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Optimizing Waste Management for Circular Economy and Low-Carbon Development: A Case Study of Depok City, Indonesia

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ABSTRACT

In Depok, Indonesia, rapid urbanization and economic growth have significantly increased waste production, exposing inefficiencies in existing management systems that contribute to environmental, health, and socio-economic problems, including pollution and rising greenhouse gas (GHG) emissions. This study evaluates the investment and operational requirements for optimal waste management, estimates potential GHG reductions compared to a Business as Usual (BAU) baseline in 2030, and examines policy implications that support a circular economy and low-carbon development. A mixed-method approach was employed by integrating field surveys, stakeholder interviews, and secondary data from local government and environmental agencies. Emissions were calculated for 2025 to 2030 using Intergovernmental Panel on Climate Change (IPCC) 2006 Tier 1 methods, while descriptive analysis was applied to interpret institutional and policy readiness. The results demonstrate that an optimized scenario, which emphasizes decentralized composting, recycling infrastructure, and improved governance, could achieve a 65% reduction in GHG emissions by 2030 relative to the BAU baseline. Beyond quantifying emissions, the novelty of this study lies in integrating financial, environmental, and governance dimensions within a city-level framework, which remains underexplored in Indonesian and Southeast Asian waste management research. Strategic recommendations include upgrading community-based facilities, implementing fair waste tariffs consistent with the polluter pays principle, and fostering greater citizen participation. By linking emission mitigation with financial feasibility and institutional mechanisms, this study highlights how secondary cities such as Depok can serve as models for advancing circular economy and low-carbon urban transitions in Indonesia.

Introduction

Urbanwaste management remains one of Indonesia's most pressing development challenges. Accelerated population growth, rapid urbanization, and expanding economic activities have significantly increased waste generation across cities. When managed ineffectively, this mounting waste contributes not only to environmental degradation but also to serious health and socio-economic problems. Poor waste handling practices often result in pollution of water, soil, and air, while also endangering ecosystems and biodiversity [1]. In addition, inadequate waste treatment methods are known to raise greenhouse gas (GHG) emissions substantially [2].

Recognizing these threats, the Indonesian government has prioritized GHG reduction in the waste sector, as articulated in both the National Medium Term Development Plan (*Rencana Pembangunan Jangka Menengah/*RPJMN) 2020–2024, as stipulated in Presidential Regulation No. 18 of 2020 on the RPJMN 2020–2024, and the newly enacted RPJMN 2025–2029, as stipulated in Presidential Regulation No. 12 of 2025. These development plans stress the importance of economic resilience, social stability, and environmental

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quality improvement. Among the core strategies are promoting circular economy principles, enhancing material efficiency, reducing waste generation, and accelerating low-carbon growth. Recent studies affirm that traditional practices such as unmanaged landfilling and open burning remain major contributors to GHG emissions in the country [3]. By transitioning to a circular economy model and strengthening waste management infrastructure, Indonesia can significantly reduce its emissions footprint [4] while also supporting the achievement of its updated Nationally Determined Contribution (NDC) targets under the United Nations Framework Convention on Climate Change (UNFCCC) framework.

In this broader policy context, it is crucial to understand waste management in the context of the circular economy and low-carbon development. The circular economy in waste management not only emphasizes reducing waste generation and promoting recycling, but also calls for systemic changes in governance, infrastructure investment, and market alignment. Studies show that shifting waste systems to circular models affects the overall system cost and service fees [5]. A balance between material recovery (recycling/composting) and energy recovery, such as incineration, can achieve cost-effective outcomes for both service providers and the public [5]. Additionally, the transition to a circular economy intensifies competition in waste and recycling markets, requiring robust governance and policy coordination to ensure institutional and market support [6].

