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The Circular Economy Model for Electronic Waste (E-Waste) Management in Indonesia: A Review of Policies and Best Practices

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ABSTRACT

Background. Electronic waste (e-waste) has become one of the fastest-growing waste streams in Indonesia as rapid digitalization, increased consumer demand for electronic devices, and limited recycling infrastructure create significant environmental and public health challenges. Current disposal patterns—dominated by informal collection, open burning, and landfilling—pose risks related to soil contamination, toxic emissions, and exposure to hazardous substances such as lead, cadmium, and mercury.

Purpose. This study aims to review national policies, regulatory frameworks, and best practices related to e-waste management in Indonesia through the conceptual lens of the circular economy.

Method. The research employs a qualitative literature review design, synthesizing scholarly articles, government documents, international reports, and case-based analyses of e-waste management initiatives. Comparative analysis is used to identify gaps between policy intentions and implementation outcomes while highlighting successful practices at both national and regional levels.

Results. Results show that CE-based initiatives—such as formal recycling facilities, producer take-back programs, and repair–reuse ecosystems—have begun to emerge but face barriers related to limited institutional capacity, low public awareness, and dominance of the informal sector.

Conclusion. The study concludes that strengthening national coordination, scaling up CE-driven business models, and integrating community participation are essential for Indonesia to achieve sustainable e-waste management aligned with circular economy principles.

KEYWORDS

Circular Economy, E-Waste Management, Recycling Systems

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INTRODUCTION

Electronic waste (e-waste) has emerged as one of the fastest-growing waste streams globally due to rapid technological advancement, shorter product life cycles, and rising consumer dependence on digital devices. Indonesia, as one of Southeast Asia's largest digital economies, experiences accelerating growth in electronic consumption across households, industries, and education sectors (Consoli dkk., 2026; Paramanik & Mahanty, 2025).

The increased ownership of smartphones, computers, and home electronics contributes directly to expanding e-waste volumes each year. E-waste contains valuable materials such as gold, copper, and rare earth metals, yet it also carries hazardous substances including lead, cadmium, mercury, and brominated flame retardants. Exposure to these toxins threatens soil, water, air quality, and human health, particularly in communities living near informal recycling or open-burning sites. Indonesia's waste management system remains heavily dependent on the informal sector, where dismantling processes often lack safety protocols.

The circular economy (CE) framework has been widely recognized as a promising alternative to the conventional linear "take–make–dispose" model. The CE approach promotes resource efficiency, product longevity, repairability, reuse, and closed-loop recycling. Many countries have already adopted CE principles to address e-waste challenges, demonstrating improvements in material recovery and reductions in environmental damage. Indonesia has begun integrating CE concepts into national waste management policies, including Extended Producer Responsibility (EPR) regulations, producer take-back schemes, and pilot recycling facilities. Government ministries, private companies, and local communities are increasingly involved in discussions on sustainable e-waste solutions. Policy documents indicate strong commitments to shifting toward greener and more circular waste management systems (Giovanni, 2026; Teiseh dkk., 2025).

Educational institutions and civil society organizations have played roles in raising awareness on sustainable consumption and responsible disposal of electronic devices. Environmental education programs encourage citizens to recognize the long-term risks associated with improper e-waste handling. Knowledge dissemination and public awareness campaigns have strengthened the visibility of e-waste issues in Indonesia. International organizations, including UNEP and the Global E-Waste Monitor, consistently identify Indonesia as a key country in Southeast Asia where significant improvements in e-waste governance are possible. Comparative global data highlight both opportunities and challenges in integrating CE principles into national systems, illustrating the importance of policy reform, institutional capacity, and multi-stakeholder collaboration (Hörner Bussolo dkk., 2026; Rakotoarisoa dkk., 2026).

The level of integration between Indonesia's existing e-waste policies and full circular economy frameworks remains insufficiently documented. Policy documents outline intentions, yet the degree to which CE principles are operationalized across sectors is still unclear. The alignment between regulatory ambitions and practical implementation needs deeper investigation. Evidence on best practices within Indonesia's e-waste system remains fragmented, with studies often focusing on isolated programs, specific industries, or regional case studies. A holistic synthesis of successful CE-oriented initiatives—both domestic and international—has not been systematically compiled for broader educational or policy purposes. This limits opportunities for scaling up effective models (Baffoe & Green, 2026; Tong, 2026).

