The Role of Waste Generation and Composition Data in Advancing Circular Economy Strategies in Indonesia

Khenza Atthaya Namira Yulianto

Department of Electrical Engineering, Faculty of Engineering, Universitas Islam Kalimantan Muhammad Arsyad Al Banjari Banjarmasin, Banjarmasin, South Kalimantan 70582, Indonesia
*Corresponding Author:
Email: khenzaatthaya240503@gmail.com

***Abstract*.**

Rapid urbanization, population growth, and shifting consumption patterns have significantly increased municipal solid waste (MSW) generation in Indonesia, exposing structural inefficiencies in material use and post-consumption management under a predominantly linear economic model. National data indicate that waste generation has reached approximately 0.833 kg per capita per day, with urban waste volumes increasing substantially between 2020 and 2024 and concentrated primarily in densely populated regions such as Java, Sumatra, and Borneo. Waste composition analysis further reveals that organic waste remains the dominant fraction at nearly 40% of total municipal waste, followed by a rising plastic fraction approaching 20%, underscoring the need for data-driven circular economy strategies. This study employs a systematic review methodology, synthesizing peer-reviewed literature, governmental reports, and institutional documents to examine how waste generation and composition data can inform circular economy planning in Indonesia. The analysis integrates national waste statistics with evaluations of existing initiatives—including waste banks, Extended Producer Responsibility (EPR) schemes, refuse-derived fuel (RDF) production, composting programs, anaerobic digestion, and Black Soldier Fly (BSF) bioconversion—and compares them with international best practices suited to similar waste profiles. The findings indicate that although Indonesia has formally adopted circular economy principles and implemented various recovery-oriented programs, their scale and integration remain insufficient relative to the dominant organic and plastic fractions. Organic waste presents significant potential for biological treatment pathways such as composting and anaerobic digestion, while increasing plastic waste necessitates stronger upstream product redesign and reverse logistics systems. The study concludes that integrating reliable waste generation and composition data into policy formulation and technology deployment is essential for advancing evidence-based, scalable, and context-sensitive circular economy strategies capable of reducing landfill dependency and enhancing resource efficiency in Indonesia.

Keywords: *Circular economy; Indonesia; Municipal Solid Waste; Waste Composition and Waste Generation.*

I. INTRODUCTION

Rapid population growth, urbanization, and shifting consumption patterns have significantly increased municipal solid waste generation, particularly in developing economies [1]. Recent studies indicate that municipal solid waste (MSW) generation is rapidly increasing due to urbanization, industrialization, and population growth, with household waste already approached 1.8 billion tons by 2020 and is expected to surge further as urban populations near 70% of the global total [2], [3], [4], [5]. As MSW generation is closely linked to everyday consumption patterns, its continued growth intensifies the difficulty of effective waste minimization and reinforces the necessity for integrated and sustainable waste management strategies [6].The prevailing linear economic model (characterized by the "take–make–dispose" paradigm) has proven unsustainable, exacerbating environmental degradation and resource depletion [7]. In response to this crisis, the circular economy has emerged as an alternative paradigm to the conventional linear model, emphasizing resource efficiency, waste reduction, and the optimization of material value through closed-loop systems [8], [9], [10]. Circular economy concept also relies on effective waste management systems—including composting, recycling, and other treatment methods—thereby enabling the integration of economic viability, social considerations, and ecological preservation within sustainable environmental practices [11], [12].

International organizations such as United Nations Environment Programme and World Bank have consistently underscored the importance of transforming waste management systems as a core component of the sustainable development agenda [13], [14]. Indonesia is among the countries that have adopted the circular economy concept [15], [16]. Waste generation and composition play a pivotal role in enabling the realization of a circular economy. Data on waste quantities and material distribution allow for accurate estimation of fractions suitable for recycling, composting, or other treatment technologies, thereby facilitating their recovery as secondary resources [1], [17], [18]. Moreover, detailed waste generation and composition analyses help identify hazardous contaminants, ensuring safer closed-loop recycling processes [19], [20]. In addition, when producers are aware that their products contribute significantly to non-recyclable waste streams, it incentivizes the development of more sustainable, repairable, and recyclable designs [21], [22], [23], [24]. Waste composition data are also essential for Life Cycle Assessments (LCAs), which evaluate the environmental performance of circular strategies and ensure that proposed interventions (such as recycling) deliver genuine emission reductions compared to disposal [17], [25], [26].

At the national level, commitment to the circular economy has increasingly been incorporated into development planning documents by Kementerian Perencanaan Pembangunan Nasional, positioning the circular economy as a strategic pathway for enhancing resource productivity and promoting green growth. Nevertheless, its implementation is often not supported by adequate quantitative analyses of local waste generation and composition characteristics. Many studies remain limited to statistical measurements without translating their findings into concrete circular system designs. This condition reveals a significant gap between technical waste data and the formulation of circular economy policies.Based on the foregoing background, the research questions addressed in this study are: (1) how can waste generation and composition characteristics serve as a foundation for circular economy planning; and (2) to what extent does the integration of such data enhance the effectiveness of circular waste management strategies. Accordingly, this study aims to examine the significance of waste generation and composition data in supporting evidence-based policy formulation and circular economy business model development.To address these research questions, it is necessary to situate waste generation and composition analysis within the broader theoretical and conceptual foundations of the circular economy.

