally. Hence, engaging all relevant stakeholders to address the established challenges is very important towards the achievement of circular economy and its optimum benefits.

## V. CONCLUSION

The shift towards adopting and embracing a circular economy in the manufacturing sector is a step in the right direction, a step that has always been awaiting to be taken. It is a breath of fresh air in the processes of production, consumption, and resource management in global manufacturing practices. The present investigation into the state of circular economy policies in different countries and geographies has shown both the advances that have been executed and the trends that remain ahead. The top strategies that have been effective in integrating CE in manufacturing are a combination of policy type that includes among others; regulatory, economic, informative and voluntary (Miliotis, 2018). Such policies, if properly formulated and in their implementation, can spur new innovations, nurture new businesses and indeed the economy in the long run and at the same time lead to less negative consequences on the environment (Geissdoerfer et al., 2017).

Despite these promising positives, the transition to circular economy for manufacturing industries is still a work in progress. It is, however, important to note that the effectiveness of policies implemented varies to a great extent in various regions due to factors such as level of economic development, technological advancement, and culture (McDowall et al., 2017). Examples of these challenges include; enforcement issues, technological limitations, market issues, and the effort to overthrow typical linear constraints (de Jesus, 2018).

Thus, forging onward, it is imperative that the policymakers, industry players, and researchers join hands to address these challenges. This will prove to be an ongoing process of policy updates, enhancement of the focus on circular technologies and business models, as well as international collaboration. Standardized units for the tracking of circular economy advancement is also one of the critical components that will be needed for comparison and policy assessment (Saidani et al., 2019). Therefore, it is important to stress that there is an obvious need to accelerate this transition. With the constantly decreasing resources, deteriorating environment, and the necessity to fight climate change, the circular economy policies emerge as the possible ways for further industrial development and sustainability. Therefore, the manufacturing sector has the potential to build a sustainable and robust circular economy globally by embracing circular economy practices (Kirchherr et al., 2017).

Conclusively, the process of achieving a circular economy in manufacturing can be challenging but is both required and possible. The study underscores the importance of integrated policy packages that combine regulatory, economic, informational, and voluntary measures, tailored to sectoral and regional contexts. And more specifically, through sustained innovation, collaboration and engagements of stakeholders, it is possible to obtain maximum benefits through the redesign of industrial systems and policies (Schot & Steinmueller, 2018).

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