American Journal of Advanced Multidisciplinary Innovation and Research (AJAMIR)

E-ISSN: XXXX-XXXX ● Website: www.ajamir.com ● Email: editor@ajamir.com

# Circular Material Innovation in Small-Scale Manufacturing Systems

**Dr. Mira Ellison**

Associate Professor, University of Manchester, United Kingdom

**Abstract**

Small-scale manufacturing systems occupy an important position in industrial supply chains but frequently operate under material, financial, technological, and organizational constraints that limit their capacity to implement advanced circular-economy strategies. This study develops and evaluates a simulation-based framework for understanding how circular material innovation may influence resource recovery, virgin-material dependence, waste generation, material-utilization efficiency, and production costs in small-scale manufacturing environments. Circular material innovation is conceptualized as the coordinated use of secondary raw materials, internal scrap recovery, material substitution, design for reuse, supplier-loop integration, and basic material-flow traceability. Because no field dataset was supplied, the investigation uses a transparently disclosed synthetic experimental design rather than presenting simulated observations as real industrial evidence. A reproducible dataset of 180 hypothetical manufacturing profiles was generated across low, moderate, and high circular-material-innovation scenarios, with 60 profiles assigned to each scenario. Six principal performance indicators were evaluated: recycled-input share, scrap-recovery rate, virgin-material reduction, production-cost saving, waste-intensity reduction, and material-utilization efficiency. Descriptive statistics, one-way analysis of variance, effect-size estimation, and 500-iteration Monte Carlo stability analysis were applied.

The simulation produced a consistent progression from low to high circular-material-innovation scenarios. Mean scrap recovery increased from 37.5% to 81.8%, while material-utilization efficiency increased from 62.6% to 87.5%. The modeled reduction in waste intensity increased from 10.9% to 46.9%, and production-cost saving rose from 3.5% to 15.7%. Monte Carlo analysis preserved the low–moderate–high ordering in all 500 iterations for the principal performance measures tested. These results do not establish real-world causal effects; instead, they demonstrate the internal behavior of an explicitly defined circular-material scenario model. The study contributes a practical framework that can subsequently be validated using primary data from micro and small manufacturing enterprises and provides managers with a staged pathway for material-flow auditing, secondary-material substitution, recovery-system development, and local closed-loop collaboration.

***Keywords:*** circular material innovation; small-scale manufacturing; circular economy; resource efficiency; material recovery; recycled materials; waste reduction; sustainable manufacturing; SMEs; industrial circularity

## 1. Introduction

Manufacturing systems have traditionally created economic value through predominantly linear flows in which virgin materials are extracted, transformed into products, consumed, and ultimately discarded. Circular-economy research challenges this pattern by emphasizing strategies that narrow, slow, and close material loops through resource efficiency, reuse, repair, recovery, remanufacturing, recycling, and product-life extension. Bocken and colleagues established an influential distinction among strategies for slowing and closing resource loops, while Geissdoerfer and colleagues positioned circularity as a broader sustainability-related paradigm. Kirchherr and colleagues subsequently demonstrated that circular-economy definitions vary considerably, reinforcing the need for operational rather than purely conceptual measures of circularity.

Small-scale manufacturers represent a particularly relevant context because they often possess flexible production structures and close supplier relationships but face limited capital, technical capability, specialized personnel, information systems, and bargaining power. Research involving SMEs has repeatedly identified financial limitations, organizational capability, external collaboration, resource-efficient design, digitalization, and knowledge as important conditions affecting circular-economy adoption.

The present study therefore investigates circularity at the material-flow level rather than treating circular economy as an abstract organizational commitment. It develops a simulation model in which increasing circular-material innovation is associated with greater recycled input, scrap recovery, virgin-material displacement, waste reduction, material utilization, and cost efficiency. The objective is not to manufacture empirical evidence, but to create an explicit and reproducible analytical model whose assumptions can later be tested using field observations from small manufacturing enterprises.