Moreover, recent research also illustrates the potential of transforming hazardous waste into bioenergy using technological innovations, exemplifying the broader principle of “waste as a resource” [7]. These studies collectively reinforce the importance of investment planning, market readiness, and governance frameworks in operationalizing waste management transitions. At the local level, Depok City, home to approximately 2.12 million people, illustrates the complexity of urban waste management in Indonesia. According to 2024 data from the Ministry of Environment’s Sistem Informasi Pengelolaan Sampah Nasional (SIPSN) platform, the city produces roughly 1,300 tons of waste daily, or about 474,500 tons annually. This accounts for 11.7% of West Java’s waste and 1.4% of the national total (33.79 million tons). Given these figures, Depok plays a crucial role in achieving regional and national circular economy targets. However, the city continues to grapple with persistent challenges, including weak regulatory enforcement, fragmented institutional arrangements, limited financing, and low public participation. These issues are reflected in the city’s Regional Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Daerah*/RPJMD) 2021–2026, which calls for integrated, climate-responsive approaches to improve the sustainability of its waste system [8].

In response to these challenges, this study seeks to analyze the investment and operational requirements necessary for advancing Depok’s waste management system in line with circular economy and low-carbon development goals. The analysis also projects potential reductions in GHG emissions under various waste treatment scenarios using a modeling approach based on emission factors [9]. While Life Cycle Assessment (LCA) is often employed for evaluating environmental impacts at the product or process level, this study adopts a system-level perspective better suited to city-scale strategic planning and emissions estimation, following available data and policy frameworks.

Materials and Methods

This study applied a scenario-based mixed methods approach to evaluate the financial and environmental performance of municipal solid waste (MSW) management strategies in Depok City, within the policy context of circular economy and low-carbon development. The analytical framework integrated investment and operational cost estimation, GHG emission modeling, and policy scenario evaluation. The approach follows Tier 1 and Tier 2 methodologies as outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and references Regulation of the Minister of Home Affairs of the Republic of Indonesia No. 7/2021 on Standard, Technical Specifications, Regional Standard Unit Prices, and Budget Classification.

The study was conducted in Depok City, West Java, from August to December 2023. Depok was selected due to its significant waste generation, approximately 1,300 tons per day, and its relevance in regional low-carbon policy agendas. Data was collected through field visits, interviews, and document reviews. A purposive sampling strategy was applied to select four key informants directly engaged in the waste management sector. Interviews were conducted in September 2023 with (i) the Head of the Waste Management Division of the Environmental and Sanitary Agency (*Dinas Lingkungan Hidup dan Kehutanan*/DLHK) of Depok City, (ii) a staff member of the Regional Development Planning Agency (*Badan Perencanaan Pembangunan Daerah*/Bappeda), (iii) an operational staff from the Cipayung Final Disposal Site (*Tempat Pembuangan Akhir*/TPA), and (iv) the coordinator of *Tempat Pembuangan Sementara* (TPS) 3R Sukmajaya. Secondary data were obtained from Statistics Indonesia (*Badan Pusat Statistik*/BPS) for data on population of Depok City, SIPSN, Ministry of National Development Planning/National Development Planning Agency (*Badan Perencanaan Pembangunan Nasional*/Bappenas) and Ministry of Public Works and Housing (*Pekerjaan Umum dan Perumahan Rakyat*/PUPR) for data on waste management policies, and Regional Financial Information System (*Sistem Informasi Keuangan Daerah*/SIKD) for data on waste budget. Triangulation was conducted between interview data, public records, and technical guidelines to ensure consistency and validity.

Three scenarios were developed to compare future waste management options. Scenario 1 assumes that 100% of the city's waste is processed at centralized Integrated Waste Processing Sites (*Tempat Pengolahan Sampah Terpadu*/TPST), incorporating refuse-derived fuel (RDF) production and incineration for energy recovery. scenario 2 represents a hybrid model in which 50% of waste is managed through TPST and the other 50% through community-based TPS 3R (reduce, reuse, recycle stations). Scenario 3 relies entirely on decentralized TPS 3R systems, promoting composting and material recovery through high community participation. These scenarios were constructed based on infrastructure capacity, current planning documents, and Regional Regulation No. 5 of 2014 on waste management in Depok. This scenario also promotes sustainability through increased recycling and composting, fostering community engagement and local circular practices [10,11].