A systematic review of the existing literature is therefore essential to examine how circular economy principles, waste generation dynamics, and material composition analysis have been conceptualized and operationalized in prior studies, and to identify the extent to which empirical waste data have been integrated into circular governance frameworks.The concept of circular economy has evolved from earlier resource management paradigms such as industrial ecology and cradle-to-cradle design [10], [27]. Industrial ecology frames economy–environment interaction as a network of material and energy exchanges, promoting the idea that industrial systems can mimic natural ecosystems where waste from one process becomes input to another [28], [29], [30]. This ecological metaphor underpins circular economy thinking, reinforcing systemic feedback loops and emphasizing metabolic flows rather than isolated end-of-pipe solutions. Circular economy thus extends beyond waste management to include product life-cycle design, remanufacturing, and resource recovery embedded across supply chains [31], [32], [33]. This aligns with circular economy principles by prioritizing utility over consumption [34]. Collectively, these frameworks underpin the circular economy as an integrative governance model that connects production systems, consumption behavior, and policy mechanisms aimed at closing material loops [27], [35], [36], [37].In the Indonesian context, studies have begun to operationalize circular principles within urban and industrial sectors [38]. For example, research on circular economy in Indonesia highlights barriers related to institutional capacity, lack of standardized metrics, and fragmented waste value chains [39], [40].

Empirical investigations in cities such as Jakarta, Bandung, and Surabaya illustrate how local policy frameworks incorporate circular strategies in waste-to-resource initiatives, yet implementation remains uneven due to limited coordination between government, private sector, and communities [41], [42]. These findings suggest that while the circular economy concept is gaining traction nationally, its translation into measurable outcomes requires strengthening analytical foundations and governance structures.Waste generation is not only an indicator of consumption patterns, but also reflects underlying socio-technical dynamics within urban systems [43]. From an urban metabolism perspective, cities are conceptualized as organisms that process energy, materials, and waste through interconnected socio-economic and infrastructural subsystems [43]. In this framework, waste generation can be interpreted as an output of material throughput, influenced by demographic shifts, economic activities, and urban form [44], [45], [46], [47]. Socio-economic stratification further affects waste profiles, with affluent areas typically generating higher per capita waste volumes, whereas informal settlements may produce more heterogeneous waste with higher organic content [48].Several studies have explored global and regional determinants of waste generation, identifying key drivers such as GDP per capita, consumer behavior, and retail expansion [49], [50], [51].

For instance, research in Southeast Asia indicates that economic modernization correlates with increased packaging waste and synthetic materials, complicating recycling processes due to mixed polymer types [52]. In Indonesia, municipal waste generation rates vary substantially among provinces and city typologies, attributable to differences in urban density, household income, infrastructure accessibility, and public awareness levels [53].Waste composition analysis serves as a key analytical tool for evaluating the quality of waste streams and identifying opportunities for material recovery [54]. In material flow studies, composition data enable the construction of Sankey diagrams, which visually map the flow of major material fractions through collection, treatment, and disposal systems [55], [56], [57]. This analytical capability supports decision-making by quantifying not only the mass of recyclable fractions but also the distribution of contaminants, moisture content, and heterogeneity [58], [59]. Beyond characterization, waste composition data are increasingly used to inform technology selection models in sustainable waste management. Waste composition analysis also underpins economic viability assessments by projecting potential revenue streams from recovered materials, allowing stakeholders to compare cost–benefit trade-offs among alternative waste treatment pathways [60].

In Indonesian cities, research indicates that organic waste often constitutes the largest fraction of household waste, while plastic fractions continue to rise with increasing consumption of packaged goods [48], [61], [62], [63], [64]. These trends have policy implications: effective composting initiatives might yield significant environmental benefits, whereas escalating plastic fractions necessitate targeted reduction and redesign strategies at the production level [65], [66]. Thus, waste composition analysis is not merely descriptive but serves as a foundational input to circular economy modeling, policy evaluation, and investment prioritization [61].

II. METHODS

Research Design

This study adopts a systematic review approach to critically examine the functional role of waste generation and waste composition data in informing circular economy strategies in Indonesia. Unlike empirical research articles that rely on primary data collection, this review synthesizes existing scholarly literature, policy documents, and governmental reports to construct an analytical framework linking waste characterization data to strategic circular interventions.The review is designed as a structured narrative synthesis with analytical categorization. It integrates environmental policy analysis, material flow perspectives, and circular economy strategy mapping to evaluate how empirical waste data, specifically waste generation rates and composition profiles, serve as decision-making instruments in determining appropriate recovery pathways such as recycling, composting, anaerobic digestion, and other resource recovery mechanisms. The methodological orientation emphasizes interpretative rigor, conceptual integration, and comparative assessment across documented cases in Indonesia.

Study Area and Sampling Framework

The geographical focus of this review is Indonesia, selected due to its rapidly increasing municipal solid waste generation and its ongoing transition toward circular economy policies at national and regional levels. Rather than employing statistical sampling of populations, this review applies purposive sampling of literature sources to ensure relevance, credibility, and contextual accuracy.The inclusion criteria consist of: (1) peer-reviewed journal articles addressing waste generation, waste composition, or circular economy implementation in Indonesia; (2) official government publications, including policy frameworks and national waste management reports; and (3) institutional reports that provide quantitative waste data or strategic circular economy evaluations. Exclusion criteria include publications lacking methodological transparency, non-Indonesian case studies without comparative relevance, and opinion-based commentaries without empirical grounding. This purposive selection ensures that the synthesized evidence reflects authoritative and policy-relevant sources.

Data Collection

Data were collected through a structured literature review conducted across academic databases, governmental repositories, and international institutional publications. The extracted data were categorized into three principal domains. First, quantitative data on waste generation rates (e.g., kg/capita/day) and material composition percentages were compiled to identify dominant waste fractions in Indonesia. Second, documentation of circular economy initiatives already implemented by the Indonesian government (such as recycling programs, composting initiatives, waste bank systems, extended producer responsibility schemes, and organic waste processing facilities) was systematically summarized. Third, international case studies were collected from countries with comparable waste composition characteristics, particularly those with high organic content or increasing plastic fractions, in order to identify applicable strategic models.Data extraction followed a standardized documentation matrix to ensure consistency in recording waste indicators, policy instruments, technological approaches, and reported outcomes.