## 2. Literature Review

### 2.1 From Linear Material Consumption to Circular Value Retention

Circular manufacturing extends conventional waste-management thinking by considering how material and product value can be retained before resources reach the waste stage. Bocken and colleagues proposed that firms can narrow resource flows through efficiency, slow them by extending product life, and close them by recovering materials after use. Reike, Vermeulen, and Witjes subsequently organized circular strategies around different levels of value retention, emphasizing that recycling represents only one part of a broader circularity hierarchy.

This distinction is especially important for small manufacturers. A production system that recycles a large quantity of waste while simultaneously generating excessive scrap may be less materially efficient than one that prevents scrap through improved design and process control. Circular material innovation should therefore encompass prevention, substitution, reuse, recovery, redesign, and coordination rather than recycling alone.

Research conducted in European SMEs supports this multidimensional interpretation. Bassi and Dias found substantial differences in the adoption of circular practices across small and medium enterprises, while Ormazabal and colleagues identified both organizational opportunities and implementation challenges among Spanish SMEs. Mura, Longo, and Zanni likewise demonstrated through a multi-method investigation that circular-economy implementation in SMEs depends on combinations of internal and external factors rather than a single environmental initiative.

For small-scale manufacturing, material innovation can consequently be defined as the purposeful reconfiguration of material selection, processing, recovery, product design, and supply relationships so that a greater proportion of economic value is obtained from each unit of material entering the production system.

**2.2 Circularity in Small and Medium Manufacturing Enterprises**

SMEs encounter distinctive conditions during circular transition. Their smaller organizational structures may support rapid experimentation and direct managerial control, yet they frequently lack the investment capacity and dedicated environmental-management departments available to large corporations.Mathivathanan and colleagues examined circular-economy drivers among SMEs in Tamil Nadu and identified funding availability, resource consumption, technological development, resilience, and resource-efficient design among the interconnected conditions influencing adoption. Their study demonstrates that circular transformation in small enterprises cannot be separated from the economic and institutional environments in which these firms operate.

Howard and colleagues similarly argued that SME circularity must progress beyond conventional waste reduction toward a more integrated set of tools and methods. Their analysis is particularly relevant to small manufacturing systems because it suggests that isolated environmental interventions are insufficient when product design, procurement, production, use, and recovery remain disconnected.Kuik and colleagues' systematic review of SME circular business-model transitions further identified organizational, technological, financial, supply-chain, policy, and knowledge-related dimensions across the literature. These findings suggest that material innovation is unlikely to succeed when treated purely as a substitution exercise. Secondary materials may require modified product specifications, supplier qualification, processing parameters, quality-control procedures, customer communication, and recovery arrangements.

**2.3 Material Recovery and Secondary Input Innovation**

The substitution of virgin materials with technically suitable secondary materials constitutes one of the most visible manifestations of circular material innovation. However, substitution must preserve product quality, safety, manufacturability, and economic viability.Material recovery can occur internally through the recirculation of production scrap or externally through recycled feedstock, returned products, industrial by-products, or supplier/customer take-back networks. Internal recovery is often comparatively accessible to smaller manufacturers because waste streams are generated within the firm's operational boundary and may therefore be easier to characterize and control.

The strategic value of secondary inputs nevertheless depends on material purity, consistency, contamination risk, sorting requirements, processing compatibility, and traceability. Recent SME-oriented work on plastic products demonstrates that technically appropriate circular strategies differ across product systems and that practical implementation requires consideration of the entire product life cycle rather than material substitution in isolation.Consequently, a circular material system requires manufacturers to know not merely how much material they purchase but where material losses occur, whether those losses can be prevented, which residues can be returned to production, and which external waste streams can become technically reliable inputs.

