

Comparative Analysis of Plastic Recycling Systems and Environmental Governance in the Philippines and Romania

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Abstract

Plastic waste management remains a critical environmental challenge in both developing and transitioning economies, necessitating integrated policy and system-level interventions to enhance the effectiveness of recycling systems and improve waste-management effectiveness. This study examined differences in plastic recycling efficiency, policy effectiveness, and resource-recovery performance between the Philippines and Romania using a multi-criteria comparative framework integrating policy, infrastructure, and recycling-performance indicators derived from secondary environmental datasets and peer-reviewed literature published from 2020 to 2025. Data were obtained from peer-reviewed literature, government reports, Eurostat databases, World Bank publications, and international environmental reports. Seven comparative indicators were evaluated, including recycling rate, process efficiency, infrastructure capacity, policy enforcement, public participation, and economic incentives. The comparative findings indicate that Romania currently maintains a more institutionally coordinated recycling system, particularly in terms of policy enforcement, collection efficiency, and technological infrastructure. These outcomes appear to be associated with the implementation of the Deposit Return System and stronger alignment with European Union environmental directives. In contrast, the Philippines exhibited lower recycling efficiency due to fragmented governance, inadequate infrastructure, and limited integration of informal waste-management systems into formal resource-recovery strategies. The findings emphasize that effective recycling systems depend not only on environmental policies but also on institutional coordination, infrastructure investment, and economic incentives. The study contributes a comparative analytical framework that may support evidence-based policy development and recycling governance and waste-management improvement strategies in developing and transitioning economies.

Highlights

- Romania demonstrated higher recycling-system efficiency than the Philippines.
- Policy enforcement strongly influenced recycling-system performance.
- Infrastructure capacity affected recycling-process quality and recovery.
- Economic incentives improved collection and recycling efficiency.
- Informal-sector integration remains critical in developing economies.

1. INTRODUCTION

The rapid growth of plastic production and consumption has intensified environmental pressures associated with waste generation, marine pollution, and unsustainable resource use across both developed and developing economies, with significant implications for ecological sustainability, public health, and resource security. Driven by industrial expansion, urban consumption patterns, and increasing dependence on disposable materials, global plastic production has continued to rise over the past decades, yet waste-management systems in many countries remain unable to effectively recover and recycle discarded materials (OECD, 2022). As a consequence, substantial quantities of plastic waste accumulate in terrestrial and aquatic ecosystems, contributing to biodiversity loss, marine pollution, greenhouse gas emissions, and long-term environmental degradation (Geyer et al., 2017; Lau et al., 2020). Recent estimates indicate that riverine systems serve as major pathways for plastic leakage into marine environments, particularly in developing regions with inadequate waste-management infrastructure (Meijer et al., 2021). These environmental challenges have increased the need for more effective waste-management systems, stronger recycling

policies, and improved resource recovery strategies (UNEP, 2023).

Plastic waste management remains a major environmental governance challenge in many developing and transitioning economies. Increasing plastic consumption, inadequate collection systems, and inconsistent recycling practices continue to contribute to environmental degradation, marine pollution, and inefficient resource recovery (OECD, 2022; UNEP, 2023). While many countries have introduced waste-management policies and recycling regulations, substantial differences remain in institutional capacity, infrastructure development, and enforcement effectiveness (World Bank, 2021; Wilson et al., 2021).

In contrast, many developing economies continue to experience persistent challenges associated with weak institutional capacity, fragmented governance systems, insufficient recycling infrastructure, and limited market integration for recycled materials. The Philippines represents one of the countries facing substantial plastic pollution challenges due to its archipelagic geography, high coastal population density, rapid urbanization, and dependence on single-use plastics. Although the country enacted Republic Act 9003 or the Ecological Solid

Waste Management Act of 2000 to establish a comprehensive waste-management framework, implementation remains inconsistent across local government units because of financial, technical, and institutional limitations (World Bank, 2021). Existing studies have shown that inadequate segregation practices, insufficient materials recovery facilities, and inconsistent policy enforcement continue to undermine recycling-system efficiency and waste-management effectiveness in the country (Wilson et al., 2021). Moreover, while informal waste sectors contribute significantly to material recovery, their operations often remain technologically limited and insufficiently integrated into formal resource-recovery systems (Velis and Cook, 2021).