Data Analysis

The analytical process was conducted through thematic synthesis and comparative evaluation. Initially, Indonesian waste generation and composition data were synthesized to establish a national waste profile, highlighting dominant material fractions and regional variations. This stage aims to clarify the structural characteristics of Indonesia's waste stream as a foundation for circular economy considerations. Subsequently, existing circular economy initiatives in Indonesia were analyzed descriptively to assess their scope, sectoral focus, and technological orientation. Given that circular economy implementation in Indonesia remains in a developing phase, the analysis does not attempt to evaluate full systemic integration, but rather documents current efforts and their alignment with prevailing waste characteristics.Finally, selected international experiences were examined to identify strategic approaches adopted in jurisdictions with similar waste composition patterns. By comparing Indonesia's waste profile with international best practices, particularly in organic waste valorization, plastic recycling optimization, and decentralized resource recovery, the study derives context-sensitive policy insights. This comparative synthesis is intended to provide evidence-based recommendations for advancing circular economy strategies in Indonesia, grounded in empirical waste data and informed by globally tested models.

III. RESULT AND DISCUSSION

Waste Generation in Indonesia

Global municipal solid waste (MSW) generation continues to rise at an alarming rate, with the increase predominantly concentrated in major economies such as China and the United States, contributing approximately 37% and 12%, respectively, of the total global MSW increase during the 2014–2019 period [67], [68]. This global escalation reflects not only demographic expansion but also structural transformations in production and consumption systems. Within this broader context, Indonesia emerges as a significant contributor to the growing waste burden in Southeast Asia. The synthesis of national reports and peer-reviewed studies indicates that Indonesia exhibits a steadily increasing municipal solid waste generation rate, driven primarily by urbanization, population growth, and shifting consumption patterns associated with economic development [69], [70].Quantitatively, national data show that waste generation in Indonesia reaches approximately 3.25 liters per capita per day, equivalent to 0.833 kg per capita per day [71]. At the urban scale, the average distribution of waste generation across Indonesian cities amounted to 56,729.76 tons in 2020 and increased substantially to 70,662 tons in 2024, confirming a persistent upward trend in municipal waste distribution [72]. Spatially, solid waste generation between 2019 and 2021 was largely concentrated on the islands of Java, Sumatra, and Borneo, which are characterized by high population density and industrial activity [73].

This geographical concentration underscores the interplay between demographic clustering, economic intensity, and waste output, suggesting that regional development patterns significantly shape national waste profiles. City-level evidence further illustrates the magnitude and heterogeneity of Indonesia's waste generation. The capital city, Jakarta, is estimated to generate approximately 7,500 tons of waste per day [74], [75], [76], positioning it among the highest waste-producing metropolitan areas in the region. Bandung produces around 1,594.18 tons per day [77], while Surabaya generates between 1,450 and 2,000 tons daily, with an average of approximately 1,600 tons per day [78], [79]. In Banten Province, Serang and Tangerang cities generate 601.38 tons and 1,011.45 tons per day, respectively [80]. Other regions, such as cities in Riau Province, demonstrate increasing waste volumes partly attributed to limited public awareness and inadequate waste management practices [81], [82], [83], [84], [85], [86]. These data collectively indicate that waste generation in Indonesia is not only high in absolute terms but also unevenly distributed, reflecting varying levels of governance capacity, infrastructure provision, and community engagement.

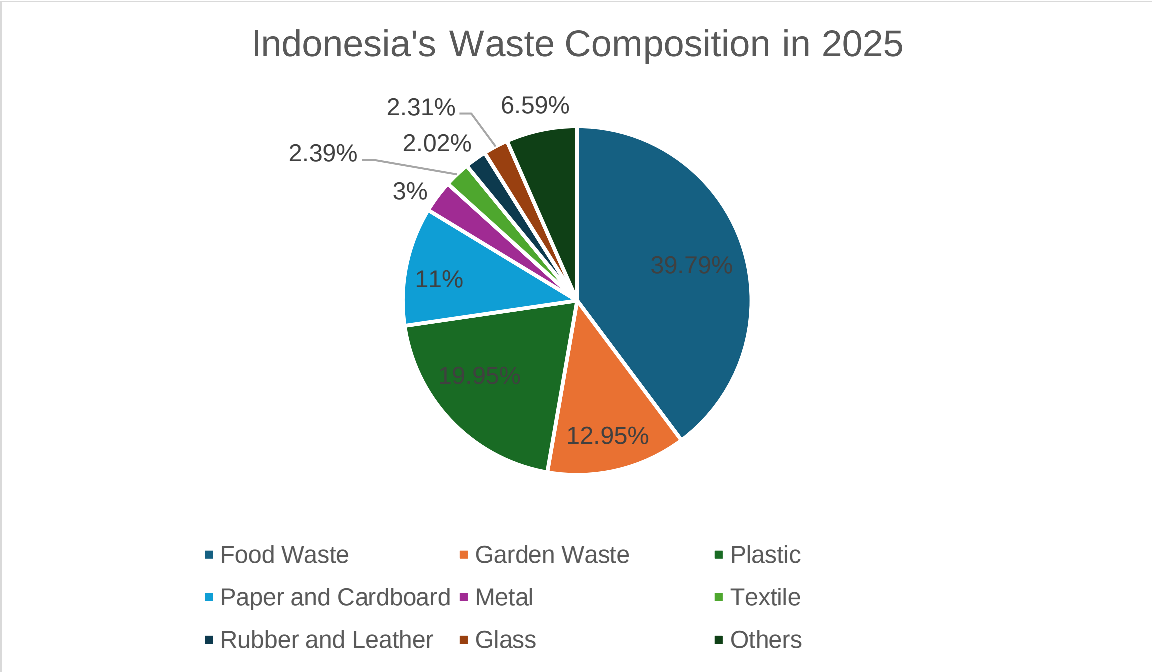
Conceptually, environmentally sound solutions to escalating waste generation emphasize waste reduction and recycling as primary interventions. These approaches align directly with circular economy principles, which seek to decouple economic growth from resource consumption by promoting material recovery and extending product life cycles. However, the persistent increase in waste generation suggests that reduction and recycling efforts have not yet offset the growth in material throughput. From a systemic perspective, the upward trajectory of waste generation highlights structural inefficiencies in material use and post-consumption management. The expansion of waste volume cannot be attributed solely to demographic growth; rather, it reflects entrenched linear consumption patterns characterized by short product lifespans, disposable packaging, and limited recovery infrastructure [87], [88]. Compounding this challenge are disparities in data consistency and methodological approaches across provinces, which reveal gaps in waste measurement and reporting systems. Inconsistent data collection practices may hinder accurate forecasting, infrastructure planning, and policy prioritization. Reliable and standardized waste generation data are therefore essential to ensure that strategic interventions are proportionate to actual waste characteristics. Without robust data governance, circular economy planning risks being normative rather than evidence-based, thereby limiting its operational effectiveness.Given the continuous increase in waste generation across Indonesia, the circular economy framework represents a strategically appropriate pathway for systemic reform.

