Resource Recovery and Circular Economy Approaches in Industrial Waste Management: Current Developments and Future Perspectives

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***Abstract*—Industrial waste management has become an important component of sustainable manufacturing due to the rapid growth of industrialization and increasing pressure on natural resources. This review presents a comprehensive overview of resource recovery technologies and circular economy approaches for improving industrial waste utilization and minimizing environmental impacts. Conventional recovery methods, including material, water, energy, and chemical recovery, are discussed along with emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), Digital Twin, Big Data Analytics, Blockchain, Robotics, and Industry 4.0. The review also highlights recent advancements in smart Waste-to-Energy systems and intelligent resource recovery for enhancing operational efficiency and resource productivity. Existing technical, environmental, economic, and regulatory challenges, together with major research gaps, are critically analyzed. Furthermore, future perspectives including Industry 5.0 integration, carbon-neutral manufacturing, AI-driven autonomous waste management, and intelligent circular economy platforms are discussed. The review concludes that integrating advanced digital technologies with circular economy principles can significantly improve industrial sustainability, resource efficiency, and environmental performance while supporting the transition toward smart and sustainable manufacturing systems.**

***Index Terms*—Industrial Waste Management Resource Recovery Circular Economy Artificial Intelligence Sustainable Manufacturing**

I. Introduction

1.1 Background of Industrial Waste Management

Industrialization has significantly increased the generation of solid, liquid, hazardous, chemical, and electronic wastes across manufacturing sectors. Rapid industrial growth has improved economic development but has also intensified environmental pollution, resource depletion, greenhouse gas emissions, and public health concerns. Effective industrial waste management has therefore become an important component of sustainable industrial development. Modern industries are increasingly adopting advanced waste management strategies that minimize waste generation while maximizing resource utilization through recycling and recovery. Circular economy concepts have further encouraged industries to transform waste into valuable secondary resources rather than disposing of them in landfills. These approaches contribute to environmental protection, economic growth, and sustainable manufacturing practices.

Industrial waste management focuses on:

- Reduction of waste generation
- Safe handling and treatment
- Resource recovery

- Recycling and reuse
- Sustainable manufacturing practices

Table 1.1 Industrial Waste Categories

Waste Type	Major Sources	Environmental Impact	Typical Recovery Method
Solid Waste	Manufacturing	Land pollution	Recycling
Liquid Waste	Chemical industries	Water pollution	Wastewater treatment
Hazardous Waste	Petrochemical industries	Toxic contamination	Specialized treatment
Electronic Waste	Electronic industries	Heavy metal pollution	Material recovery
Chemical Waste	Process industries	Soil and water contamination	Chemical recovery

1.2 Resource Recovery Concept

Resource recovery refers to the systematic extraction of valuable materials, energy, water, and chemicals from industrial waste streams. Instead of considering waste as an unwanted by-product, modern industries treat waste as a potential resource that can contribute to economic value and environmental sustainability. Resource recovery enhances resource efficiency, reduces raw material consumption, minimizes landfill disposal, and supports circular economy implementation. It also promotes cleaner production and reduces greenhouse gas emissions associated with primary resource extraction.

Major benefits include:

- Conservation of natural resources
- Reduced production cost
- Lower environmental pollution
- Improved resource efficiency
- Sustainable industrial development

1.3 Circular Economy Fundamentals

The circular economy is a sustainable economic model that replaces the traditional linear production system with a regenerative approach based on resource circulation. The concept has evolved from industrial ecology, cleaner production, and sustainable development philosophies. Its primary objective is to maintain the value of products, materials, and resources for the longest possible period while minimizing waste generation. The four fundamental principles include Reduce, Reuse, Recycle, and Recover, which collectively improve resource productivity and environmental performance. Industries worldwide are adopting circular economy strategies to improve competitiveness, reduce waste disposal costs, and achieve long-term sustainability goals.

Table 1.2 Linear Economy vs Circular Economy

Linear Economy	Circular Economy
Take-Make-Dispose	Reduce-Reuse-Recycle-Recover
High resource consumption	Efficient resource utilization
Large waste generation	Minimum waste generation
Landfill disposal	Resource recovery
Environmental degradation	Sustainable development