Previous investigations examining plastic waste management have largely focused on isolated dimensions of recycling systems, including technological efficiency, policy implementation, consumer behavior, and environmental impacts. Lau et al. (2020) emphasized the need for systemic interventions across the plastic value chain to substantially reduce environmental leakage, while Meijer et al. (2021) identified inadequate waste-management infrastructure

as a major contributor to marine plastic emissions. Studies focusing on public participation further suggest that recycling effectiveness is strongly influenced by environmental awareness, accessibility of collection systems, and behavioral factors affecting waste segregation practices (Almulhim, 2022; Zhang et al., 2015). Other research has highlighted the environmental implications of plastic packaging materials and the importance of transitioning toward more sustainable production systems within sustainable waste-management frameworks (Ncube et al., 2020). Although these studies contribute significantly to understanding plastic waste challenges, most investigations either focus on single-country analyses or examine environmental, institutional, and economic factors separately rather than within a unified comparative framework.

Consequently, important gaps remain in the literature regarding how governance structures, infrastructure capacity, public participation, and economic incentives interact to shape recycling-system performance across different socio-economic contexts. Although recycling governance has received increasing scholarly attention, relatively few comparative investigations have examined how institutional capacity,

infrastructure conditions, and policy implementation collectively influence recycling outcomes across developing and transitioning economies. Existing research also provides insufficient integration between environmental governance perspectives and recycling-system performance assessment, particularly in relation to policy implementation and institutional effectiveness. This limitation restricts the development of transferable policy insights capable of supporting evidence-based recycling-system improvements in countries facing different structural and governance conditions.

The consequences of inefficient recycling systems extend beyond environmental degradation alone. Poor waste-management practices contribute directly to increased plastic leakage into rivers, coastal ecosystems, and marine environments while also increasing greenhouse gas emissions associated with virgin plastic production (OECD, 2022). Indirectly, weak recycling systems reduce opportunities for environmentally sustainable economic development, technological innovation, and formal employment generation within recycling industries. In developing economies, inefficient waste-management

systems may also exacerbate public health and occupational risks among informal waste collectors operating under unsafe and unregulated conditions (Velis and Cook, 2021). These challenges demonstrate the need for more integrated and context-sensitive approaches to evaluating recycling-system performance and environmental governance effectiveness.

Given these concerns, this study comparatively assesses plastic recycling efficiency, policy effectiveness, infrastructure conditions, and waste-governance performance in the Philippines and Romania using a multi-criteria analytical framework. The study examines how policy implementation, institutional coordination, infrastructure development, and socio-economic conditions influence recycling-system effectiveness in both countries. By integrating comparative policy analysis with operational performance assessment, the study aims to provide evidence-based insights for strengthening waste-management systems in developing and transitioning economies.

Unlike bibliometric investigations that examine the evolution of recycling governance research, this study focuses on operational and institutional differences in

plastic recycling systems between two national contexts. The analysis emphasizes environmental governance, recycling performance, and policy implementation factors influencing waste-management effectiveness.

2. METHODOLOGY

2.1 Research design

This study employed a comparative mixed-method analytical approach to evaluate plastic recycling systems in the Philippines and Romania. The approach combined qualitative policy analysis with quantitative comparative assessment to examine differences in recycling efficiency, policy effectiveness, infrastructure capacity, and resource-recovery performance between the two countries. Comparative environmental assessment methods are widely used in environmental-governance and waste-management studies because they enable the systematic evaluation of institutional and operational differences across varying socio-economic contexts (Velis and Cook, 2021).

The study was guided primarily by environmental governance and waste-management assessment frameworks. These perspectives provided the conceptual basis for evaluating how governance structures,

policy instruments, and socio-economic conditions influence recycling performance in both countries.

2.2 Study areas and comparative context

The Philippines and Romania were selected because they represent contrasting governance and recycling-management contexts within developing and transitioning economies. The Philippines was selected due to its persistent challenges in plastic waste management despite the implementation of Republic Act 9003 or the Ecological Solid Waste Management Act of 2000. Romania was selected because of its integration of European Union waste-management directives and the implementation of a national Deposit Return System (DRS), which has significantly improved recycling performance in recent years.