Nevertheless, circular economy implementation in Indonesia remains suboptimal. Several factors constrain its effectiveness, including limited source segregation, insufficient technological infrastructure, fragmented regulatory enforcement, financial constraints, and varying levels of stakeholder commitment. Institutional coordination between central and local governments, private sector actors, and community organizations remains uneven, reducing the scalability of circular initiatives. Consequently, strengthening multi-stakeholder collaboration and enhancing regulatory coherence are imperative to overcoming these structural barriers [89], [90]. A coordinated and data-driven circular economy strategy, grounded in accurate waste generation metrics, is therefore essential to transforming Indonesia's waste challenge into an opportunity for sustainable resource management and long-term environmental resilience.

Waste Composition in Indonesia

Data reported by the National Waste Management Information System (SIPSN) in 2021 indicate that Indonesia's waste composition is predominantly characterized by food waste, accounting for 40.5% of total waste generated nationwide [15]. Subsequent data from SIPSN in 2025 demonstrate that food waste remains the largest fraction, with a marginal decline to 39.79%. Although this slight reduction may suggest incremental improvements in waste reduction efforts, the dominance of food waste over a four-year period confirms that biodegradable materials continue to constitute the principal component of Indonesia's municipal waste stream. This persistence underscores the structural nature of organic waste generation, closely linked to household consumption patterns, traditional market systems, and limited upstream food loss prevention mechanisms.The global relevance of food waste further amplifies the significance of these findings. Food waste is widely recognized as a major contributor to greenhouse gas emissions, particularly methane emissions from landfills, thereby exacerbating global warming and climate change impacts. Consequently, the sustained dominance of food waste in Indonesia not only represents a domestic waste management challenge but also situates the country within broader international climate mitigation concerns. The consistency between the 2021 and 2025 SIPSN datasets reinforces the reliability of national waste composition reporting while simultaneously highlighting the urgency of systemic intervention in organic waste management.

Fig 1. Waste Composition in Indonesia (2025)



Source: SIPSN (2025)

Plastic waste constitutes the second-largest fraction of Indonesia's waste composition. According to SIPSN data, plastics accounted for 17.85% of total waste in 2021, increasing to 19.95% in 2025. This upward trend indicates a structural shift in consumption patterns, particularly the proliferation of single-use packaging, e-commerce distribution systems, and modern retail expansion. Unlike organic waste, plastics exhibit extremely low decomposition rates, persisting in terrestrial and marine environments for decades or even centuries. The environmental implications of rising plastic fractions therefore extend beyond landfill capacity constraints to include marine pollution, microplastic contamination, and ecosystem degradation. Beyond food and plastic waste, other fractions—such as paper, textiles, metals, and glass—contribute smaller yet still significant shares to the overall waste stream. However, the comparative dominance of organic and plastic fractions defines the structural profile of Indonesia's municipal solid waste. This composition pattern is not isolated to national aggregates; rather, it is consistently reflected in city-level analyses across diverse urban contexts. Such consistency strengthens the credibility of SIPSN data and indicates that the observed national profile accurately represents prevailing material distributions.

Empirical studies from major Indonesian cities further corroborate this composition pattern. In Jakarta, organic waste accounts for 53.75% of total waste, followed by paper (14.92%) and plastics (14.02%) [91]. Similarly, Pandansari Lor Village reports 58.42% organic waste and 26.74% plastic waste [92], while an urban kampong records 61.62% organic waste and 13.14% plastics [93]. In Bekasi, food waste dominates at 66%, with plastics contributing 8.81% [94]. Surabaya exhibits a comparable structure, with 54.31% organic waste and 19.44% plastics [95]. The recurrence of organic dominance across metropolitan, peri-urban, and community-level settings demonstrates that biodegradable waste is structurally embedded in Indonesia's urban metabolism.The convergence between national SIPSN data and localized empirical findings confirms that organic waste typically exceeds 50% of total waste in many regions. This fraction primarily consists of food residues and biodegradable materials originating from households and traditional markets, reflecting dietary patterns and distribution systems. Plastics consistently represent the second-largest fraction, followed by paper and other recyclables in smaller proportions. The rising plastic share mirrors retail modernization and increased reliance on packaged goods, suggesting that economic transformation directly shapes waste composition dynamics.