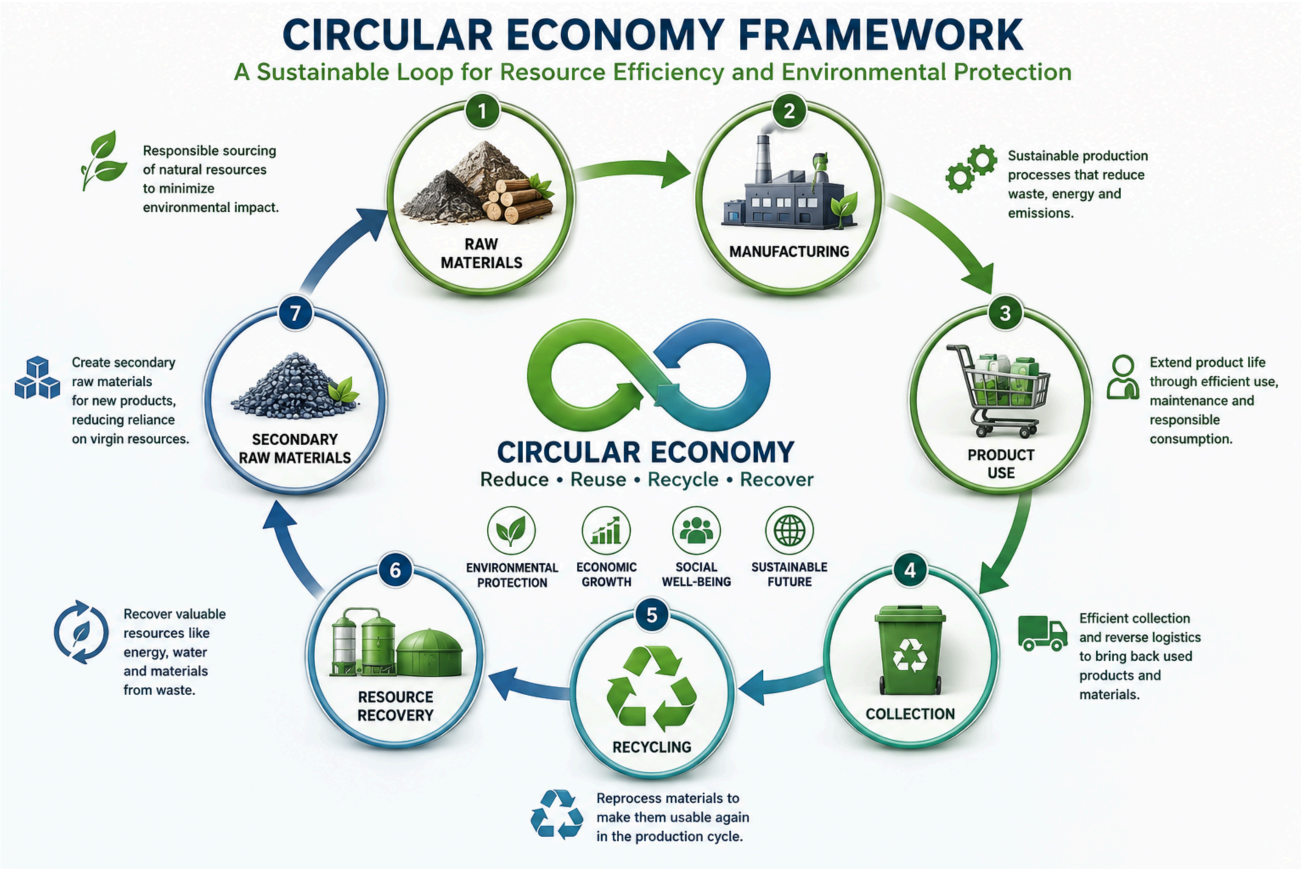


Figure 1.1 Circular Economy Framework

1.4 Objectives of the Review

This review aims to summarize recent developments in industrial resource recovery technologies and circular economy approaches for sustainable waste management. The study evaluates different recovery technologies, compares their applications, discusses industrial implementation strategies, and identifies future research opportunities. The review also highlights the integration of resource recovery with sustainable manufacturing and circular economy principles.

Research objectives

- Review industrial waste management practices.
- Study resource recovery technologies.
- Evaluate circular economy approaches.
- Compare available recovery techniques.
- Identify future research directions.

1.5 Organization of the Review Paper

The review paper is organized into three major chapters. Chapter 1 introduces industrial waste management, resource recovery concepts, circular economy fundamentals, and research objectives. Chapter 2 presents different resource recovery technologies, including material, water, energy, and chemical recovery methods. Chapter 3 discusses circular economy principles, industrial applications, performance indicators, and the benefits and limitations associated with sustainable industrial waste management.

II. Resource Recovery Technologies in Industrial Waste Management

2.1 Industrial Waste Classification

Industrial waste is generally classified into solid, liquid, hazardous, electronic, and chemical waste according to its composition and environmental impact. Proper classification enables efficient segregation, treatment, recycling, and recovery of valuable resources while reducing environmental risks. Each waste category requires different handling and processing technologies to ensure sustainable management.

2.2 Material Recovery Technologies

Material recovery involves extracting reusable materials from industrial waste streams. Common recovery technologies include metal recovery through smelting and hydrometallurgy, plastic recycling by mechanical and chemical processes, glass recycling through remelting, paper recycling by pulping, and rubber recovery through devulcanization. These technologies reduce dependence on virgin raw materials and improve circular resource utilization.

Table 2.1 Material Recovery Technologies

Material	Recovery Technique	Main Application
Metals	Smelting, Hydrometallurgy	Manufacturing
Plastics	Mechanical recycling	Packaging
Glass	Remelting	Construction
Paper	Pulp recycling	Paper industry
Rubber	Devulcanization	Automotive

2.3 Water Recovery Technologies

Water recovery technologies are increasingly adopted to reduce freshwater consumption in industries. Conventional wastewater treatment, membrane filtration, reverse osmosis, and water reuse systems remove contaminants and enable treated water to be recycled for industrial processes. These technologies improve water efficiency while reducing environmental pollution.