The comparison between the two countries was intended to examine how differences in policy enforcement, infrastructure development, institutional coordination, and economic incentives affect recycling-system outcomes. The analysis considered national-level recycling systems rather than specific local government units or municipalities to ensure consistency in cross-country comparison.

2.3 Data sources and data collection

This study relied on secondary data obtained from peer-reviewed journal articles, international institutional reports, government publications, and environmental databases published between 2020 and 2025. Secondary-data analysis is appropriate for comparative environmental-policy studies because it enables the integration of multiple data sources and facilitates cross-national evaluation using standardized indicators (Lau et al., 2020).

- Eurostat databases and European Commission reports for Romania;
- World Bank reports and Department of Environment and Natural Resources (DENR) publications for the Philippines;
- OECD and UNEP reports related to plastic pollution and resource recovery;
- Peer-reviewed articles indexed in Scopus and Web of Science databases.

The literature search was conducted using ScienceDirect, SpringerLink, Scopus, and Web of Science databases. Keywords used in the search process included “plastic recycling”, “resource recovery”, “waste

management”, “Deposit Return System”, “plastic policy”, “recycling efficiency”, “Philippines”, and “Romania”.

Only studies meeting the following criteria were included:

1. published between 2020 and 2025;
2. focused on plastic recycling, waste governance, or resource-recovery systems;
3. published in peer-reviewed journals or official institutional reports;
4. contained measurable or policy-relevant recycling indicators.

Duplicate studies, non-English publications, opinion articles, and sources lacking methodological transparency were excluded from the analysis.

2.4 Analytical framework and comparative indicators

A multi-criteria comparative framework was developed to assess recycling-system performance in both countries. The framework integrated environmental, institutional, economic, and operational dimensions commonly used in environmental governance and waste-management research (Watkins et al., 2020).

Seven key indicators were used in the comparative assessment:

1. recycling rate;
2. recycling-process efficiency;
3. waste-management system effectiveness;
4. infrastructure and technological capacity;
5. policy implementation and enforcement;

6. public participation and awareness;
7. economic incentives and resource-recovery integration.

Each indicator was evaluated using qualitative and quantitative evidence obtained from the reviewed sources. To improve analytical consistency, indicators were scored using a five-point comparative scale, where:

Table 1. Scoring Criteria for Recycling Performance Indicators

Score	Interpretation	Operational Description
1	Very Low Performance	Recycling systems exhibit severe infrastructure deficiencies, weak policy enforcement, minimal public participation, and limited resource-recovery capacity.
2	Low Performance	Recycling operations are present but remain inconsistent due to inadequate infrastructure, fragmented governance, and weak implementation mechanisms.
3	Moderate Performance	Recycling systems demonstrate partial operational effectiveness, moderate infrastructure availability, and improving policy implementation with some institutional coordination.
4	High Performance	Recycling systems are supported by functional infrastructure, relatively strong policy enforcement, organized collection mechanisms, and effective stakeholder participation.
5	Very High Performance	Recycling systems demonstrate highly coordinated governance, advanced technological infrastructure, strong enforcement mechanisms, stable recovery systems, and integrated resource-recovery operations.

Table 1 presents the operational scoring criteria used to evaluate recycling-system

performance across the selected indicators. The framework was developed to improve

analytical consistency in the comparative assessment of recycling governance, infrastructure conditions, policy implementation, and operational effectiveness between the Philippines and Romania. Scores were assigned based on comparative interpretation of evidence reported in peer-reviewed literature, institutional databases, and government environmental reports.

The five-point scoring system was adopted to improve comparative consistency and simplify cross-country evaluation of qualitative and quantitative recycling-system indicators commonly used in environmental governance assessments. Indicator scores were assigned based on comparative interpretation of reported recycling performance, infrastructure availability, policy implementation effectiveness, and environmental governance conditions described across the reviewed literature and institutional datasets.

The composite Recycling Performance Index (RPI) was calculated using Equation (1):

$$RPI = \sum Si / n$$

(1)

Where:

Si =indicator score;
and
 n =total number of indicators.