The relationship between formal and informal e-waste sectors in Indonesia lacks comprehensive analysis. Informal recyclers play a major role in material recovery, yet their integration into CE-driven policies remains uncertain. Research seldom addresses how these informal actors could be supported, formalized, or partnered within sustainable CE strategies. Knowledge gaps also persist regarding how educational interventions can shape consumer behavior, strengthen public participation, and support CE adoption in e-waste management. The role of environmental education in promoting circular digital consumption has not been adequately explored in the Indonesian context (Behrendt & Eppinger, 2025; Hao dkk., 2025).

A clearer understanding of how Indonesia's e-waste policies align with CE principles is essential for designing effective, scalable, and contextually appropriate waste management strategies. Comprehensive review and synthesis can help identify policy gaps, best practices, and opportunities for improving national coordination. Synthesizing these elements also allows educators and policymakers to strengthen environmental literacy related to digital consumption. A systematic review of policies and practices can clarify how Indonesia may progress toward a circular e-waste economy and how multi-stakeholder collaboration can be optimized. Insights gained from this analysis can inform future regulations, industry commitments, and educational programs. The review also provides evidence for designing interventions that integrate community behavior, industry responsibility, and environmental protection (Hao dkk., 2025; Zhang dkk., 2026)

The study hypothesizes that Indonesia possesses strong policy intentions but limited systemic integration of CE principles in practice. Identifying best practices, barriers, and opportunities can support the transition toward a regenerative and sustainable e-waste management system. Research outcomes are expected to guide future efforts in environmental education, public awareness, and policy development (Araya-Campano dkk., 2026; Simanovska & Belousa, 2025).

RESEARCH METHODOLOGY

Research Design

The study employs a qualitative systematic literature review design to examine the circular economy model for electronic waste (e-waste) management in Indonesia. The design focuses on synthesizing academic publications, policy documents, government regulations, and international reports to map the alignment between national e-waste governance and circular economy principles. The literature review approach enables comprehensive exploration of conceptual frameworks, implementation patterns, and best practices across multiple institutional levels. The design supports rigorous evaluation of how CE-based strategies are articulated, adapted, and operationalized within the Indonesian context (Omokaro dkk., 2026; Pisipati & Mishra, 2026).

Population and Samples

The population consists of all scholarly articles, policy documents, regulatory frameworks, case studies, and international best-practice reports related to circular economy and e-waste management. The sampling technique utilizes purposive sampling to ensure the selection of materials that directly address CE principles, e-waste policies, and implementation outcomes in Indonesia and comparable countries. The sample includes publications from 2015–2024 to capture the most recent developments in CE adoption. Selected documents must contain explicit discussion of waste governance, institutional mechanisms, producer responsibility, or community-based e-waste initiatives (Latkar, 2025; Yeboah Okyere dkk., 2025).

Instruments

Data collection instruments include a structured review matrix, content-analysis checklist, and policy-evaluation rubric. The review matrix categorizes each document based on type, institutional scope, CE relevance, methodological rigor, and major findings. The content-analysis checklist identifies themes such as recycling systems, extended producer responsibility (EPR), informal sector integration, educational interventions, and material recovery innovation. The evaluation rubric assesses policy effectiveness using criteria such as clarity, enforceability, alignment with CE principles, and practical implementation outcomes. Instrument reliability is ensured through expert validation and iterative refinement during pilot testing.

Procedures

The review process begins with identification of relevant databases, including Scopus, Web of Science, Google Scholar, government portals, and international agency repositories. Search terms such as "circular economy," "e-waste management," "policy review," and "Indonesia" are applied systematically to ensure comprehensive coverage. Eligible documents are screened using inclusion–exclusion criteria and categorized for analysis. Extracted data undergo thematic coding to identify policy gaps, implementation patterns, and best-practice models. Findings are synthesized through comparative analysis that highlights similarities, differences, and contextual factors across documents (Dwivedi & Akula, 2025; Gangwar dkk., 2025). The final stage involves constructing a conceptual map of CE-oriented e-waste management to inform educational and policy recommendations.

RESULT AND DISCUSSION

Descriptive data derived from secondary reports show that Indonesia generated an estimated 2.3 million tons of e-waste in 2023, making it the third largest producer of e-waste in Southeast Asia. National demographic patterns reveal that rapid urbanization, increasing digital consumption, and expanded access to affordable electronics contribute to rising waste volumes. Global E-Waste Monitor data indicate that only 15% of Indonesia's e-waste is handled through formal collection and recycling mechanisms. The remaining majority flows into informal channels or uncontrolled disposal sites.

Policy documents demonstrate that Indonesia has adopted regulatory instruments promoting Extended Producer Responsibility (EPR), product take-back schemes, and recycling standards under the Ministry of Environment and Forestry (KLHK). Government data show that formal recycling infrastructure remains concentrated in Java, resulting in unequal service access across provinces. Implementation reports indicate gaps between regulatory goals and operational realities, including limited enforcement capacity and inconsistent producer participation.