2.4 Energy Recovery Technologies

Energy recovery converts industrial waste into useful energy through Waste-to-Energy (WtE) technologies. Common methods include incineration, pyrolysis, gasification, anaerobic digestion, and Refuse-Derived Fuel (RDF). These technologies reduce landfill requirements while producing electricity, heat, or fuel for industrial applications.

Figure 2.1 Industrial Waste → Segregation → Material Recovery / Water Recovery / Energy Recovery / Chemical Recovery → Sustainable Industry

2.5 Chemical and Nutrient Recovery

Chemical recovery technologies recover valuable solvents, acids, catalysts, and nutrients from industrial waste streams. These recovered resources can be reused in manufacturing processes, thereby reducing chemical consumption, lowering operational costs, and minimizing hazardous waste disposal. Nutrient recovery is particularly valuable for wastewater treatment and agricultural applications.

2.6 Comparative Analysis of Resource Recovery Technologies

Different recovery technologies vary in efficiency, cost, environmental benefits, and industrial applicability. Material recovery offers high economic value, water recovery improves water conservation, energy recovery generates renewable energy, and chemical recovery enhances resource reuse. Selecting an appropriate technology depends on waste composition, industrial processes, and sustainability objectives.

Table 2.2 Comparison of Resource Recovery Technologies

Technology	Resource Recovered	Major Benefit
Material Recovery	Metals, Plastics	Resource conservation
Water Recovery	Process water	Water savings
Energy Recovery	Heat, Electricity	Renewable energy
Chemical Recovery	Solvents, Catalysts	Reduced chemical cost

III. Circular Economy Approaches for Sustainable Industrial Waste Management

3.1 Circular Economy Principles

The circular economy promotes Reduce, Reuse, Recycle, Recover, Remanufacture, and Refurbishment to extend product life and minimize waste generation. These principles improve resource utilization, reduce environmental impacts, and support sustainable industrial development by maintaining materials within productive cycles for as long as possible.

3.2 Circular Economy Models

Major circular economy models include closed-loop manufacturing, industrial symbiosis, product life-cycle management, and zero-waste manufacturing. These models facilitate resource sharing, by-product utilization, and efficient material circulation among industries, leading to improved environmental and economic performance.

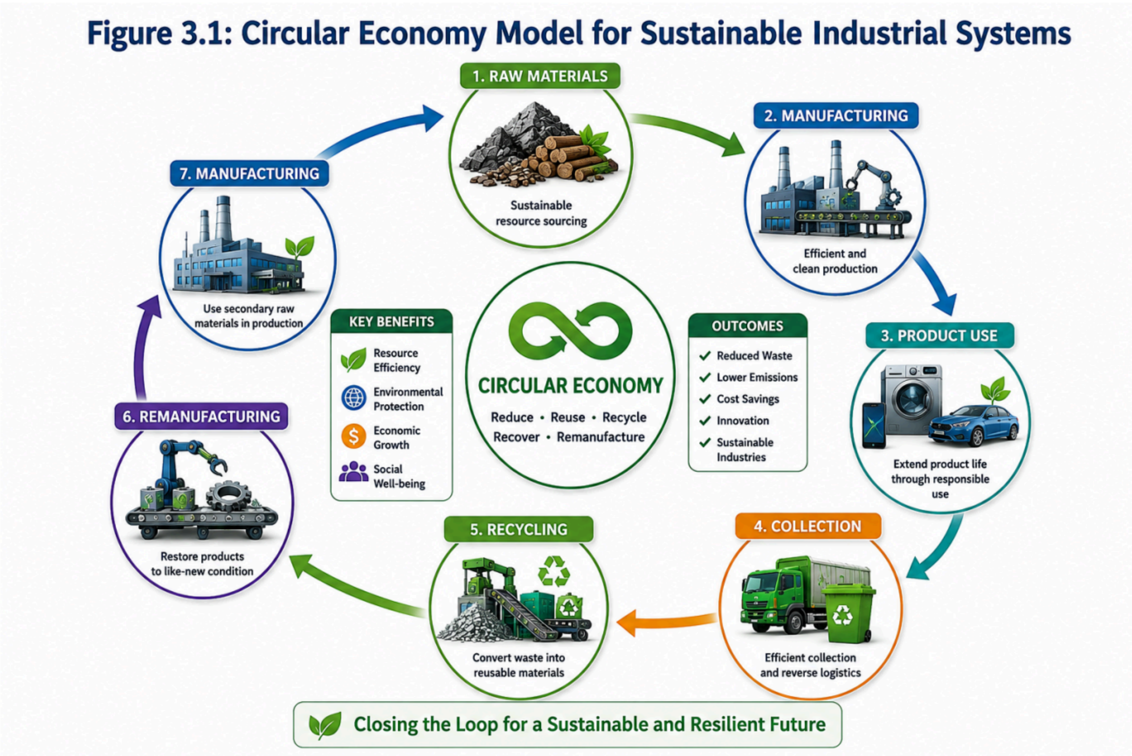


Figure 3.1 Raw Materials → Manufacturing → Product Use → Collection → Recycling → Remanufacturing → Manufacturing

3.3 Circular Economy Performance Indicators

Performance evaluation of circular economy implementation commonly uses Material Circularity Indicator (MCI), recycling efficiency, carbon footprint, resource productivity, and sustainability index. These indicators help industries assess resource efficiency and environmental performance while supporting continuous improvement.