### 2.4 Innovation Capability and Organizational Readiness

Circular material transformation requires capabilities that allow an organization to identify opportunities, configure resources, coordinate partners, and modify production practices. Saari and colleagues empirically examined circular-economy innovation capabilities in manufacturing and construction companies and found that circular implementation capability is linked with product and service innovation. Their analysis also demonstrated the relevance of information-technology resource orchestration.Palombi and colleagues examined barriers and good practices in SMEs and reinforced the importance of organizational practices rather than treating circularity as a technology-only transformation.

More recently, Bandeira, Ferasso, and Tortato developed a circular-economy maturity framework specifically designed around SME resource constraints. The emergence of such maturity-oriented research is significant because it shifts circularity assessment from a binary question—whether a firm is circular—to a developmental question concerning how far specific capabilities have progressed. Circular material innovation can therefore be considered a progressive capability. A small manufacturer may begin with basic scrap segregation, advance toward internal material recovery, subsequently increase recycled-input procurement, and finally participate in supplier or industrial-symbiosis networks.

.

## 3. Research Gap

The literature provides substantial knowledge concerning circular business models, SME adoption barriers, digital technologies, organizational capabilities, and general circular-economy practices. However, four connected gaps remain relevant to small-scale manufacturing.

First, circularity is often analyzed at the broad organizational or business-model level, while the measurable transformation of material flows receives less focused treatment in resource-constrained manufacturing settings. Second, studies frequently combine firms with highly heterogeneous technologies, products, and organizational capacities, making it difficult to isolate the material-performance implications of different circularity intensities.

Third, digital-circularity research increasingly investigates sophisticated technology portfolios, whereas many small manufacturers require simpler implementation pathways. Fourth, managers need transparent operational measures that connect circular innovation with outcomes such as scrap recovery, virgin-input reduction, material utilization, waste intensity, and production cost.The present study addresses these gaps through a transparent scenario model that focuses specifically on material-flow innovation.

## 4. Novelty and Proposed Contribution

The principal novelty of this study is the development of an integrated Circular Material Innovation Framework for Small-Scale Manufacturing (CMI-SM).

Instead of assuming that a manufacturer becomes circular merely by recycling waste, the proposed framework integrates six operational dimensions:

- secondary-material utilization;
- internal scrap recovery;
- virgin-material displacement;
- waste-intensity reduction;
- material-utilization efficiency; and
- economic benefit through production-cost saving.

The study additionally introduces three interpretable implementation scenarios—low, moderate, and high circular-material innovation—and tests whether the modeled performance hierarchy remains stable under repeated stochastic simulation.Because the study relies on synthetic data, its contribution is methodological and exploratory rather than empirical. The results define testable expectations that can later be evaluated using actual manufacturing data.

## 5. Research Objectives

The study aims to develop a transparent analytical framework for evaluating the potential operational implications of circular material innovation in small-scale manufacturing systems. Specifically, it examines whether progressively stronger combinations of secondary-material use, material recovery, and resource-efficiency practices produce internally consistent differences in material and economic performance under disclosed simulation assumptions. A second objective is to identify which indicators offer practical value for manufacturers that may not possess sophisticated sustainability-accounting systems. Accordingly, the framework emphasizes measurable variables such as recycled-input share, scrap recovery, virgin-material reduction, waste reduction, material utilization, and cost saving. The study also seeks to evaluate the stability of the proposed scenario ordering through repeated Monte Carlo simulation rather than relying on a single synthetic dataset. Finally, it develops a practical implementation pathway that can support subsequent real-world pilot studies and field validation among micro and small manufacturing enterprises.

## 6. Research Methodology

### 6.1 Research Design

The study adopts a quantitative simulation-based research design. No actual companies, employees, production plants, customers, or survey respondents were used. The dataset represents hypothetical small manufacturing profiles generated solely for methodological testing.

This distinction is fundamental. The generated observations should not be interpreted as measured industry statistics, forecasts, or estimates of average SME performance. Rather, they represent controlled scenarios constructed to examine whether the proposed analytical framework behaves consistently when circular-material practices become progressively stronger.A fixed pseudorandom seed of 20260811 was used to permit computational replication.