The index was used to provide an overall comparative assessment of recycling-system performance in the Philippines and Romania.

2.5 Data analysis

The collected data were analyzed using thematic synthesis and comparative scoring analysis. Qualitative information related to policy implementation, governance structures, and operational practices was coded into thematic categories corresponding to the selected indicators. Quantitative information, including recycling rates and recovery performance, was extracted and compared using descriptive statistics.

Cross-country comparison focused on identifying:

- similarities and differences in recycling-system structure;
- relationships between policy instruments and recycling outcomes;
- barriers affecting recycling governance implementation;
- factors contributing to improved recycling efficiency.

Comparative findings were interpreted within the context of environmental governance and resource-recovery transition frameworks.

2.6 Reliability and validity

To improve reliability and validity, the study utilized triangulation through the use of multiple independent data sources, including institutional databases, government reports, and peer-reviewed literature. Only sources with clear methodological descriptions and verifiable data were included in the analysis. Cross-validation of recycling indicators was conducted by comparing values reported across multiple references where available.

Additionally, the use of standardized comparative indicators and scoring criteria

improved consistency in evaluating recycling performance between the two countries.

3. RESULTS AND DISCUSSION

3.1 Comparative recycling performance

The comparative assessment revealed substantial differences in recycling-system performance between Romania and the Philippines across the seven analytical indicators. Across most indicators, Romania exhibited comparatively stronger recycling outcomes than the Philippines.

Table 2 presents the comparative Recycling Performance Index (RPI) scores for both countries based on the developed analytical framework.

Table 2. Comparative Recycling Performance Index Scores of the Philippines and Romania

Indicator	Philippines	Romania
Recycling rate	2	4
Recycling-process efficiency	2	4
Waste-management system effectiveness	2	4
Infrastructure and technological capacity	2	4
Policy implementation and enforcement	2	5
Public participation and awareness	3	4
Economic incentives and resource-recovery integration	2	4
Composite RPI score	2.14	4.14

The results indicate that Romania demonstrated substantially higher composite recycling-system performance compared with the Philippines. The observed differences appear to be linked to more consistent institutional coordination, stronger enforcement mechanisms, and broader infrastructure investment within the Romanian system. The implementation of the national Deposit Return System (DRS), aligned with European Union waste-management directives, appears to have improved collection efficiency and overall material recovery outcomes.

In contrast, the Philippines continues to face major structural limitations despite the presence of Republic Act 9003. Implementation challenges at the local-government level continue to constrain recycling efficiency in many parts of the Philippines. Previous studies similarly reported that inconsistencies in governance and infrastructure remain major barriers to effective waste recovery in developing economies (World Bank, 2021; Wilson et al., 2021).

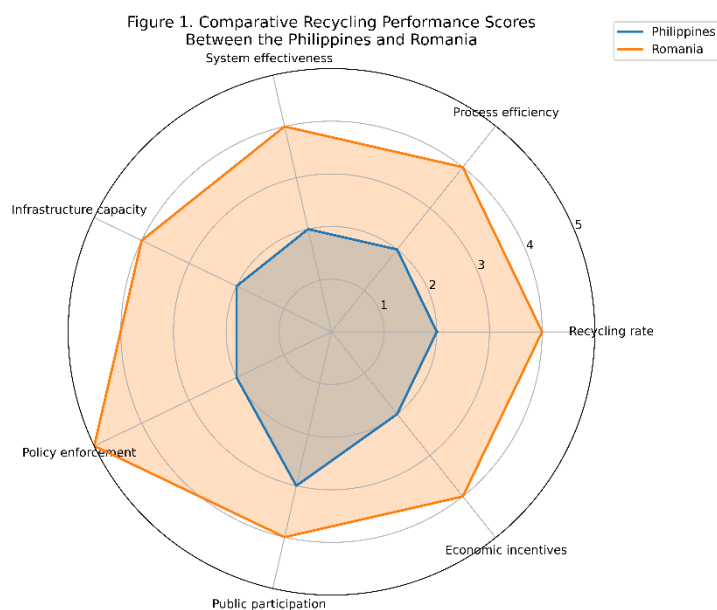


Figure 1. Comparative Recycling Performance Scores Between the Philippines and Romania.