3.4 Industrial Applications

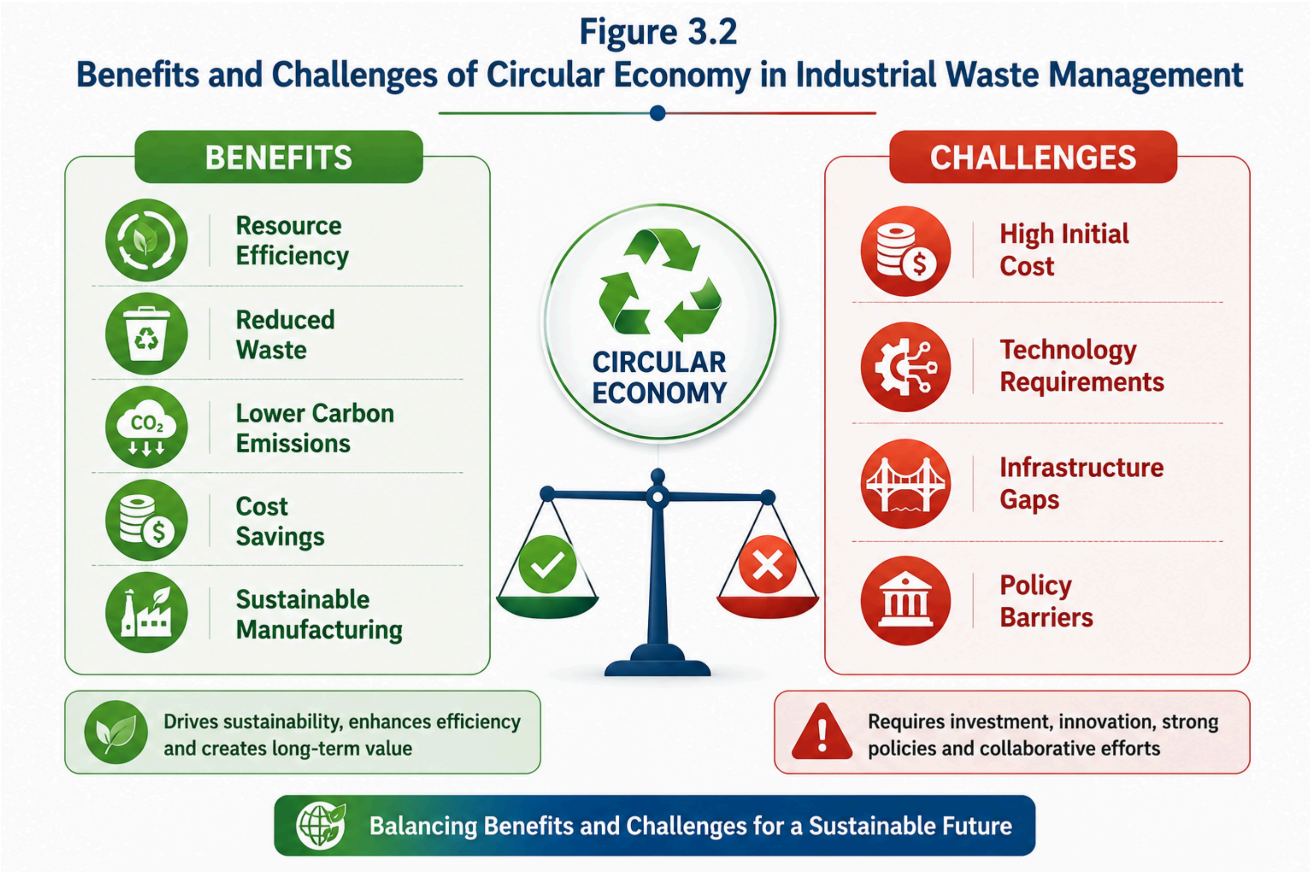
Circular economy practices are widely implemented in manufacturing, automobile, steel, chemical, food processing, and textile industries. These sectors recover valuable materials, recycle wastewater, optimize energy utilization, and reduce industrial waste generation through sustainable production systems.

Table 3.1 Industrial Applications of Circular Economy

Industry	Circular Practice	Major Benefit
Manufacturing	Closed-loop production	Waste reduction
Automobile	Component remanufacturing	Cost reduction
Steel	Slag recovery	Material conservation
Chemical	Solvent recovery	Resource efficiency
Food	Organic waste recovery	Bioenergy generation
Textile	Fibre recycling	Reduced raw material use

3.5 Benefits and Limitations of Circular Economy

The circular economy provides significant environmental, economic, and social benefits by improving resource efficiency, reducing pollution, conserving natural resources, and supporting sustainable industrial growth. However, challenges such as high initial investment, technological complexity, limited infrastructure, and policy constraints may affect large-scale implementation. Continued technological innovation and supportive regulations are essential for successful adoption across industrial sectors.