Investment and operational cost estimation was conducted according to the classification provided in the Regulation of the Minister of Home Affairs No. 7 of 2021 on Standard, Technical Specifications, Regional Standard Unit Prices, and Budget Classification. The cost structure includes waste collection, sorting and processing, transportation, and final disposal. Capital expenditure (CAPEX) includes infrastructure construction and equipment procurement, while operational expenditures (OPEX) cover staffing, maintenance, and operating activities. Table 1 summarizes the structure and types of costs calculated for this study.

Table 1. Components of waste management cost calculation.

Waste management	Investment cost	Operational cost
Waste collection	Purchase of collection vehicles. Purchase of tools and equipment used in waste collection.	Wages and benefits for personnel Maintenance costs of collection vehicles. Costs associated with fueling the collection vehicles.
Waste sorting and processing	Costs for constructing temporary waste storage facilities. Construction of sorting facilities where waste is separated for recycling, composting, or disposal. Construction expenses related to setting up recycling plants. Costs for building composting facilities.	Operating costs for sorting facilities. Operational expenses for recycling plants. Operational costs for composting organic waste.
Waste transportation	Purchase vehicles for transporting waste from collection points to processing or disposal sites.	Maintenance and operational costs for vehicles used in transporting waste.
Final waste processing	Construction expenses for facilities designed to incinerate waste that cannot be recycled or composted. Construction costs for facilities to treat liquid that drains from landfills. Installation expenses related to capturing and managing methane emissions from landfills.	Operating and maintenance costs for sanitary landfills. Operating expenses for incineration facilities. Operating costs for treating liquid from landfills. Operating expenses related to managing methane emissions from landfills.

Source: Regulation of the Minister of Home Affairs No. 7 of 2021

In parallel with the scenario development, a GHG emissions analysis was undertaken to evaluate the environmental implications of each waste management pathway. The estimation followed the 2006 IPCC Guidelines (Tier 1), which provide default emission factors for methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). Emissions were calculated across the major treatment options relevant to Depok City, namely landfilling, composting, incineration, and open burning.

The assessment was structured into sequential stages. The first stage involved the collection of activity data, including population statistics, waste composition, the distribution of waste streams into different treatment options, and the type of landfill facilities. These datasets served as the foundation for quantifying the mass of waste entering each treatment pathway. In the second stage, default emission factors from the IPCC were applied. The use of Tier 1 was deemed appropriate given the absence of localized emission factors and the need to maintain comparability with national and city-level inventories.

The third stage comprised the actual emission calculations. For landfilling, methane emissions were estimated using the first-order decay (FOD) model (Equation 1).

$$CH_4\ emission = \left[\sum CH_{4,x,T} - R_T\right] \times (1 - OX_T) \tag{1}$$

where $CH_{4,x,T}$ represents methane generated in year T, R_T is methane recovered through gas capture, and OX_T is the oxidation factor of the landfill cover.

For composting, both methane and nitrous oxide emissions were determined based on the mass of organic waste treated biologically (M_i), multiplied by the corresponding emission factors (FE_i) (Equation 2 and 3).

$$CH_4\ emission = \sum((M_i \times FE_i) \times\ 10^{-3}) -\ R \tag{2}$$

$$N_2O\ emission = \sum((M_i \times FE_i) \times\ 10^{-3}) \tag{3}$$

where R denotes methane recovered, and i represents the specific biological treatment option, such as composting or anaerobic digestion.

For open burning and incineration, methane and nitrous oxide emissions were estimated using the same mass–factor approach (Equation 4 and 5).

$$CH_4\ emission = \sum((M_i \times FE_i) \times\ 10^{-3}) \tag{4}$$

$$N_2O\ emission = \sum((M_i \times FE_i) \times\ 10^{-3}) \tag{5}$$

Carbon dioxide emissions, however, were calculated through a stoichiometric equation that incorporated waste fractions, dry matter content, and carbon properties (Equation 6).

$$CO_2\ emission = MSW \times \sum j\ ((WFj \times dmj \times CFj \times FCFj \times OFj) \times (44 \div 12)) \tag{6}$$

Here, MSW is the total municipal solid waste incinerated or openly burned, WFj is the fraction of waste type j, dmj the dry matter content, CFj the carbon fraction, $FCFj$ the fossil carbon fraction, and OFj the oxidation factor. The factor 44/12 reflects the molecular weight ratio converting carbon to carbon dioxide.