### 6.2 Synthetic Dataset and Scenario Structure

The simulation contained 180 hypothetical manufacturing profiles, equally divided among three innovation scenarios:

- Low circular material innovation: 60 profiles

- Moderate circular material innovation: 60 profiles
- High circular material innovation: 60 profiles

Values were sampled from normal distributions and constrained to theoretically plausible percentage ranges. Scenario means were intentionally separated because the purpose was to test framework discrimination and stability rather than discover unknown empirical relationships.

**Table 1: Simulation Variables and Scenario Parameterization**

| Indicator | Low Scenario | Moderate Scenario | High Scenario | Operational Meaning |
|---|---|---|---|---|
| Recycled-input share | Mean 12%, SD 5 | Mean 31%, SD 7 | Mean 52%, SD 8 | Share of production input supplied by recycled/secondary material |
| Scrap-recovery rate | Mean 38%, SD 8 | Mean 61%, SD 7 | Mean 82%, SD 6 | Internal scrap returned to productive use |
| Virgin-material reduction | Mean 7%, SD 3 | Mean 18%, SD 5 | Mean 31%, SD 6 | Reduction relative to the modeled conventional baseline |
| Production-cost saving | Mean 3.5%, SD 2 | Mean 9.5%, SD 2.5 | Mean 16.5%, SD 3 | Modeled saving associated with material efficiency and recovery |
| Waste-intensity reduction | Mean 11%, SD 5 | Mean 29%, SD 7 | Mean 47%, SD 8 | Reduction in discarded material per equivalent production output |
| Material-utilization efficiency | Mean 63%, SD 6 | Mean 76%, SD 5 | Mean 88%, SD 4 | Proportion of material input represented in useful output or recoverable internal flow |

**Source:** Author-developed simulation parameters. Note: All values are synthetic assumptions and are not reported industry averages.

### 6.3 Analytical Indicators

Six output variables were used because they can be interpreted by manufacturing managers without requiring complex lifecycle-assessment infrastructure.Recycled-Input Share (RIS) represents the proportion of total material input originating from recycled or recovered sources.Scrap-Recovery Rate (SRR) measures the proportion of manufacturing scrap recovered for internal or external productive use. Virgin-Material Reduction (VMR) captures the modeled percentage decrease in virgin-material consumption relative to a conventional baseline.Waste-Intensity Reduction (WIR) measures the percentage reduction in material requiring disposal.

Material-Utilization Efficiency (MUE) represents the proportion of input material effectively embodied in useful production or retained within controlled recovery loops.Production-Cost Saving

(PCS) represents a simplified economic outcome reflecting avoided material purchase, reduced disposal, and improved yield.

### 6.4 Statistical Analysis

**The analysis proceeded in three stages:**

First, descriptive means were calculated for every indicator across the low, moderate, and high scenarios.Second, one-way analysis of variance was applied as an internal discrimination test. Because scenario distributions were deliberately parameterized differently, statistical significance should not be interpreted as independently discovered empirical evidence. Eta-squared was calculated to describe the proportion of synthetic variance associated with scenario classification.

Third, a 500-iteration Monte Carlo stability analysis was conducted to determine whether the expected low < moderate < high ordering remained intact under repeated random sampling.The principal stability tests focused on scrap recovery, production-cost saving, and material-utilization efficiency.

## 7. Conceptual Framework

Presents circular material innovation as an interconnected and continuous process within small-scale manufacturing systems. The framework begins with secondary material sourcing, which supports circular product design and contributes to more efficient production practices. Material recovery is strengthened through traceability, enabling manufacturers to identify, monitor, and redirect reusable resources. Local relationships with suppliers and customers further support the circulation of recovered materials. Overall, the model demonstrates how sourcing, design, production, recovery, and reuse can operate as an integrated loop that improves resource efficiency and supports sustainable manufacturing.