IV. Current Developments and Emerging Technologies

4.1 Artificial Intelligence in Waste Management

Artificial Intelligence (AI) has transformed industrial waste management by enabling intelligent waste classification, automated monitoring, predictive analytics, and decision support. AI algorithms analyze large volumes of waste-related data to identify waste types, predict equipment failures, optimize recycling operations, and improve resource recovery efficiency. AI-driven systems reduce human intervention while increasing operational accuracy and sustainability in industrial processes.

Major AI applications

- Waste classification
- Predictive analytics
- Intelligent decision support
- Resource recovery optimization

4.2 Internet of Things (IoT)

The Internet of Things (IoT) enables continuous monitoring of industrial waste through interconnected smart sensors and communication networks. IoT devices collect real-time information on waste quantity, quality, temperature, pH, gas concentration, and storage conditions. Cloud-based platforms process these data to support timely decision-making, predictive maintenance, and efficient waste management. Integration of IoT with AI significantly enhances industrial sustainability and operational efficiency.

Table 4.1 IoT Components in Smart Waste Management

Component	Function	Industrial Benefit
Smart Sensors	Data collection	Real-time monitoring
IoT Gateway	Data transmission	Fast communication
Cloud Platform	Data storage	Centralized management
Dashboard	Visualization	Decision support
AI Analytics	Prediction	Process optimization

4.3 Machine Learning and Deep Learning

Machine Learning (ML) and Deep Learning (DL) algorithms provide advanced capabilities for industrial waste analysis. Artificial Neural Networks (ANN), Random Forest (RF), Support Vector Machine (SVM), Long Short-Term Memory (LSTM), and XGBoost are widely applied for waste classification, process optimization, fault prediction, and intelligent decision-making. These techniques improve prediction accuracy, reduce operational costs, and enhance recovery efficiency.

4.4 Industry 4.0 Technologies

Industry 4.0 technologies are reshaping industrial waste management through Digital Twin, Big Data Analytics, Blockchain, Robotics, Automation, and Edge Computing. Digital Twins enable virtual monitoring of waste management systems, while robotics improves automated sorting and material recovery. Blockchain enhances transparency in waste tracking, and Edge Computing supports rapid local data processing for real-time control. Together, these technologies contribute to smart and sustainable manufacturing systems.

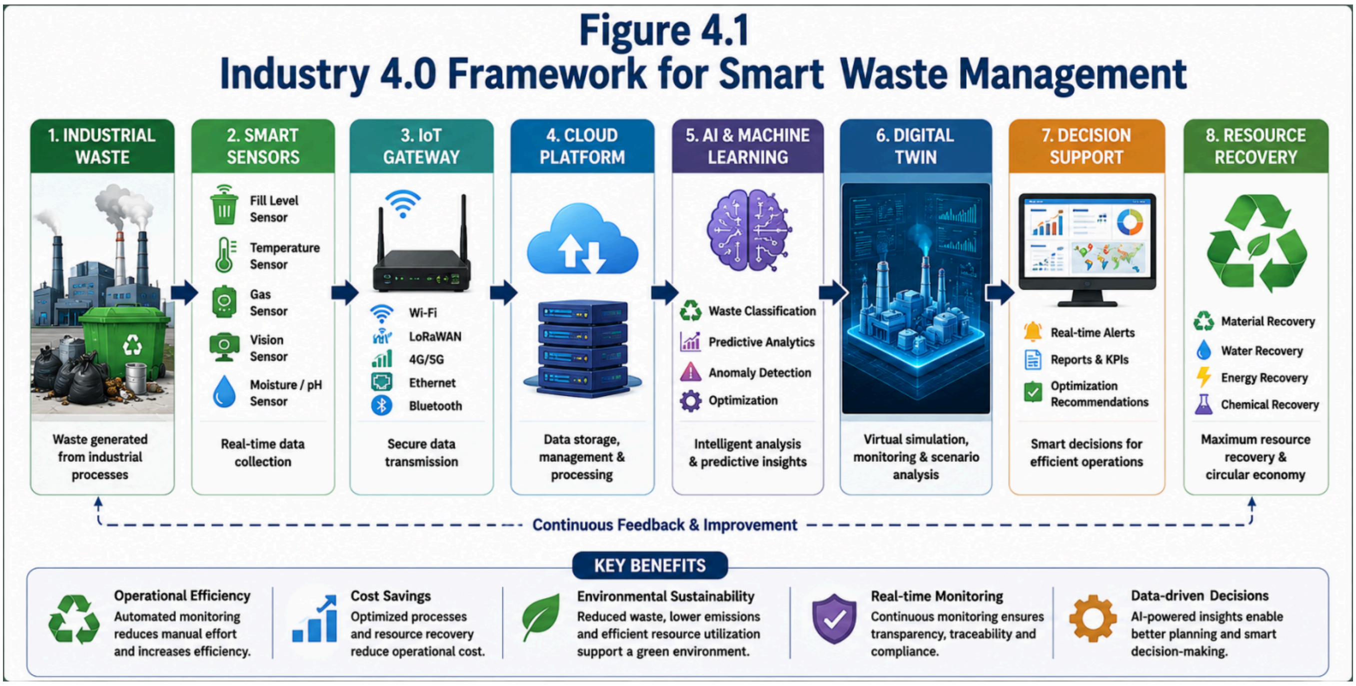


Figure 4.1 Industry 4.0 Framework for Smart Waste Management

4.5 Smart Waste-to-Energy Systems

Smart Waste-to-Energy (WtE) systems integrate AI, IoT, and advanced conversion technologies to recover energy from industrial waste. Intelligent monitoring optimizes incineration, pyrolysis, gasification, anaerobic digestion, and Refuse-Derived Fuel (RDF) production. These systems improve energy efficiency, reduce emissions, and support circular economy objectives by converting waste into electricity, heat, and valuable fuels.