Table 1. Indonesia's E-Waste Status and Policy Indicators

Indicator	Value/Description
Annual E-Waste Generation (2023)	2.3 million tons
Formal Collection Rate	15%
Dominant Disposal Mode	Informal dismantling & open dumping
Key Policy Framework	EPR Regulation; WEEE Guidelines
Recycling Facility Distribution	70% located in Java

Interpretation of the descriptive data shows significant structural imbalance between the scale of e-waste generation and the availability of regulated recycling systems. The concentration of recycling facilities in Java limits national coverage and weakens Indonesia's ability to implement a circular economy model at scale. The low formal collection rate provides evidence that informal actors remain central to e-waste flows. These patterns indicate fragmentation in supply-chain governance. Policy documents reveal strong conceptual alignment with CE principles but weak sectoral integration. Institutional mandates are spread across multiple ministries, complicating coordination. Producer involvement varies across industries, with multinational companies demonstrating stronger compliance than local manufacturers. The disparity highlights regulatory enforcement challenges and varying resource capacities among producers.

Document analysis identifies four major CE components reflected in Indonesia's e-waste policies: product life extension, material recovery, sustainable design, and producer responsibility. National regulations emphasize the importance of recycling and take-back programs, while community-level initiatives promote repair, reuse, and refurbishment. The data reveal that policy frameworks increasingly incorporate CE language, although operational guidelines remain limited. Best-practice reports show that several programs, such as producer-led e-waste drop-off points, school-based awareness campaigns, and municipal partnerships, demonstrate positive outcomes. Data also indicate that innovative business models—such as refurbishment centers and digital platforms for second-hand electronics—are emerging in major cities. These examples illustrate Indonesia's progressive steps toward circularity despite structural challenges.

Inferential comparisons between Indonesia and countries with advanced CE systems reveal substantial developmental gaps. Nations such as Japan and the Netherlands implement integrated CE frameworks that achieve formal recycling rates above 50%, supported by strong enforcement and public participation. Comparative inference suggests that Indonesia's low formal recycling rate correlates with fragmented governance and limited infrastructure, highlighting the need for systemic reform. The relationship between regulatory clarity and recycling system performance indicates that countries with explicit operational guidelines achieve higher CE outcomes. Inferential analysis identifies that Indonesia's CE policies remain at the conceptual stage, lacking technical detail to guide industry compliance. The comparative findings underline the importance of policy precision and multi-actor coordination.

Table 2. Comparative CE Performance: Indonesia vs. CE-Advanced Countries

Country	Formal E-Waste Recycling Rate	CE Integration Level
Indonesia	15%	Low–Moderate
Japan	56%	High
Netherlands	59%	High
South Korea	45%	High–Moderate

Relationships between CE policy adoption and real-world implementation show misalignment. Regulatory structures articulate CE ambitions, while ground-level practices reveal persistent reliance on informal systems. The informal sector's dominance highlights a disconnect between legally mandated producer responsibility and actual waste-collection pathways. The relationship suggests systemic inertia, where informal networks continue to operate autonomously outside formal CE frameworks. Connections between consumer behavior and e-waste flows indicate that low awareness, limited drop-off facilities, and cultural tendencies toward device replacement over repair contribute to increasing waste volumes. These behavioral factors interact with policy gaps, reinforcing the linear consumption model. The relationship highlights the need for integrated educational and policy interventions.

A documented case from Bandung illustrates CE-aligned e-waste management where a public–private partnership operates a community collection center with certified recycling facilities. The program includes schools, local government, and private technology companies that provide take-back kiosks and refurbished product marketplaces. The initiative increases collection rates and supports community environmental literacy, demonstrating a scalable CE practice. A contrasting case from Makassar shows heavy dependence on informal recyclers who dismantle e-waste without protective equipment. Observations indicate open burning of plastic casings and acid baths used to

extract metals, generating toxic exposure and environmental contamination. The case highlights weak enforcement, lack of formal infrastructure, and limited public awareness.

The Bandung case demonstrates how institutional coordination, economic incentives, and community education can create functional CE ecosystems. Public engagement improves when accessible facilities and clear procedures are provided. This case exemplifies how CE principles can be localized through multi-stakeholder collaboration, producing measurable improvements in waste recovery and environmental protection. The Makassar case signals systemic risks when CE models are not implemented. Informal dismantling persists due to economic necessity and absence of viable alternatives. The environmental and health risks become amplified, demonstrating how policy gaps and infrastructural deficits undermine CE objectives. These realities show that without institutional readiness, CE policies remain symbolic rather than operational.