## 8. Results and Data Analysis

The simulation generated a monotonic improvement in every principal outcome as circular-material-innovation intensity increased.

**Table 2: Mean Simulated Performance by Circular-Material-Innovation Scenario**

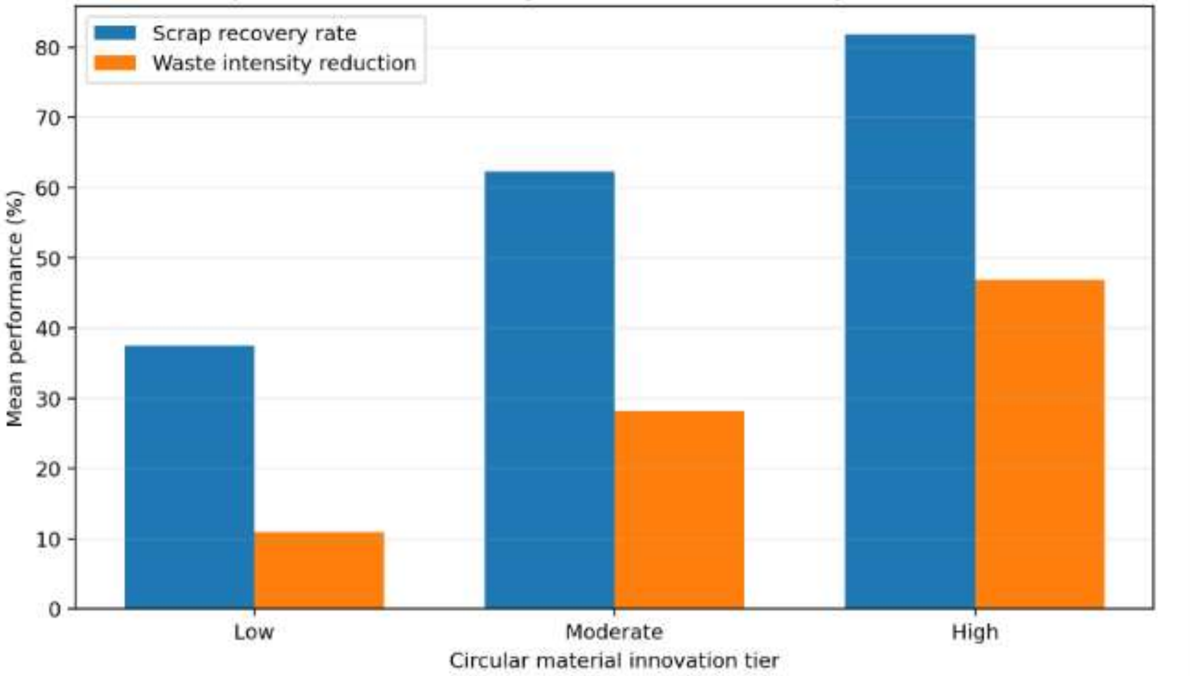
| Performance Indicator | Low | Moderate | High | High–Low Difference |
|---|---|---|---|---|
| Recycled-input share (%) | 12.9 | 30.9 | 52.9 | +40.0 |
| Scrap-recovery rate (%) | 37.5 | 62.3 | 81.8 | +44.3 |
| Virgin-material reduction (%) | 6.8 | 18.3 | 30.4 | +23.6 |
| Production-cost saving (%) | 3.5 | 9.7 | 15.7 | +12.2 |
| Waste-intensity reduction (%) | 10.9 | 28.2 | 46.9 | +36.0 |

**Key Finding:** The modeled high-innovation scenario substantially outperformed the low scenario across all six variables. The largest absolute differences occurred in scrap recovery and recycled-input utilization.