4.6 Recent Global Research Trends

Recent studies emphasize AI-enabled waste management, digital circular economy platforms, Industry 4.0 integration, smart resource recovery, carbon-neutral manufacturing, and sustainable industrial ecosystems. Researchers are increasingly focusing on autonomous waste management, intelligent recycling, and data-driven optimization to improve industrial sustainability and environmental performance.

Table 4.2 Emerging Technologies and Applications

Technology	Major Application	Expected Outcome
Artificial Intelligence	Waste prediction	Smart decision-making
IoT	Real-time monitoring	Process control
Digital Twin	Virtual simulation	Performance optimization
Blockchain	Waste traceability	Transparency
Robotics	Automated sorting	Higher recovery efficiency

V. Challenges, Research Gaps, and Future Perspectives

5.1 Technical Challenges

Despite technological advancements, industries continue to face challenges in waste segregation, mixed waste processing, sensor reliability, and integration of heterogeneous data sources. These technical issues affect monitoring accuracy and resource recovery performance. Developing robust AI-IoT frameworks with standardized communication protocols is essential for reliable industrial implementation.

Major technical challenges

- Waste segregation
- Mixed waste processing
- Sensor accuracy
- Data integration

5.2 Environmental and Economic Challenges

High implementation costs, energy consumption, carbon emissions, and limited availability of recyclable resources remain significant barriers to sustainable waste management. Small and medium-sized industries often experience financial and technological constraints that hinder the adoption of advanced recovery systems. Improving process efficiency and reducing operational costs are important priorities for future development.

5.3 Policy and Regulatory Challenges

Successful implementation of circular economy practices depends on effective environmental regulations, supportive government policies, and internationally accepted standards. Inconsistent regulatory frameworks and the absence of standardized waste management guidelines limit large-scale industrial adoption. Harmonized policies can encourage investment in sustainable technologies and resource recovery infrastructure.

5.4 Research Gaps

Current literature reveals several important research gaps. Most studies focus on individual technologies rather than integrated AI-IoT systems. Industrial-scale validation remains limited, and real-time optimization techniques require further investigation. Standardized datasets and comprehensive life-cycle assessment studies are also insufficient, restricting comparative evaluation across industries.

Table 5.1 Major Research Gaps

Research Gap	Future Requirement
Integrated AI-IoT systems	Unified framework
Industrial validation	Large-scale implementation
Real-time optimization	Intelligent control
Standard datasets	Performance comparison
Life-cycle assessment	Sustainability evaluation

5.5 Future Perspectives

Future industrial waste management is expected to rely on AI-driven autonomous systems, Digital Twin-enabled circular manufacturing, intelligent resource recovery, carbon-neutral industries, green hydrogen production from industrial waste, intelligent circular economy platforms, and sustainable smart factories. Integration of Industry 5.0 technologies with human-centered and environmentally responsible manufacturing will further improve industrial sustainability and resilience.