In the fourth stage, emissions of each gas were converted into carbon dioxide equivalents (CO_2-eq) using Global Warming Potentials (GWP), with conversion factors of 1 for CO_2, 27.2 for CH_4, and 273 for N_2O. This enabled the integration of different gases into a single, comparable metric.

The final stage consisted of compiling baseline and projected emissions for the period 2025–2030. This provided an overview of the relative contribution of each waste management scenario to GHG emissions, thereby supporting evaluation of their environmental performance.

To complement the quantitative analysis, a descriptive assessment was also conducted to interpret the policy implications of the findings. This included examining institutional readiness, cost-effectiveness, the scale of emission reductions achieved, and the extent to which the scenarios align with existing regulatory frameworks. By combining environmental outcomes with financial and institutional considerations, the analysis offers policy-relevant recommendations that reflect practical implementation conditions in Depok City.

Results

Current Waste Management Baseline

Building upon the methodological framework, this section discusses the outcomes of a scenario-based assessment of Depok City's waste management system. This analysis integrates financial feasibility, emission mitigation potential, and the alignment of strategies with circular economy and low-carbon development objectives. Three scenarios were explored, reflecting varying degrees of centralized and decentralized waste treatment approaches: scenario 1 (100% TPST), scenario 2 (50% TPST and 50% TPS 3R), and scenario 3 (100% TPS 3R).

Depok City generates approximately 1,300 tons of municipal solid waste daily, which equates to around 474,500 tons annually. The current management system shows that about 69% of this waste is directly transported to the landfill without prior treatment. Composting accounts for 13% of the waste processed, while recycling represents only 8%. A significant portion, approximately 10%, remains unmanaged, consisting of 5% open burning and another 5% being dumped in open environments [12]. The high proportion of unmanaged waste poses serious environmental and public health hazards while contributing notably to GHG emissions. A growing body of literature highlights the benefits of adopting sustainable waste management strategies, which not only reduce environmental degradation but also enhance urban health outcomes [13,14]. The structure of Depok City's current waste management system is illustrated in Figure 1.