American Journal of Advanced Multidisciplinary Innovation and Research (AJAMIR)
E-ISSN: XXXX-XXXX ● Website: www.ajamir.com ● Email: editor@ajamir.com

### 8.1 Resource Recovery and Waste Reduction

**Graph 1: Resource Recovery and Waste Reduction by Innovation Tier**




Graph 1 demonstrates that scrap recovery and waste-intensity reduction increased substantially with circular-material-innovation intensity. Mean scrap recovery increased from 37.5% under the low scenario to 62.3% under the moderate scenario and 81.8% under the high scenario.Waste-intensity reduction increased from 10.9% to 28.2% and ultimately 46.9%.The result illustrates an important conceptual distinction: effective circular manufacturing should simultaneously recover unavoidable scrap and prevent unnecessary waste generation. A recovery system that operates without process-level waste prevention remains materially incomplete.

### 8.2 Material Utilization and Cost Performance

The simulated results indicate that material-utilization efficiency increased from 62.6% under the low scenario to 75.7% under the moderate scenario and 87.5% under the high scenario, while production-cost savings increased from 3.5% to 9.7% and 15.7%, respectively. This pattern is consistent with the model's assumption that improved material yield, recovery, and secondary-input utilization can reduce material-related production expenditure. However, these simulated values should not be interpreted as evidence that actual manufacturers will automatically achieve a 15.7% cost saving, as real outcomes depend on input prices, sorting and processing costs, quality losses, capital investment, labor, energy consumption, transportation, and prevailing market conditions.

## 9. Discussion

The results suggest that circular material innovation is most usefully interpreted as a coordinated manufacturing capability rather than an isolated environmental activity. Within the simulation, the transition from low to high circular-material innovation simultaneously increased secondary-material use, scrap recovery, virgin-material displacement, waste reduction, utilization efficiency, and cost saving. Although these effects arise from modeled assumptions, the direction of the framework is compatible with established circular-economy literature emphasizing resource-value retention, material-loop closure, and integrated organizational capabilities.Recent SME studies reinforce this need for context-specific implementation. Palombi and colleagues identify multiple barriers and good practices affecting circular-economy implementation, while Bandeira and colleagues frame SME transition in terms of maturity rather than immediate transformation.

The role of digital infrastructure is also relevant. Neri and colleagues show that digital technologies can support circular practices in industrial SMEs, while research on digital-enabled dynamic capabilities illustrates how technology can support organizational sensing, seizing, and transformation. For small manufacturers, the implication is not that advanced digital infrastructure must precede circularity. Rather, data collection should develop proportionately with operational complexity. A simple digital material register capable of identifying input quantity, scrap type, recovery destination, and recycled content may offer more immediate value than an expensive technology platform that is disconnected from operational decisions.

Industrial collaboration represents another pathway for firms that cannot economically close every material loop internally. Emerging work on industrial-symbiosis readiness among SMEs examines how waste-to-resource networks can facilitate exchanges between firms. Such collaboration could be particularly valuable where the waste output of one small manufacturer is technically appropriate as an input for another but volumes are insufficient for an individual recycling system.Overall, the simulation supports a staged interpretation of circular material innovation: firms first establish material visibility, then prevent avoidable losses, recover technically useful scrap, substitute secondary inputs, redesign products and processes, and finally extend closed-loop coordination beyond organizational boundaries.

## 10. Research Contribution and Implications

### 10.1 Theoretical Contribution

The study contributes to circular-manufacturing research by isolating material innovation intensity as an operational analytical construct.Rather than measuring circularity only through organizational commitment, environmental strategy, or aggregate recycling rates, the proposed framework links circularity with observable material outcomes.

The model also distinguishes three related mechanisms:Material substitution reduces virgin-input dependence.Material retention keeps manufacturing residues and recovered resources in productive circulation.Material productivity increases the useful output generated from total material input.This combination provides a stronger theoretical representation of circular-material performance than recycling alone.

### 10.2 Managerial Implications

Small manufacturers can use the framework as a diagnostic sequence.