From a circular economy perspective, these structural characteristics carry significant strategic implications. The predominance of organic waste indicates substantial untapped potential for biological treatment pathways, including composting and anaerobic digestion. Such approaches could simultaneously reduce landfill dependency, mitigate methane emissions, and generate value-added outputs such as compost and biogas. However, technological feasibility is frequently constrained by inadequate source segregation and contamination of organic fractions with mixed materials, which reduce process efficiency and product quality. At the same time, the increasing plastic fraction presents complex technical challenges due to heterogeneous polymer types and limited domestic capacity for advanced recycling technologies. Accordingly, waste composition data function not merely as descriptive statistics but as foundational determinants of technological selection, investment prioritization, and policy design within Indonesia's evolving circular economy framework.

Circular Economy in Indonesia

From waste generation and composition data, organic waste constitutes the largest fraction of municipal solid waste in Indonesia, presents both a challenge and an opportunity for circular economy strategies. One promising approach is the implementation of decentralized bioconversion systems using Black Soldier Fly (BSF) larvae to process organic waste at the community level. A case study in Bandung demonstrated that BSF-based bioconversion, integrated with composting methods, enabled neighborhoods to process significant volumes of household organic waste, generate high-value biomass for animal feed, and produce organic fertilizer, while mitigating methane emissions associated with traditional disposal. This model exemplifies how community-scale interventions rooted in circular economy principles can effectively address dominant waste composition fractions, complementing existing waste bank systems focused primarily on recyclables [96].In rural and peri-urban contexts, circular economy strategies have also been applied successfully to organic waste management. For example, research conducted in Tegal Tugu Village highlights the community's practice of sorting, composting, and fermenting organic waste to produce compost and biogas, resulting in improved soil quality, reduced dependency on chemical fertilizers, and enhanced economic opportunities through sales of organic products. Such models illustrate the potential for circular organic waste processing to contribute to sustainable local economies and strengthen community resilience, particularly in areas where organic waste accounts for the majority of waste streams [97].

Beyond community and village-level practices, quantitative assessments at the regional scale further substantiate the economic potential of organic waste valorization. An analysis of the organic fraction of municipal solid waste in Buleleng Regency estimated resource recovery potential from multiple valorization technologies, including anaerobic digestion, composting, BSF processing, and production of eco-enzymes. The study quantified both resource outputs and their potential economic value, demonstrating that circular organic waste strategies can generate substantial returns and should be considered in municipal planning and investment decisions. This reinforces the strategic importance of aligning waste composition data with technology choices to optimize circular outcomes [98].Technological interventions targeting organic waste also extend into renewable energy generation. Research on the utilization of household organic waste for biogas production—integrated with Internet-of-Things monitoring systems—illustrates how organic fractions can be repurposed as renewable energy sources, reducing reliance on fossil fuels and mitigating greenhouse gas emissions. Although such technological pilots remain nascent, they demonstrate the feasibility of integrating digital monitoring with organic waste valorization, further expanding the scope of circular economy applications beyond conventional composting and recycling [99].

Despite these advances, challenges remain in scaling organic waste circular economy strategies across Indonesia. Limitations in processing capacity, uneven community awareness, and inadequate infrastructure are frequently cited barriers. Nonetheless, the diversity of demonstrated approaches—from BSF bioconversion to village composting and regional valorization assessments—indicates a growing body of evidence supporting the integration of organic waste into circular systems. By leveraging empirical waste composition data and technology-specific research, policymakers and practitioners can design more effective, scalable, and context-sensitive circular economy strategies that address the country's dominant waste fractions and unlock substantial environmental and socio-economic benefits [9].Indonesia has taken meaningful steps toward embedding circular economy principles into its waste management framework, as evidenced by a growing body of peer-reviewed research and documented initiatives. For example, community-based waste bank models have been analyzed as platforms that operationalize circular economy practices by enabling material recovery and reintegration into productive uses, particularly for plastic waste streams that align with the country's waste composition profile and national plastic waste patterns [100]. These waste bank systems promote source segregation, material reuse, and community awareness, reflecting the official endorsement of decentralized waste recovery interventions within broader sustainability agendas.

Academic analysis of specific waste bank implementations, such as Mekar Sari Waste Bank in South Jakarta and Waste bank in Maros Regency, demonstrates how these institutions function as local hubs for participatory recycling and reuse practices, fostering partnerships among households, recyclers, and municipal authorities. The study highlights that waste bank operations not only divert recyclable materials from landfill but also educate residents about waste sorting and sustainable consumption—an essential behavioral element for effective circular ecosystem design [101]. In addition to community-based mechanisms, Indonesia has also explored circular economy strategies within production and industry contexts. Extended Producer Responsibility (EPR) schemes have been proposed and analyzed for post-consumer plastic waste management, where producers are encouraged (or required) to participate in the lifecycle management of packaging materials. Such regulatory frameworks aim to internalize waste management costs and stimulate eco-design, which is necessary given the increasing proportion of plastics in the national waste composition [102]. Municipal waste governance studies further indicate that evolving circular economy implementation includes structured waste management planning with reverse logistics principles. For instance, optimized reverse logistics network designs have been developed for plastic waste in Jakarta, acknowledging both the need for integrated collection systems and the utilization of recovered plastics within value chains—an approach that is reflective of the second largest waste fraction identified in composition datasets [103].