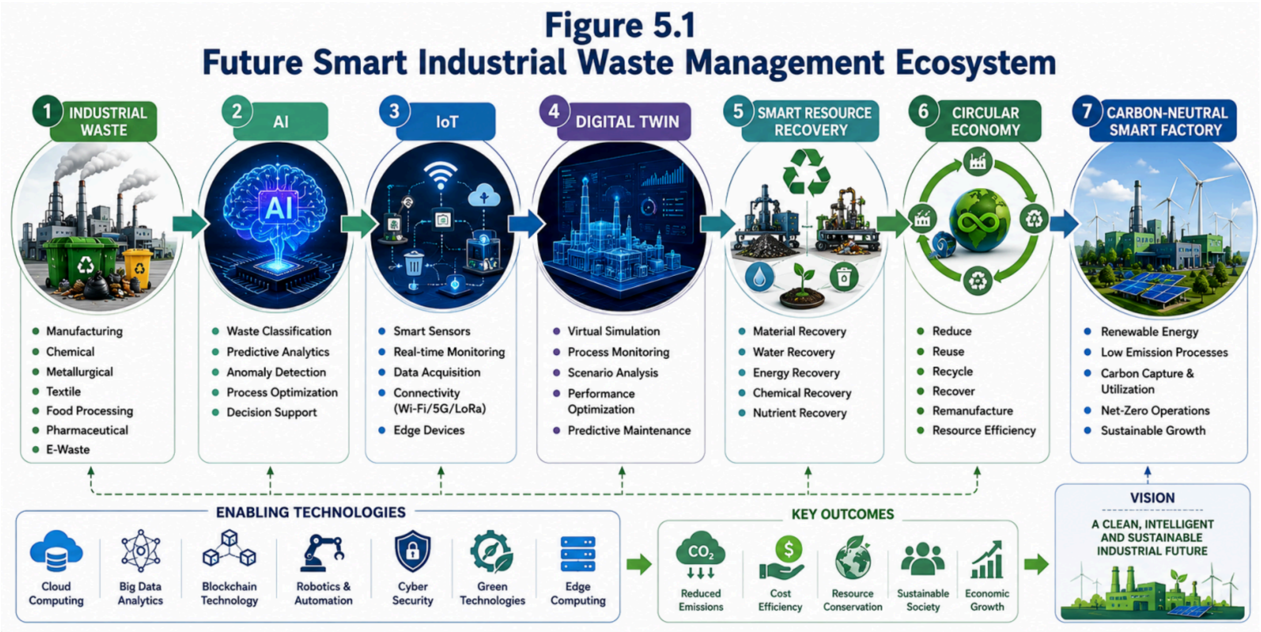


Figure 5.1 Future Smart Industrial Waste Management Ecosystem

VI. Conclusions and Future Scope

6.1 Summary of the Review

This review summarizes recent advances in industrial waste management, resource recovery technologies, circular economy principles, and emerging digital technologies. It demonstrates that integrating AI, IoT, Industry 4.0, and circular economy concepts significantly improves resource efficiency, environmental sustainability, and industrial productivity.

6.2 Major Findings

The review indicates that modern resource recovery technologies reduce waste generation, improve recycling efficiency, conserve natural resources, and support sustainable manufacturing. AI and IoT enhance monitoring accuracy, while Industry 4.0 technologies facilitate intelligent process optimization and data-driven decision-making. Circular economy models enable long-term economic and environmental benefits across industrial sectors.

6.3 Research Contributions

The review provides a comprehensive overview of conventional and emerging resource recovery technologies, summarizes recent developments in AI-based waste management, highlights research gaps, and identifies promising directions for sustainable industrial waste management and circular manufacturing.

6.4 Recommendations for Industry

Industries should adopt integrated AI-IoT platforms, strengthen digital monitoring infrastructure, implement circular manufacturing practices, invest in advanced resource recovery systems, and improve collaboration among industrial partners to enhance sustainability and operational efficiency.

6.5 Recommendations for Researchers

Future research should focus on developing standardized datasets, hybrid AI models, Digital Twin-based optimization, real-time industrial validation, comprehensive life-cycle assessment, and scalable circular economy frameworks that can be applied across diverse industrial sectors.

6.6 Conclusions

Industrial waste management is rapidly evolving through the integration of advanced digital technologies and circular economy principles. Resource recovery not only minimizes environmental impacts but also creates economic value by transforming waste into valuable materials and energy. Continuous technological innovation and supportive policy frameworks will play a crucial role in achieving sustainable and resilient industrial ecosystems.

6.7 Future Scope

Future research and industrial implementation should emphasize:

- AI-enabled decision-making for industrial waste management.
- IoT-based real-time monitoring and predictive control.
- Hybrid resource recovery technologies.
- Advanced Waste-to-Energy systems.
- Circular manufacturing ecosystems.
- Industry 5.0 integration.
- Net-zero and carbon-neutral industrial waste management.
- Green hydrogen production from industrial waste.
- Intelligent circular economy platforms.
- Sustainable smart factories supported by Digital Twin and Edge Computing.

Table 6.1 Future Research Directions

Future Area	Expected Impact
AI-based decision support	Intelligent waste management
IoT monitoring	Real-time optimization
Hybrid recovery technologies	Higher resource efficiency
Advanced Waste-to-Energy	Clean energy generation
Industry 5.0 integration	Sustainable smart manufacturing
Carbon-neutral industries	Reduced environmental impact

References

[1] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. Resources, Conservation and Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

[2] Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy—A New Sustainability Paradigm? Journal of Cleaner Production, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

[3] Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. Journal of Cleaner Production, 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

[4] Iacovidou, E., Velis, C. A., Purnell, P., et al. (2017). Metrics for Optimising the Multi-Dimensional Value of Resources Recovered from Waste in a Circular Economy: A Critical Review. Journal of Cleaner Production, 166, 910–938. https://doi.org/10.1016/j.jclepro.2017.07.100

[5] Velenturf, A. P. M., & Purnell, P. (2021). Principles for a Sustainable Circular Economy. Sustainable Production and Consumption, 27, 1437–1457. https://doi.org/10.1016/j.spc.2021.02.018

[6] Nizami, A. S., Rehan, M., Waqas, M., Naqvi, M., Ouda, O. K. M., Shahzad, K., Miandad, R., Khan, M. Z., Syamsiro, M., & Ismail, I. M. I. (2017). Waste Biorefineries: Enabling Circular Economies in

Developing Countries. Bioresource Technology, 241, 1101–1117. https://doi.org/10.1016/j.biortech.2017.05.097

[7] Morseletto, P. (2020). Targets for a Circular Economy. Resources, Conservation and Recycling, 153, 104553. https://doi.org/10.1016/j.resconrec.2019.104553