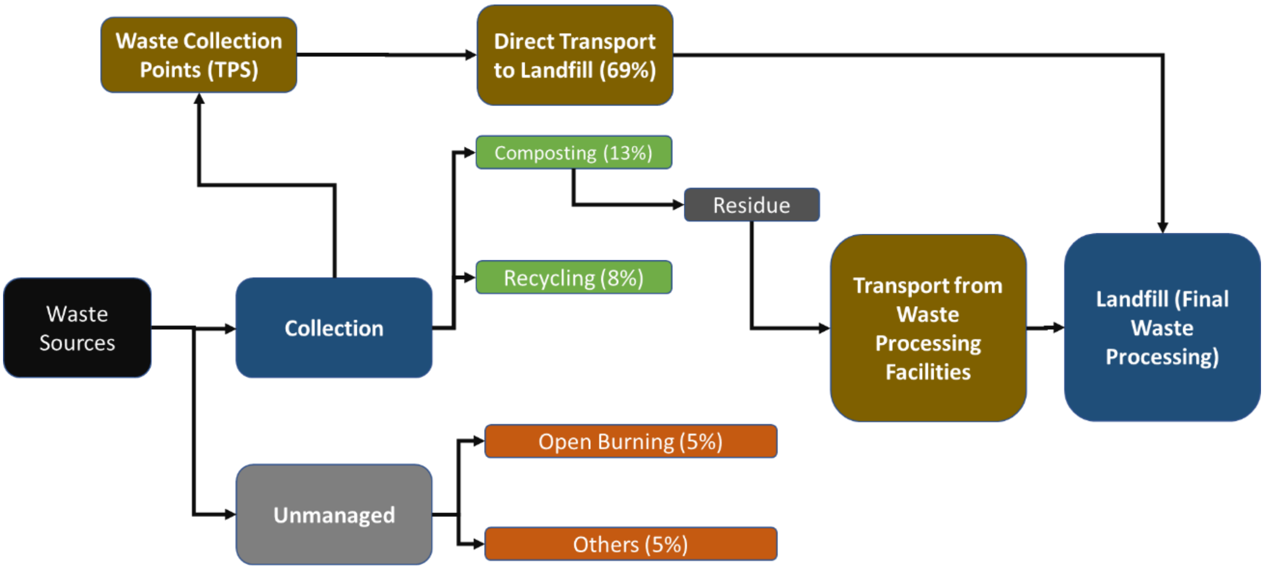

Figure 1. Existing waste management flow in Depok City.

Investment and Operational Costs

Using data obtained from DLHK Depok, the Ministry of Public Works and Housing, the Ministry of Environment and Forestry, and BPS, this study estimates the investment and operational costs associated with each waste management scenario. Scenario 3, which implements a fully community-based waste processing system through TPS 3R, is found to be the most cost-efficient. This approach minimizes infrastructure investment by focusing on source-level waste management while maximizing public participation. Table 2 summarizes the estimated investment and operational costs for each scenario.

Table 2. Recapitulation of investment and operational costs for waste management in Depok City (in Billion Rupiah).

Waste management	Scenario 1*			Scenario 2**			Scenario 3***		
	Operational	Investment	Total	Operational	Investment	Total	Operational	Investment	Total
Collection	177	14	191	177	14	191	177	14	191
Sorting		20	20		20	20		20	20
Processing	166	109	275	150	65	215	130	19	149
Transportation	4	-	4	4	-	4	31	2	33
Final processing (landfill)	33	-	33	34	-	34	43	-	43
Grand total			523			464			436

*Scenario 1: 100% waste processing at TPST, **Scenario 2: 50% waste processing at TPS 3R and 50% at TPST,***Scenario 3: 100% waste processing at TPS 3R.

Scenario 3 requires an annual operational budget of IDR 381.6 billion and an additional investment of IDR 53.8 billion. Despite its high operational cost, this scenario offers the lowest capital expenditure. Furthermore, it fosters inclusive participation and emphasizes sustainability by promoting composting and recycling. These qualities align with both the polluter pays principle and sustainable development goal (SDG) 12 [15,16]. The scenario represents a proactive strategy that establishes a more balanced and sustainable waste management framework through increased recycling and composting. Its implementation has the potential to greatly enhance environmental hygiene, protect public health, and raise the overall quality of life for Depok residents, while aligning with both national and international standards for sustainable waste management [17].

Greenhouse Gas Emissions

In terms of climate impact, emissions under a business-as-usual (BAU) scenario are projected to rise steadily from 393.82 Gg CO_2e in 2024 to 419.00 Gg CO_2e in 2030, primarily due to continued reliance on landfilling. This underscores the urgent need for transformative changes in the waste management system. To quantify emission mitigation potential, the study compares the BAU trajectory with a 3R-focused approach (scenario 3), applying the IPCC 2006 Tier 1 [18]. Scenario 3 is projected to reduce GHG emissions by up to 65% by 2030 due to enhanced composting, increased recycling, and the elimination of both open burning and unmanaged disposal.

The fact that landfill-related emissions dominate the total further highlights the importance of prioritizing waste reduction, composting, and recycling to alter the emission trajectory. The persistent increase in projected emissions serves as a call to action for adopting more sustainable practices that can significantly reduce the city's environmental footprint [19].

The emissions projection under BAU conditions (Figure 2) demonstrates a steady increase in total GHG emissions, reinforcing the case for intervention. Bridging from this trend, Table 3 presents projected shifts in waste processing distributions under the three modelled scenarios, each designed to minimize landfill use while enhancing resource recovery in alignment with circular economy goals.