Moreover, Indonesia's circular economy practices extend beyond recyclables to include waste conversion technologies. Case studies of Regional Public Service Agencies illustrate the conversion of mixed waste into Refuse Derived Fuel (RDF), which is subsequently used as alternative fuel in industrial applications. This approach signals a strategic alignment with circular economy objectives to reduce landfill dependency while gaining energy from waste streams [42]. Research also highlights the application of circular economy principles in rural and agricultural contexts, where organic waste — the dominant fraction identified in SIPSN data — can be transformed into compost or other useful bioproducts at local levels, thereby turning waste liabilities into resource flows. Such approaches underscore the potential for community-based circularity beyond urban settings and demonstrate adaptability in regions where organic garbage constitutes the majority of waste generation [104]. Despite these advances, studies consistently observe that circular economy implementation in Indonesia remains uneven and challenged by limited scale, institutional fragmentation, and insufficient integration with empirical waste data systems. National regulatory frameworks like the Extended Producer Responsibility guidelines and solid waste roadmaps underscore intent but require strengthened enforcement and broader infrastructural support to fully leverage material recovery potential and respond to the country's evolving waste generation and composition dynamics [40].

Adaptable International Circular Economy Technologies Based on Indonesia's Waste Generation and Composition Profile

Indonesia's waste composition profile—dominated by organic waste at roughly 40% of the total stream—creates both a necessity and an opportunity for targeted circular economy interventions that valorize biodegradable materials into productive outputs. This structural dominance of organic fractions, combined with rapidly increasing waste generation, underscores the urgency of deploying technologies that can handle large volumes of organic biomass effectively. Such interventions not only address environmental impacts but also align with circular economy objectives by converting organic residues into nutrients, energy, and other value-added products.A particularly promising technology that has gained international attention is Black Soldier Fly (BSF) larvae bioconversion, which transforms organic waste into insect biomass, frass (organic fertilizer), and potentially feed products. Research has demonstrated that BSF larvae rapidly consume significant quantities of organic waste, converting it into by-products with economic value, and that such systems can form the biological backbone of circular waste strategies [105]. In Indonesia, community-level initiatives in Surabaya have successfully applied BSF bioconversion to neighborhood waste streams, reducing landfill loads and demonstrating community engagement in resource recovery [106].

Beyond insect-mediated transformation, anaerobic digestion represents another scalable technology capable of converting organic waste into renewable energy, specifically biogas, while simultaneously producing digestate that can be used as soil amendment. Literature in circular waste management indicates that both aerobic and anaerobic digestion technologies contribute to the advancement of bio-economy models by supplying chemicals, nutrients, and fuels necessary for a resource-efficient society [107]. Pilot studies in Indonesia, such as biodigester utilization for biogas production from organic feedstocks in PT PLN Nusantara Power UP Muara Karang, illustrate community interest in generating energy from waste, thereby reducing dependency on fossil fuels and mitigating greenhouse gas emissions [108].In addition to advanced bioconversion and digestion systems, straightforward composting technologies remain highly relevant and adaptable to local contexts. Household and community composting systems have been documented across Indonesian villages, showing that even low-tech methods can significantly reduce food waste volumes and produce nutrient-rich soil amendments for agriculture [109]. Such systems are particularly suitable given Indonesia’s substantial organic waste fraction and strong agrarian linkages, enabling organic residues to reenter nutrient cycles rather than being relegated to landfill disposal.Comparative international experiences further inform Indonesia’s circular economy roadmap. In European contexts, waste management strategies explicitly mandate source separation for organic waste, as seen in municipal ordinances that require households to divert compostable materials from residual streams for dedicated biological treatment, thereby enhancing both recycling rates and compost quality; although not from a journal article, this case exemplifies the type of policy frameworks that can support technology adoption.

International systematic reviews also show that countries like Germany, the Netherlands, and Sweden implement integrated organic waste valorization strategies—including fermentation, vermicomposting, and engineered biomass production—that combine policy support with technological innovation [110].However, the successful deployment of these technologies in Indonesia requires not only technical adaptation but also enabling policy environments, financial incentives, and participatory governance structures. Research indicates that community empowerment and capacity building are critical to ensuring that organic waste technologies do not remain peripheral projects but become integral components of urban and rural waste systems [111]. These studies underscore the importance of aligning waste generation and composition data with technology selection to ensure that interventions are both contextually appropriate and scalable.In synthesizing both national trends and international best practices, it becomes apparent that circular economy strategies for organic waste must be multi-modal—combining bioconversion, anaerobic digestion, composting, and decentralized energy systems—to effectively address Indonesia’s waste profile. By leveraging empirical waste data and proven technological pathways, policymakers can design integrative frameworks that reduce landfill pressure, generate economic opportunities, and contribute to climate mitigation goals. Ultimately, embedding these technologies into a broader circular economy strategy will require sustained coordination across government, industry, and community stakeholders, supported by evidence-based planning and robust monitoring systems.

IV. CONCLUSION

Indonesia’s municipal solid waste generation continues to show a consistent upward trend, reaching approximately 0,833 kg per capita per day (equivalent to 3,25 liters per capita per day) at the national level. In aggregate urban distribution, waste volumes increased from around 56.729,76 tons in 2020 to 70.662 tons in 2024, reflecting rapid urbanization, population growth, and shifting consumption patterns. Waste generation is heavily concentrated in densely populated islands such as Java, Sumatra, and Borneo, with major metropolitan areas like Jakarta generating approximately 7.500 tons per day, followed by Bandung and Surabaya with daily outputs exceeding 1.500 tons. These figures confirm that Indonesia faces a structurally escalating waste burden driven by demographic and economic transformation.In terms of composition, Indonesia's waste stream is dominantly characterized by organic (food) waste, accounting for approximately 40,5% in 2021 and 39,79% in 2025, making it the largest fraction nationwide. The second-largest component is plastic waste, which increased from 17,85% in 2021 to 19,95% in 2025, indicating a growing reliance on packaged and single-use products. City-level studies consistently reinforce this pattern, with organic waste often exceeding 50% of total municipal waste in several urban areas, while plastics remain the primary non-biodegradable fraction.