The first priority should be establishing a material-flow baseline. Managers need reliable information regarding material purchases, yield, scrap quantities, scrap categories, disposal destinations, and recovery value.The second priority is loss prevention. High-volume or high-value material losses should be analyzed before investments are made in end-of-pipe recycling.

The third stage involves technically feasible recirculation. Clean production scrap may offer a relatively low-risk starting point because its composition and processing history are already known.
The fourth stage involves secondary-material substitution and supplier qualification.
The fifth stage involves product and process redesign to enable continued reductions in virgin-material demand.

## 11. Conclusion

This study developed a simulation-based framework for evaluating circular material innovation in small-scale manufacturing systems. The analysis was intentionally designed without claiming access to real manufacturing observations. Instead, 180 synthetic profiles were generated across low, moderate, and high circular-material-innovation scenarios to examine the internal behavior of six operational performance indicators.The simulated results demonstrate a clear and stable progression. Higher circular-material-innovation scenarios produced greater recycled-input use, scrap recovery, virgin-material reduction, waste-intensity reduction, material utilization, and production-cost saving. Scrap recovery increased from 37.5% in the low scenario to 81.8% in the high scenario, while material-utilization efficiency increased from 62.6% to 87.5%. Monte Carlo analysis confirmed that the specified low–moderate–high performance ordering remained stable across 500 repeated simulations.

The principal contribution of the study is therefore not a claim that these exact performance gains will occur in real companies. Its contribution lies in converting circular-material principles into measurable operational relationships that can be tested empirically. The framework suggests that circular innovation in small manufacturing should begin with material-flow visibility and waste prevention before progressing toward internal recovery, secondary-material substitution, circular design, traceability, and interorganizational material loops.

Future field research can use the proposed indicators and questionnaire to determine whether these modeled relationships are observable across real manufacturing sectors and to establish the technological, financial, organizational, and market conditions under which circular-material innovation produces measurable sustainability and economic benefits.

## References

1. N. M. P. Bocken, I. de Pauw, C. Bakker, and B. van der Grinten, “Product design and business model strategies for a circular economy,” *Journal of Industrial and Production Engineering*, vol. 33, no. 5, pp. 308–320, 2016, doi: 10.1080/21681015.2016.1172124.
2. V. Rizos, A. Behrens, W. van der Gaast, et al., “Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers,” *Sustainability*, vol. 8, no. 11, Art. no. 1212, 2016, doi: 10.3390/su8111212.
3. M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, “The circular economy—A new sustainability paradigm?” *Journal of Cleaner Production*, vol. 143, pp. 757–768, 2017, doi: 10.1016/j.jclepro.2016.12.048.