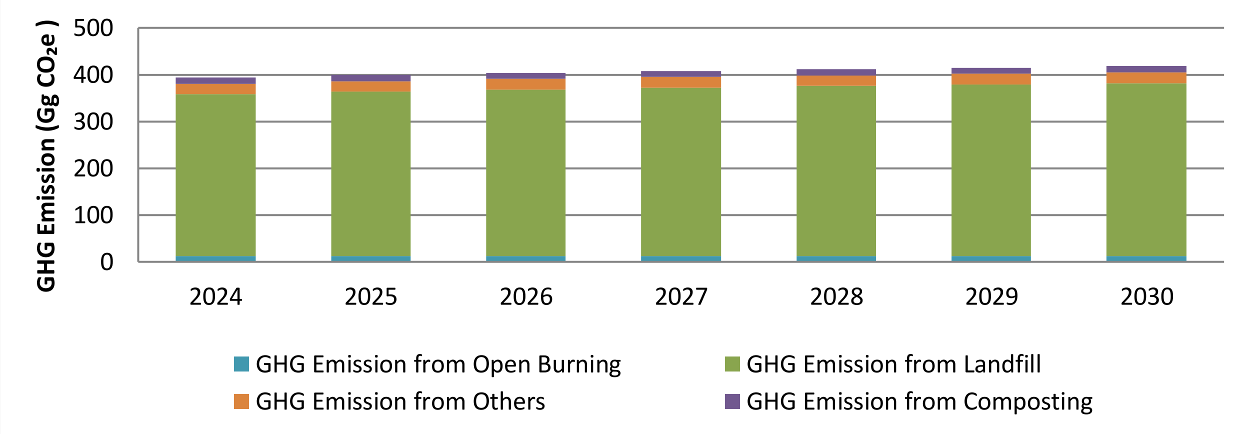

Figure 2. Projected greenhouse gas emission in Depok City under the BAU Scheme, 2024–2030.

Table 3. Scenario-based approaches to greenhouse gas mitigation in waste management.

Type of waste management distribution	Existing condition (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
Transported to landfill	69	2.5	6.25	10
Composting	13	17.5	33.75	60
Recycling	8	30	30	30
Incinerator	0	50	25	0
Open burning	5	0	0	0
Final processing	5	0	0	0
Total	100	100	100	100

These shifts in waste treatment distribution show clear pathways toward a more sustainable system. The reductions in landfill dependency and increases in composting and recycling reflect a deliberate transition aligned with low-emission development objectives. Each scenario reflects a tailored waste allocation strategy, setting the stage for further evaluation. As each scenario presents a different mix of processing strategies, Figure 3 visualizes their relative climate benefits in terms of projected GHG reductions over time.