This dominance of organic and plastic materials defines Indonesia's structural waste profile and directly influences the selection of appropriate circular economy strategies.The findings further indicate that Indonesia has initiated multiple circular economy practices, including waste banks, Extended Producer Responsibility (EPR) frameworks, RDF production, community composting, and decentralized bioconversion systems. However, these initiatives remain fragmented, uneven in scale, and insufficiently integrated with empirical waste generation and composition datasets. Strengthening institutional coordination, regulatory enforcement, and standardized data governance is essential to enhance systemic coherence and scalability.Drawing on international experiences in organic waste valorization and advanced recycling systems, this study concludes that Indonesia's circular economy transition should prioritize technologies aligned with its dominant organic fraction while reinforcing plastic circularity through upstream design and reverse logistics integration. A data-driven, multi-technology approach—supported by strong governance and stakeholder collaboration—offers the most viable pathway for transforming Indonesia's waste challenge into a resource-efficient and environmentally resilient circular system.

REFERENCES

[1] Z. Zhang *Dkk.*, "Municipal Solid Waste Management Challenges In Developing Regions: A Comprehensive Review And Future Perspectives For Asia And Africa," *Science Of The Total Environment*, Vol. 930, Hlm. 172794, Jun 2024, Doi: 10.1016/J.Scitotenv.2024.172794.

[2] A. Maalouf Dan A. Mavropoulos, "Re-Assessing Global Municipal Solid Waste Generation," *Waste Manag Res*, Vol. 41, No. 4, Hlm. 936–947, Apr 2023, Doi: 10.1177/0734242x221074116.

[3] N. Valenzuela-Levi, "Factors Influencing Municipal Recycling In The Global South: The Case Of Chile," *Resources, Conservation And Recycling*, Vol. 150, Hlm. 104441, Nov 2019, Doi: 10.1016/J.Resconrec.2019.104441.

[4] L. Zhao, T. Dai, Z. Qiao, P. Sun, J. Hao, Dan Y. Yang, "Application Of Artificial Intelligence To Wastewater Treatment: A Bibliometric Analysis And Systematic Review Of Technology, Economy, Management, And Wastewater Reuse," *Process Safety And Environmental Protection*, Vol. 133, Hlm. 169–182, Jan 2020, Doi: 10.1016/J.Psep.2019.11.014.

[5] T. A. Kurniawan, M. H. Dzarfan Othman, G. H. Hwang, Dan P. Gikas, "Unlocking Digital Technologies For Waste Recycling In Industry 4.0 Era: A Transformation Towards A Digitalization-Based Circular Economy In Indonesia," ***Journal Of Cleaner Production,*** Vol. 357, Hlm. 131911, Jul 2022, Doi: 10.1016/J.Jclepro.2022.131911.

[6] S. Mor Dan K. Ravindra, "Municipal Solid Waste Landfills In Lower- And Middle-Income Countries: Environmental Impacts, Challenges And Sustainable Management Practices," *Process Safety And Environmental Protection*, Vol. 174, Hlm. 510–530, Jun 2023, Doi: 10.1016/J.Psep.2023.04.014.

[7] A. Garcilazo-Lopez, D. A. Lizarzaburu-Aguinaga, E. V. Ramos Farroñán, C. D. V. Jurado, C. F. Cabrera Carranza, Dan J. L. Jave Nakayo, "The Circular Economy As An Environmental Mitigation Strategy: Systematic And Bibliometric Analysis Of Global Trends And Cross-Sectoral Approaches," *Environments*, Vol. 13, No. 1, Hlm. 48, Jan 2026, Doi: 10.3390/Environments13010048.

[8] M. Geissdoerfer, P. Savaget, N. M. P. Bocken, Dan E. J. Hultink, "The Circular Economy – A New Sustainability Paradigm?," ***Journal Of Cleaner Production,*** Vol. 143, Hlm. 757–768, Feb 2017, Doi: 10.1016/J.Jclepro.2016.12.048.

[9] Ikponmwosa Aiguobarueghian, Uwaga Monica Adanma, Emmanuel Olurotimi Ogunbiyi, Dan Nko Okina Solomon, "Waste Management And Circular Economy: A Review Of Sustainable Practices And Economic Benefits," ***World J. Adv. Res. Rev.,*** Vol. 22, No. 2, Hlm. 1708–1719, Mei 2024, Doi: 10.30574/Wjarr.2024.22.2.1517.

[10] J. Kirchherr, N.-H. N. Yang, F. Schulze-Spüntrup, M. J. Heerink, Dan K. Hartley, "Conceptualizing The Circular Economy (Revisited): An Analysis Of 221 Definitions," *Resources, Conservation And Recycling*, Vol. 194, Hlm. 107001, Jul 2023, Doi: 10.1016/J.Resconrec.2023.107001.

[11] D. Ferraz Dan A. Pyka, "Circular Economy, Bioeconomy, And Sustainable Development Goals: A Systematic Literature Review," *Environ Sci Pollut Res*, Sep 2023, Doi: 10.1007/S11356-023-29632-0.

[12] M. Ayilara, O. Olanrewaju, O. Babalola, Dan O. Odeyemi, "Waste Management Through Composting: Challenges And Potentials," *Sustainability*, Vol. 12, No. 11, Hlm. 4456, Mei 2020, Doi: 10.3390/Su12114456.

[13] F. Sgroi, "Circular Economy And Environmental Protection," *Aimses*, Vol. 9, No. 2, Hlm. 122–127, 2022, Doi: 10.3934/Environsci.2022009.