Figure 1 illustrates the comparative indicator scores between the two countries. The radar chart demonstrates that Romania consistently

achieved higher scores across nearly all indicators, particularly in policy enforcement, infrastructure capacity, and

recycling-process efficiency. The Philippines showed relatively stronger performance in public participation due to the contribution of informal waste collectors and community-based recycling activities. However, lower scores in technological infrastructure and institutional enforcement limited overall recycling effectiveness. The visual comparison highlights how institutional coordination and infrastructure investment influence overall recycling-system effectiveness.

3.2 Policy implementation and institutional effectiveness

The comparative findings suggest that policy effectiveness depends less on the existence of legislation itself and more on the capacity of institutions to implement and sustain operational waste-management systems. Romania's recycling governance benefits from alignment with European Union

environmental directives, including extended producer responsibility (EPR) policies and mandatory recycling targets. The implementation of the Deposit Return System created direct financial incentives for consumers and improved collection efficiency through structured return mechanisms.

Conversely, the Philippines relies heavily on decentralized implementation under Republic Act 9003, where local government units are responsible for waste segregation, collection, and recycling operations. While the legislation itself provides a comprehensive framework for ecological solid waste management, implementation varies substantially depending on financial resources, technical capacity, and local political priorities. As a result, recycling performance differs significantly across municipalities and regions.

Table 3. Comparative Policy and Institutional Characteristics of Recycling Systems

Aspect	Philippines	Romania
Main policy framework	RA 9003	EU-aligned DRS
Governance structure	Decentralized	Coordinated national system
Collection mechanism	Municipal and informal sector	Structured return and collection system
Enforcement consistency	Variable	Relatively strong

Incentive mechanism Limited

Financial deposit incentives

Informal-sector
participation High Limited

The findings indicate that legislative frameworks alone are insufficient unless supported by institutional capacity, enforcement mechanisms, and operational infrastructure. Instead, enforcement capacity, institutional coordination, and economic incentives determine whether recycling targets can be operationalized successfully. Similar observations were reported by Watkins et al. (2020), who emphasized that regulatory instruments are more effective when supported by market-based incentives and organized recovery infrastructure.

The dominance of the informal sector in the Philippines also presents both opportunities and challenges. Informal waste collectors contribute substantially to material recovery, particularly for high-value recyclable plastics, yet their operations often remain disconnected from formal waste-management systems. Velis and Cook (2021)

argued that integrating informal recycling sectors into formal waste-recovery strategies may improve recovery efficiency while also supporting social inclusion and occupational protection.

3.3 Infrastructure and recycling-process efficiency

Infrastructure availability strongly influenced recycling-process efficiency in both countries. Romania demonstrated higher technological and logistical capacity due to investments in sorting facilities, organized collection systems, and recycling-processing infrastructure supported by European Union funding mechanisms.

In contrast, recycling infrastructure in the Philippines remains unevenly distributed, particularly outside highly urbanized areas. Limited access to advanced sorting technologies, inconsistent waste segregation practices, and insufficient materials recovery facilities reduce the quality and marketability of recycled plastics.