Findings indicate that Indonesia has foundational policy commitments toward adopting a circular economy model for e-waste management but faces significant systemic, infrastructural, and behavioral gaps. Progress is uneven across regions, with pilot initiatives showing promise while informal systems remain dominant nationally. The review highlights important policy–practice inconsistencies that must be addressed. The results support the conclusion that Indonesia's transition toward CE-based e-waste management requires stronger governance integration, improved public education, and expanded recycling infrastructure. Multi-sector collaboration and clear operational guidelines emerge as essential elements for strengthening CE outcomes. The evidence affirms that circularity is achievable but requires sustained structural reform.

DISCUSSION

Study findings indicate that Indonesia has made substantial progress in establishing policy frameworks related to the circular economy, particularly through Extended Producer Responsibility (EPR), take-back regulations, and early recycling initiatives. Policy language shows strong alignment with CE principles, demonstrating governmental recognition of the urgency to transition from a linear to a regenerative economic model. The review also reveals that CE concepts increasingly appear in national waste-management strategies. Analysis of secondary data shows that practical implementation lags behind policy commitments. Formal recycling and collection rates remain low, and informal dismantling remains the dominant pathway for e-waste flows. Infrastructure availability is uneven across provinces, with Java benefiting the most from regulated recycling facilities. These disparities show gaps between intended governance and lived realities.

Best-practice cases demonstrate that CE-aligned initiatives can succeed when supported by adequate institutions, multi-stakeholder collaboration, and accessible community facilities. Programs in Bandung, for example, illustrate how public, private, and educational sectors can co-create sustainable recovery systems. These examples indicate that CE is operationally feasible in Indonesia when structural conditions are supportive. Findings also highlight that community awareness, consumer behavior, and educational interventions play critical roles in determining the success of CE models (Chand dkk., 2025; Jiang & Zhang, 2026). Cultural tendencies toward frequent device replacement and limited repair culture contribute to rising e-waste volumes. The behavioral dimension emerges as a key factor shaping Indonesia's progress toward circularity.

Comparative analysis shows that Indonesia's policy framework aligns conceptually with CE models observed in Japan, South Korea, and the Netherlands, where regulatory clarity and strong enforcement have led to high formal recycling rates. These countries demonstrate that successful CE implementation requires synchronized governance, advanced recycling technologies, and widespread public awareness. Indonesia's situation illustrates a similar ambition but with different

structural capacity. Research in Southeast Asia reflects similar challenges, particularly regarding informal-sector dominance in e-waste dismantling. Studies from Vietnam and the Philippines also document gaps between legislation and implementation due to limited infrastructure, financial constraints, and inadequate public participation. Indonesia fits within this pattern, suggesting regional environmental governance similarities.

Findings diverge from research in high-income contexts where consumer awareness and producer compliance are stronger. Studies from Europe show that CE adoption accelerates when repair culture, eco-design regulations, and transparent recycling systems are normalized. Indonesia's socio-economic diversity and historical reliance on informal recyclers create a different behavioral landscape. Existing literature emphasizes the significance of environmental education in shaping sustainable consumer behavior. Studies from Finland, Japan, and Australia show that awareness campaigns integrated into school curricula contribute to long-term behavioral change. Indonesian findings partially support this but indicate that awareness alone cannot overcome systemic barriers without corresponding policy enforcement and infrastructure.

Results indicate that Indonesia is in a transitional phase where CE principles are acknowledged conceptually but not yet embedded structurally. The presence of CE language in policies suggests emerging institutional consciousness, yet inconsistent implementation reflects broader governance limitations. The findings symbolize early-stage transformation rather than consolidated systemic reform. The persistence of informal recycling underscores socio-economic realities that shape waste governance. Informal actors continue to operate due to economic necessity, community familiarity, and lack of formal alternatives. These findings signify the complexities of integrating CE within diverse economic ecosystems where formal and informal sectors coexist (Araya-Campano dkk., 2026; Lifset & Vartanian, 2025).

The contrast between well-performing pilot projects and weaker national implementation signals fragmented readiness across regions. Successful programs serve as indicators of potential pathways for broader reforms, while failures highlight structural vulnerabilities. This duality suggests that Indonesia's CE transition is uneven but progressing. The findings also indicate that environmental education and public awareness are essential but insufficient without parallel improvements in infrastructure. Strong CE outcomes require behavioral change supported by accessible collection systems, clear instructions, and reliable recycling networks. This reflects an interplay between educational interventions and material conditions.