[8] Winans, K., Kendall, A., & Deng, H. (2017). The History and Current Applications of the Circular Economy Concept. Renewable and Sustainable Energy Reviews, 68, 825–833. https://doi.org/10.1016/j.rser.2016.09.123

[9] Kristensen, H. S., & Mosgaard, M. A. (2020). A Review of Micro-Level Indicators for a Circular Economy: Moving Away from the Three Dimensions of Sustainability? Journal of Cleaner Production, 243, 118531. https://doi.org/10.1016/j.jclepro.2019.118531

[10] Stahel, W. R. (2016). The Circular Economy. Nature, 531(7595), 435–438. https://doi.org/10.1038/531435a

[11] Vogiantzi, C., & Tserpes, K. (2023). On the Definition, Assessment, and Enhancement of Circular Economy across Various Industrial Sectors: A Literature Review and Recent Findings. Sustainability, 15(23), 16532. https://doi.org/10.3390/su152316532

[12] Geetha, R. (2025). Circular Economy through Integrated Industrial Ecology: Innovations in Resource Recovery and Process Re-Design. Biotechnology Notes, 6, 245–259. https://doi.org/10.1016/j.biotno.2025.10.005

[13] Zaman, A. (2026). Are Industrial Ecology, Circular Economy and Zero Waste Converging or Diverging Frameworks for Sustainable Resource and Waste Management? Circular Economy and Sustainability. https://doi.org/10.1007/s43615-026-00889-0

[14] Mansouri, A., Bennis, I., Siadat, A., et al. (2026). Transitioning Manufacturing Toward Circular Economy: A Systematic Review of Practices, Digital Enablers, and Implementation Barriers. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-026-00994-0

[15] Osuizugbo, I. C., Awuzie, B. O., & Oyeyipo, O. O. (2026). Closing the Loop: A Systematic Review and Future Directions for Resource Recovery in the Construction Industry. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-026-00801-w

[16] Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and Its Limitations. Ecological Economics, 143, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

[17] Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product Design and Business Model Strategies for a Circular Economy. Journal of Industrial and Production Engineering, 33(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

[18] de Jesus, A., & Mendonça, S. (2018). Lost in Transition? Drivers and Barriers in the Eco-Innovation Road to the Circular Economy. Ecological Economics, 145, 75–89. https://doi.org/10.1016/j.ecolecon.2017.08.001

[19] Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular Economy – From Review of Theories and Practices to Development of Implementation Tools. Resources, Conservation and Recycling, 135, 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034

[20] Merli, R., Preziosi, M., & Acampora, A. (2018). How Do Scholars Approach the Circular Economy? A Systematic Literature Review. Journal of Cleaner Production, 178, 703–722. https://doi.org/10.1016/j.jclepro.2017.12.112

[21] Velenturf, A. P. M., Archer, S. A., Gomes, H. I., Christgen, B., Lag-Brotons, A. J., & Purnell, P. (2019). Circular Economy and the Matter of Integrated Resources. Science of the Total Environment, 689, 963–969. https://doi.org/10.1016/j.scitotenv.2019.06.449

[22] Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union. Ecological Economics, 150, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

[23] Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A Taxonomy of Circular Economy Indicators. Journal of Cleaner Production, 207, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014

[24] Campbell-Johnston, K., ten Broeke, G., Witte, B., & Reike, D. (2021). The Circular Economy and Cascading: Towards a Framework. Resources, Conservation and Recycling, 164, 105180. https://doi.org/10.1016/j.resconrec.2020.105180

[25] Nogueira, I. M. C. A., Gohr, C. F., & Santos, L. C. (2026). Exploring the Integration Between Industry 4.0 Technologies and Circular Economy Practices: A Systematic Literature Review and ISM/MICMAC Approach. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-026-00835-0

[26] Wada, O. Z., Ige, A. O., Egbewole, B. I., & Olawade, D. (2026). Circular Economy from Wastewater Resource Recovery: A Review of Recent Advances and Global Disparities. Sustainable Chemistry One World, Article 100187. https://doi.org/10.1016/j.scowo.2026.100187

[27] Olawade, D., Yadav, R. N., Ijiwade, J. O., & Wada, O. Z. (2026). AI-Driven Circular Economy Optimization in Waste Management: A Review of Current Evidence. Environmental Progress & Sustainable Energy, 45(3), e70322. https://doi.org/10.1002/ep.70322

[28] Veerasundaram, J., Suyamburajan, V., Kumarasamy, S., Govindasamy, M., Manickam, A., & Meenashisundaram, G. K. (2026). The Circular Economy Paradigm: Integrating Theory, Practices, and Innovations for Sustainable Development. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-026-01022-x

[29] Maqsoom, A. (2026). Research Trends and Thematic Evolution of Circular Economy and Industrial Symbiosis in Construction and Demolition Waste. Sustainability, 18(11), 5440. https://doi.org/10.3390/su18115440

[30] Sharma, V., Dua, S., Garg, S., Arora, P., Garg, S., Arif, N., et al. (2026). Material Resource Recovery from Municipal Solid Waste in India: Policy Evolution, Implementation Challenges, and the Path Forward. Waste Management & Research. https://doi.org/10.1177/0734242X261419236