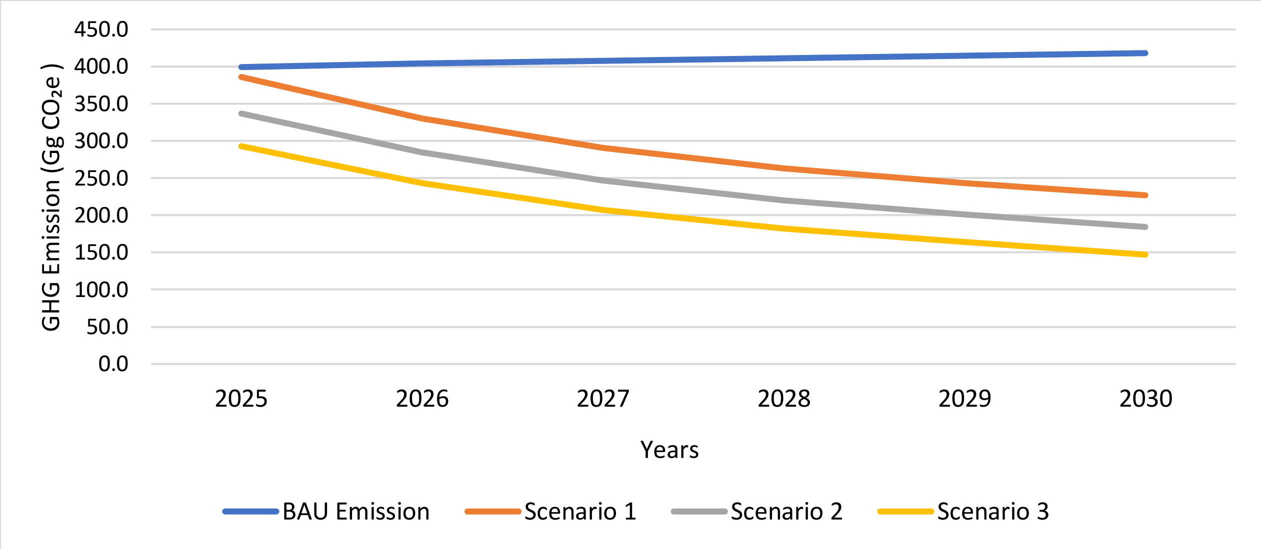

Figure 3. Comparison of the projected emissions of Depok City between the BAU and intervention based on 3R schemes, 2025–2030.

Figure 3 presents the estimated GHG emission reductions achieved under the three intervention scenarios compared to the BAU condition as outlined in Table 4. Among them, scenario 3 demonstrates the most substantial impact, achieving a 65% reduction in emissions relative to baseline levels. This is primarily due to minimized landfill use and the maximization of source-level recycling and composting. The scenario also integrates strong community engagement efforts, such as waste separation, sustainable consumption, and increased recycling, which further reinforces its effectiveness. As Leifeld [18] emphasizes, raising public awareness and participation is key to reducing waste generation and associated emissions.

Table 4. Comparison of waste management scenarios for GHG mitigation in Depok City.

Scenario	Strengths	Limitations
1	Strong downstream capacity through incineration	High investment (IDR 141.8 billion), limited land availability
2	Balanced approach between TPST and TPS 3R	Still dependent on TPST land and moderate investment needs
3	Highest emission reduction, lowest investment, inclusive	Highest operational cost, requires robust community systems

Discussion

This study provides one of the first integrated assessments of GHG mitigation pathways for municipal solid waste in Depok City, combining scenario-based modeling with enabling-condition analysis. The results contribute not only to local policy debates but also to the academic literature on sustainable waste governance in rapidly urbanizing contexts. Methodologically, the study advances understanding by linking IPCC (2006) Tier 1 emission estimates with institutional and community dynamics. This approach responds to calls in recent scholarship for greater integration of environmental modeling with governance and behavioral perspectives in waste management studies [20].

Among the three scenarios, scenario 3 emerged as the most effective, offering the highest GHG mitigation at the lowest capital cost. Unlike scenario 1, which relies heavily on incineration with high investment demands (IDR 141.8 billion) and limited land availability, and scenario 2, which balances TPST expansion with TPS 3R but still requires substantial land resources, scenario 3 leverages decentralized and community-based systems. Although this pathway entails higher operational complexity, it demonstrates the feasibility of achieving substantial emission reductions while promoting inclusiveness. These findings resonate with studies from Pakistan [21] and European countries [22], where the integration of technological, social, and institutional measures proved critical for advancing low-emission waste management.

The enabling conditions identified in this study, namely the modernization of TPS 3R infrastructure, capacity-building for communities, stronger regulatory incentives, carbon financing, and enhanced citizen participation, are consistent with empirical evidence from Indonesia. Hartono et al. [23] highlighted the importance of community engagement and modernization of waste banks in Depok, although household participation remains limited (36%). Lokahita et al. [24] reported that Waste Processing Units (*Unit Pengolahan Sampah*/UPS) in Depok could theoretically process 94% of organic waste, but weak management and governance gaps constrain efficiency. These results emphasize that technological advances must be accompanied by institutional strengthening and financial support.

Comparative evidence reinforces these conclusions. In Semarang, enhanced composting and recycling were shown to stabilize emissions despite rising waste generation [25]. Kerala's household composting program provides another example of how decentralized and community-based approaches can effectively divert organic waste and reduce methane emissions [26]. In Depok, Dahlan et al. [27] demonstrated that local initiatives such as the Hasvil Waste Bank have reduced household waste volumes by over 30%, underscoring the potential of citizen-led solutions. Complementarily, Fauziah et al. [28] found that the conversion of household paper and garden waste into RDF offers viable opportunities for energy recovery while reducing landfill dependency. Together, these cases illustrate how scenario 3's emphasis on community-driven, low-cost strategies is not only contextually appropriate but also theoretically significant, as it empirically links decentralized participation with measurable GHG mitigation outcomes—an underexplored dimension in waste governance scholarship (Table 5).