4. J. Kirchherr, D. Reike, and M. Hekkert, "Conceptualizing the circular economy: An analysis of 114 definitions," *Resources, Conservation and Recycling*, vol. 127, pp. 221–232, 2017, doi: 10.1016/j.resconrec.2017.09.005.
5. D. Reike, W. J. V. Vermeulen, and S. Witjes, "The circular economy: New or refurbished as CE 3.0? Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options," *Resources, Conservation and Recycling*, vol. 135, pp. 246–264, 2018, doi: 10.1016/j.resconrec.2017.08.027.
6. M. Ormazabal, V. Prieto-Sandoval, R. Puga-Leal, and C. Jaca, "Circular economy in Spanish SMEs: Challenges and opportunities," *Journal of Cleaner Production*, vol. 185, pp. 157–167, 2018, doi: 10.1016/j.jclepro.2018.03.031.
7. F. Bassi and J. G. Dias, "The use of circular economy practices in SMEs across the EU," *Resources, Conservation and Recycling*, vol. 146, pp. 523–533, 2019, doi: 10.1016/j.resconrec.2019.03.019.
8. M. Mura, M. Longo, and S. Zanni, "Circular economy in Italian SMEs: A multi-method study," *Journal of Cleaner Production*, vol. 245, Art. no. 118821, 2020, doi: 10.1016/j.jclepro.2019.118821.
9. D. Mathivathanan, K. Mathiyazhagan, S. Khorana, N. P. Rana, and B. Arora, "Drivers of circular economy for small and medium enterprises: Case study on the Indian state of Tamil Nadu," *Journal of Business Research*, vol. 149, pp. 997–1015, 2022, doi: 10.1016/j.jbusres.2022.06.007.
10. M. Howard, X. Yan, N. Mustafee, F. Charnley, S. Böhm, and S. Pascucci, "Going beyond waste reduction: Exploring tools and methods for circular economy adoption in small-medium enterprises," *Resources, Conservation and Recycling*, vol. 182, Art. no. 106345, 2022, doi: 10.1016/j.resconrec.2022.106345.
11. A. Chaudhuri, N. Subramanian, and M. Dora, "Circular economy and digital capabilities of SMEs for providing value to customers: Combined resource-based view and ambidexterity perspective," *Journal of Business Research*, vol. 142, pp. 32–44, 2022, doi: 10.1016/j.jbusres.2021.12.039.
12. S. Kuik, A. Kumar, L. Diong, and J. Ban, "A systematic literature review on the transition to circular business models for small and medium-sized enterprises (SMEs)," *Sustainability*, vol. 15, no. 12, Art. no. 9352, 2023, doi: 10.3390/su15129352.
13. A. Neri, M. Negri, E. Cagno, S. Franzò, V. Kumar, T. Lampertico, and C. A. Bassani, "The role of digital technologies in supporting the implementation of circular economy practices by industrial small and medium enterprises," *Business Strategy and the Environment*, vol. 32, no. 7, pp. 4693–4718, 2023, doi: 10.1002/bse.3388.
14. A. Neri, M. Negri, E. Cagno, V. Kumar, and J. A. Garza-Reyes, "What digital-enabled dynamic capabilities support the circular economy? A multiple case study approach," *Business Strategy and the Environment*, vol. 32, no. 7, pp. 5083–5101, 2023, doi: 10.1002/bse.3409.
15. U. A. Saari, S. Damberg, M. Schneider, L. Aarikka-Stenroos, C. Herstatt, M. Lanz, and C. M. Ringle, "Capabilities for circular economy innovation: Factors leading to product/service innovations in the construction and manufacturing industries," *Journal of Cleaner Production*, vol. 434, Art. no. 140295, 2024, doi: 10.1016/j.jclepro.2023.140295.
16. G. Palombi, V. Schiaroli, L. Fraccascia, and F. Nonino, "Identifying barriers and good practices for implementing circular economy principles in small and medium enterprises," *Business Strategy and the Environment*, vol. 33, no. 7, pp. 6773–6794, 2024, doi: 10.1002/bse.3835.

17. W. Reim, S. Tabares, and V. Parida, "Small and medium-sized enterprises and the circular economy: Leveraging ecosystem strategies for circular business model implementation," *Organization & Environment*, vol. 38, no. 2, pp. 257–283, 2025, doi: 10.1177/10860266251325247.
18. A. Chakraborty, D. De, and P. K. Dey, "Circular economy in small and medium-sized enterprises—Current trends, practical challenges and future research agenda," *Systems*, vol. 13, no. 3, Art. no. 200, 2025, doi: 10.3390/systems13030200.
19. A. Adesua-Lincoln, "Challenges to environmental sustainability and circular economy practices of Nigerian small and medium enterprises," *Journal of Sustainable Business*, vol. 10, Art. no. 6, 2025, doi: 10.1186/s40991-025-00110-9.
20. I. Thopte, A. Evangelista, R. Jenner, and K. Poldner, "Regenerative business practices: Supporting micro, small and medium enterprises' transition to a net-positive circular economy," *Journal of Circular Economy*, vol. 3, no. 1, 2025, doi: 10.55845/GQBD2542.