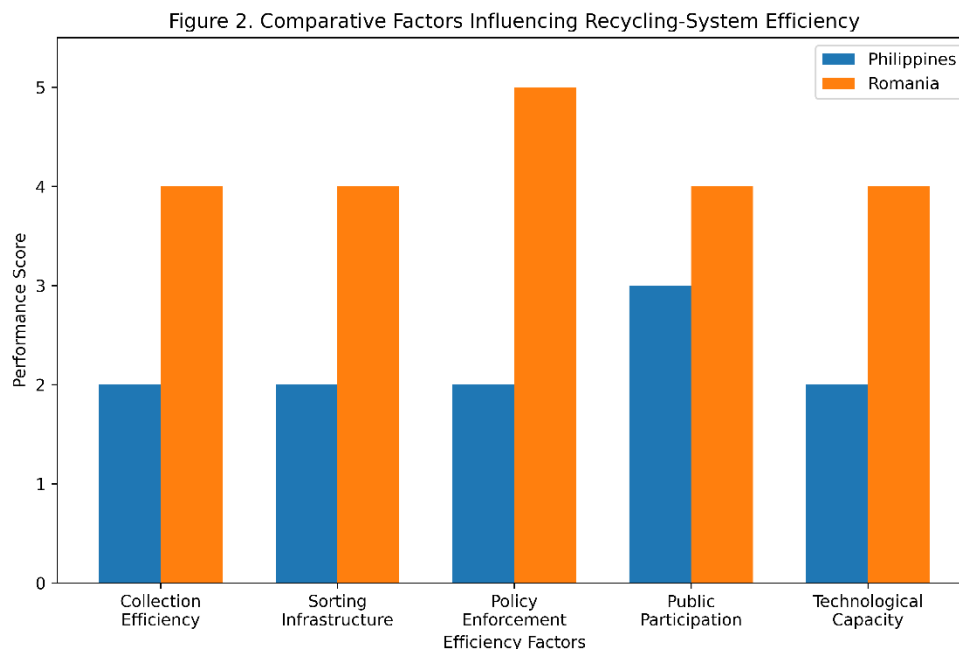


Figure 2. Comparative Factors Influencing Recycling-System Efficiency

Figure 2 shows that Romania achieved higher performance in collection efficiency and technological infrastructure, reflecting the advantages of centralized coordination and policy-driven investment. The Philippines demonstrated moderate public participation but lower technological and operational efficiency. These differences suggest that infrastructure development remains essential for improving recycling efficiency, collection quality, and long-term waste-management performance.

The findings support previous studies indicating that recycling efficiency depends not only on public awareness but also on the availability of functional infrastructure and

reliable collection systems (Meijer et al., 2021). Without adequate sorting and processing capacity, recyclable plastics often become contaminated, reducing their economic value and limiting opportunities for higher-value industrial reuse.

3.4 Resource Recovery and Value-Added Recycling Utilization

The comparative analysis also revealed differences in how recycled plastics are integrated into structured resource-recovery systems. Romania showed stronger integration of recycled materials into packaging, manufacturing, and construction sectors, reflecting more developed

secondary-material markets and regulatory support for recycled-content utilization.

In the Philippines, recycled plastics are primarily used in low-value applications such

as plastic lumber, eco-bricks, and low-cost construction materials. Although these applications contribute to waste diversion, they often do not maximize material value recovery or long-term recycling efficiency.

Table 4. Comparative Resource Recovery and Recycling Utilization Systems

Aspect	Philippines	Romania
Dominant recycling pathway	Low-value reuse	Higher-value material recovery
Industrial integration	Limited	Moderate to high
Market demand for recycled plastics	Developing	More established
Resource-recovery policy integration	Emerging	Stronger institutional integration
Technology adoption	Limited	More advanced

The findings indicate that material recovery alone is insufficient unless supported by stable secondary-material markets, technological innovation, and long-term institutional support. The development of stable secondary-material markets, technological innovation, and regulatory support for recycled products are equally important in sustaining long-term resource recovery.

The results further indicate that economic incentives significantly influence recycling participation and system performance. Romania's DRS provides direct financial motivation for consumers to return recyclable

containers, improving collection rates and reducing environmental leakage. In contrast, limited incentive structures in the Philippines reduce participation consistency and place greater dependence on informal recovery systems.

3.5 Implications for environmental sustainability and governance

The differences observed between the two countries highlight the importance of integrated environmental governance in improving recycling-system performance. Countries with stronger institutional coordination, robust infrastructure investment, and enforceable policy

mechanisms tend to achieve better environmental outcomes and higher levels of recycling-system integration.

For the Philippines, strengthening policy enforcement, expanding materials recovery infrastructure, and formally integrating informal waste sectors may significantly improve recycling efficiency and environmental sustainability. Public education campaigns and economic incentives may also enhance household participation in segregation and recycling practices.

The findings also demonstrate that the improvement of recycling systems is shaped by broader socio-economic and institutional conditions. While European policy models such as DRS may provide useful insights, direct policy transfer without contextual adaptation may not be fully effective in developing economies characterized by fragmented governance and infrastructural limitations.