Table 5. Enabling conditions for advancing 3R-based waste management.

Key points	Challenges	Enabling conditions
TPS 3R infrastructure	High initial investment	Public grants, tech partnerships
Community education	Resistance to new practices	Media campaigns, participatory training
Policy and regulation	Compliance gaps, resistance from stakeholders	Incentives, monitoring systems
Recycling market	Volatile demand, product perception issues	Industrial partnerships, consumer campaigns
Carbon financing	GHG measurement complexity	Adoption of MRV standards, participation in carbon markets
Public participation	Low engagement, lack of transparency	Community events, reporting platforms

At the same time, the study acknowledges its limitations. Reliance on secondary data and IPCC Tier 1 emission factors may reduce accuracy, as these default values do not capture local heterogeneity. Future research should incorporate localized emission factors, primary measurement of methane capture, and behavioral surveys. As Putri et al. [29] demonstrated through the Theory of Planned Behavior in Depok, household decisions to segregate organic waste are strongly shaped by social norms and perceived convenience, insights that could be embedded into scenario modeling for greater behavioral realism.

Finally, the findings align closely with the polluter-pays principle, which emphasizes that waste producers must bear responsibility for the impacts they generate. This principle has practical relevance in Indonesia, as shown by Yulia et al. [30], who found that tourists in the *Gunung Salak Endah* area were willing to pay for improved waste management services. Such evidence suggests that user-based financing mechanisms can operationalize polluter-pays approaches in both tourism and urban waste contexts, providing a financial foundation for sustainable waste governance.

In conclusion, scenario 3 offers a scalable, low-cost, and inclusive pathway for waste management in Depok City, with the highest mitigation potential and strongest community ownership. Beyond its local application, the findings carry broader implications for Indonesia's transition toward a low-carbon and circular economy. Integrating decentralized waste systems into national frameworks such as the RPJMN 2025–2029 and the Circular Economy Roadmap could support the achievement of SDG 12 on sustainable consumption and production, while positioning waste management as a vital contributor to Indonesia's net-zero commitments. With robust institutional frameworks, climate financing instruments, and community-based mechanisms, innovations tested in Depok can be scaled up as a national model for sustainable urban waste governance.

Conclusions

A transformative and integrated approach to waste management in Depok City is essential to address the increasing volume of unmanaged waste and its associated greenhouse gas emissions. Among the three scenarios analyzed, Scenario 3, which implements 100% waste management through TPS 3R, emerges as the most effective, both environmentally and economically. This scenario results in the highest emission reduction, reaching 65% compared to the baseline, and simultaneously offers the lowest total cost for implementation, amounting to IDR 436 billion. While operational costs in Scenario 3 are higher than in other scenarios, its additional investment requirement is the lowest at IDR 53.8 billion, which significantly enhances its financial feasibility, particularly for local governments operating within constrained budgets. Scenario 3 prioritizes localized waste processing at the village or sub-district level, thereby empowering communities, increasing recycling and composting rates, and minimizing reliance on central landfills or the need for additional land for new TPST infrastructure. It also eliminates environmentally harmful practices such as open burning and illegal dumping. The effectiveness of this scenario is further supported by the integration of modern waste treatment technologies, intensive community education and participation programs, and strengthened regulatory and institutional frameworks. By aligning with the principles of a circular economy and SDG 12 (responsible consumption and production), scenario 3 offers a scalable and resilient waste management model that can significantly improve environmental quality, public health, and the overall well-being of Depok's residents, while supporting national and global sustainability targets.

Author Contributions

ETU: Conceptualization, Methodology, Software, Investigation, Writing - Review & Editing; **ME**: Writing - Review & Editing; and **ZA**: Writing - Review & Editing.

Conflict of Interest

There are no conflicts to declare.

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