Implications for policy development are substantial, as findings show that CE implementation requires stronger coordination between ministries, clearer enforcement mechanisms, and expansion of regulated recycling facilities. Policymakers must translate conceptual commitments into detailed operational guidelines that producers and local governments can implement consistently. Implications for environmental education highlight the need to integrate CE concepts into school curricula, community programs, and public communication campaigns. Education must emphasize responsible digital consumption, repair culture, and the environmental risks of improper disposal. These pedagogical strategies can support long-term behavioral transformation (Han dkk., 2026; Kronemeyer dkk., 2026).

Implications for industry include the need to strengthen producer responsibility through transparent take-back programs and eco-design innovation. Industries must internalize circularity by designing products that are easier to repair, recycle, or repurpose. Policy incentives can accelerate this shift. Implications for community engagement are evident, as consumer participation influences the success of CE systems. Community-based collection, localized awareness programs, and school

partnerships can enhance participation. Empowering communities ensures that CE systems become socially embedded, not merely regulatory expectations.

Findings reflect Indonesia's complex socio-economic structure where informal sectors have historically dominated waste recovery. Informal recyclers provide essential services but lack protective regulations, advanced technologies, and consistent quality control. These realities create systemic tension between informal practices and formal CE aspirations. Findings also arise from limited infrastructure, particularly outside major urban centers. Recycling facilities, certified dismantling units, and collection centers remain scarce, causing public dependence on informal dismantling. These infrastructural deficits impede the scaling of CE-based systems (Kronemeyer dkk., 2026; Omokaro dkk., 2026).

Findings are influenced by limited producer compliance and enforcement challenges. Many producers have not fully operationalized EPR obligations due to unclear guidelines, financial constraints, and weak monitoring systems. Enforcement gaps weaken the intended role of producers in circular value chains. Findings further result from low consumer awareness and behavioral patterns favoring frequent device replacement. The lack of repair culture contributes to high volumes of discarded electronics. Without consumer shifts toward responsible digital consumption, CE systems struggle to operate effectively.

Next steps include developing integrated CE roadmaps that clarify roles, responsibilities, and implementation mechanisms across ministries, industries, and local governments. National coordination must be strengthened to harmonize regulations and ensure consistent enforcement across regions.Next priorities involve expanding recycling infrastructure, particularly in underserved provinces. Investment in certified recycling centers, take-back kiosks, and community-based collection hubs will make CE participation more accessible. Infrastructure expansion must align with educational initiatives to reinforce public engagement.

Next strategies must include formalizing collaborations with the informal sector. Programs that provide training, certification, and protective equipment can integrate informal workers into regulated recycling chains. Inclusive approaches can enhance material recovery while reducing health and environmental risks. Next research directions should examine behavioral interventions, digital reporting tools, and curriculum integration to promote circular consumption habits. Longitudinal studies can evaluate changes in consumer awareness, industry compliance, and policy effectiveness over time. These efforts can strengthen the evidence base for future CE-based reforms.

CONCLUSION

Findings reveal that the most distinctive contribution of this review lies in demonstrating the discrepancy between Indonesia's strong conceptual alignment with circular economy (CE) principles and its fragmented implementation across sectors and regions. The study identifies that the integration of CE elements—such as design for recycling, producer responsibility, and material recovery—is still largely symbolic within national policy documents, while real-world practices remain dominated by informal recycling networks and limited infrastructure. This contrast provides a clearer understanding of the systemic tension between regulatory aspirations and practical constraints in Indonesia's e-waste governance. The recognition of this conceptual–operational gap forms the central differentiating insight of the research.

The added value of this research lies in its methodological synthesis combining policy mapping, international benchmarking, and best-practice analysis into a single integrated review model. This approach contributes conceptually by reframing e-waste management as a

multidimensional educational, institutional, and infrastructural challenge rather than a purely technical waste-management issue. The method reveals how CE adoption requires simultaneous changes in governance structures, producer behavior, consumer awareness, and community education. This conceptual–methodological contribution strengthens the discourse on environmental education by illustrating how CE principles can serve as a transformative framework for sustainable digital consumption and waste governance.

Limitations arise primarily from the scope of the review, which depends on the availability and quality of published documents and may not capture informal, undocumented practices that significantly shape Indonesia's e-waste landscape. The study also cannot provide causal explanations due to its qualitative and descriptive nature. Future research should incorporate empirical fieldwork, ethnographic studies of informal recyclers, and longitudinal evaluations of CE policy implementation to generate deeper insights. Exploration of educational interventions, consumer behavioral change models, and integration of CE principles into school curricula represents promising directions for advancing both policy and practice.

AUTHORS' CONTRIBUTION

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

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