Overall, the study emphasizes that effective recycling-system improvement depends on coordinated institutional governance, technological investment, and sustained stakeholder participation involving government institutions, private industries,

local communities, and environmental stakeholders.

4. CONCLUSION

The study highlights how differences in governance capacity, infrastructure development, and policy implementation continue to shape recycling outcomes in developing and transitioning economies. Using a multi-criteria comparative framework grounded in environmental governance and recycling-system assessment perspectives, the study identified major institutional, infrastructural, and policy-related factors influencing recycling-system performance across the Philippines and Romania.

The findings revealed substantial differences between the two countries in terms of recycling-system efficiency and resource-recovery implementation. Romania consistently demonstrated higher performance across most indicators, particularly in policy enforcement, infrastructure development, technological capacity, and collection efficiency. The implementation of the Deposit Return System, combined with European Union regulatory alignment and financial incentives, contributed to more organized

collection systems and stronger material recovery outcomes. In contrast, the Philippines exhibited lower overall recycling performance due to fragmented governance structures, inconsistent implementation of Republic Act 9003, inadequate recycling infrastructure, and continued dependence on informal waste-management systems. Although the informal sector significantly contributes to waste recovery and public participation in the Philippines, limited institutional integration and technological support reduce the overall efficiency and sustainability of recycling operations.

The study further demonstrated that recycling-system performance is shaped not only by the existence of environmental policies but also by the effectiveness of institutional coordination, enforcement mechanisms, infrastructure investment, and socio-economic support systems. These findings reinforce the principles of integrated waste-management governance, which emphasize the importance of coordinated resource-management systems and long-term material recovery. From an environmental governance perspective, the study highlights the critical role of institutional capacity and stakeholder coordination in translating policy frameworks into measurable environmental

outcomes. The results also suggest that financial incentives and structured collection systems significantly improve public participation and recycling efficiency, particularly when supported by accessible infrastructure and market demand for recycled materials.

The broader implications of this study are particularly relevant for policymakers, environmental managers, and sustainability practitioners in developing and transitioning economies. The findings indicate that improving recycling systems requires more than legislative reform alone; it also demands long-term investments in infrastructure, technological innovation, public education, and institutional strengthening. For countries such as the Philippines, integrating informal waste collectors into formal recycling systems may improve both environmental outcomes and social inclusion while supporting long-term recycling-system improvement. Additionally, the comparative framework developed in this study may serve as a practical tool for evaluating recycling-system performance in other national contexts facing similar waste-management challenges.

Despite these contributions, the study has several limitations. First, the analysis relied

primarily on secondary environmental datasets, institutional reports, and peer-reviewed literature. Variations in national reporting standards and data availability between countries may have influenced comparative interpretation across indicators. Second, the study focused on national-level systems and did not examine regional or local variations within each country, which may reveal important differences in recycling practices and institutional effectiveness. Third, while the multi-criteria framework provided a structured comparative approach, future studies may incorporate more advanced quantitative techniques such as material flow analysis, life cycle assessment, or econometric modeling to strengthen environmental-performance evaluation.

Future research may also explore the long-term effectiveness of Deposit Return Systems in developing economies, the role of informal recycling networks in resource-recovery transitions, and the environmental impacts of emerging plastic-recycling technologies. Comparative investigations involving additional Southeast Asian and European countries may further improve understanding of how governance structures and socio-economic conditions shape recycling performance across different contexts.

Overall, the study demonstrates that effective plastic recycling systems depend on strong institutional coordination, consistent policy enforcement, adequate infrastructure investment, and sustained stakeholder participation. The comparative findings provide practical insights for strengthening recycling governance and improving environmental waste-management systems in developing and transitioning economies.

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6. AUTHOR CONTRIBUTIONS

Conceptualization, T.D. and E.W.T.; Methodology, T.D.; Formal analysis, T.D. and E.W.T.; Investigation, E.W.T.; Data curation, E.W.T.; Writing – original draft preparation, E.W.T.; Writing – review and

editing, T.D.; Visualization, E.W.T.;
Supervision, T.D.

7. DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

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