[14] B. Corona, L. Shen, D. Reike, J. Rosales Carreón, Dan E. Worrell, "Towards Sustainable Development Through The Circular Economy—A Review And Critical Assessment On Current Circularity Metrics," *Resources, Conservation And Recycling*, Vol. 151, Hlm. 104498, Des 2019, Doi: 10.1016/J.Resconrec.2019.104498.

[15] Waluyo Dan D. B. Kharisma, "Circular Economy And Food Waste Problems In Indonesia: Lessons From The Policies Of Leading Countries," *Cogent Social Sciences*, Vol. 9, No. 1, Hlm. 2202938, Des 2023, Doi: 10.1080/23311886.2023.2202938.

[16] F. Mulyani, A. Frian, Dan T. Mohd. Khairal Abdullah, "Circular Economy Implementation: A Case Study In Indonesia," *Inovasi Global Jurnal*, Vol. 2, No. 2, Hlm. 388–405, Mar 2024, Doi: 10.58344/Jig.V2i2.72.

[17] V. Bisinella, R. Götze, K. Conradsen, A. Damgaard, T. H. Christensen, Dan T. F. Astrup, "Importance Of Waste Composition For Life Cycle Assessment Of Waste Management Solutions," ***Journal Of Cleaner Production*,** Vol. 164, Hlm. 1180–1191, Okt 2017, Doi: 10.1016/J.Jclepro.2017.07.013.

[18] I. M. Hernández-Romero, J. C. Niño-Caballero, L. T. González, M. Pérez-Rodríguez, A. Flores-Tlacuahuac, Dan A. Montesinos-Castellanos, "Waste Management Optimization With Nlp Modeling And Waste-To-Energy In A Circular Economy," *Sci Rep*, Vol. 14, No. 1, Hlm. 19859, Agu 2024, Doi: 10.1038/S41598-024-69321-7.

[19] E. A. Shalaby, "Prospects Of Effective Microorganisms Technology In Wastes Treatment In Egypt," ***Asian Pacific Journal Of Tropical Biomedicine*,** Vol. 1, No. 3, Hlm. 243–248, Jun 2011, Doi: 10.1016/S2221-1691(11)60035-X.

[20] O. Novikova, I. Vladimirov, Dan T. Bugaeva, "Expansion Of The Fuel And Energy Balance Structure In Russia Through The Development Of A Closed-Loop Recycling," *Sustainability*, Vol. 13, No. 9, Hlm. 4965, Apr 2021, Doi: 10.3390/Su13094965.

[21] Q. Liu *Dkk.*, "The Role Of Plastic Chemical Recycling Processes In A Circular Economy Context," *Chemical Engineering Journal*, Vol. 498, Hlm. 155227, Okt 2024, Doi: 10.1016/J.Cej.2024.155227.

[22] M. Jain, D. Kumar, J. Chaudhary, S. Kumar, S. Sharma, Dan A. Singh Verma, "Review On E-Waste Management And Its Impact On The Environment And Society," *Waste Management Bulletin*, Vol. 1, No. 3, Hlm. 34–44, Des 2023, Doi: 10.1016/J.Wmb.2023.06.004.

[23] H. El Bari, *Waste Management In Developing Countries*, 1st Ed. Dalam Waste As A Resource Series. Cham: Springer International Publishing Ag, 2023.

[24] P. Singh, S. Daga, K. Yadav, Dan V. Mishra, Ed., *Circular Economy And Environmental Resilience: Solutions For A Sustainable Tomorrow, Volume 1*, 1st Ed. 2025. Cham: Springer Nature Switzerland, 2025. Doi: 10.1007/978-3-031-93091-1.

[25] Y. Fernando, M.-L. Tseng, N. Aziz, R. B. Ikhsan, Dan I. S. Wahyuni-Td, "Waste-To-Energy Supply Chain Management On Circular Economy Capability: An Empirical Study," *Sustainable Production And Consumption*, Vol. 31, Hlm. 26–38, Mei 2022, Doi: 10.1016/J.Spc.2022.01.032.

[26] F. Liu, M. Shafique, Dan X. Luo, "Dynamic Lifecycle Emissions Of Electric And Hydrogen Fuel Cell Vehicles In A Multi-Regional Perspective," *Environmental Impact Assessment Review*, Vol. 111, Hlm. 107695, Jan 2025, Doi: 10.1016/J.Eiar.2024.107695.

[27] J. Kirchherr, D. Reike, Dan M. Hekkert, "Conceptualizing The Circular Economy: An Analysis Of 114 Definitions," *Resources, Conservation And Recycling*, Vol. 127, Hlm. 221–232, Des 2017, Doi: 10.1016/J.Resconrec.2017.09.005.

[28] O. Genc Dan A. Kurt, "Mimicking Nature To Design Eco-Industrial Parks: Exploring The Influence Of Connectance On Industrial Network Optimization," ***Journal Of Cleaner Production*,** Vol. 475, Hlm. 143704, Okt 2024, Doi: 10.1016/J.Jclepro.2024.143704.

[29] R. Geetha, "Circular Economy Through Integrated Industrial Ecology: Innovations In Resource Recovery And Process Re-Design," *Biotechnology Notes*, Vol. 6, Hlm. 245–259, 2025, Doi: 10.1016/J.Biotno.2025.10.005.

[30] S. Al-Quradaghi, Q. P. Zheng, Dan A. Elkamel, "Generalized Framework For The Design Of Eco-Industrial Parks: Case Study Of End-Of-Life Vehicles," *Sustainability*, Vol. 12, No. 16, Hlm. 6612, Agu 2020, Doi: 10.3390/Su12166612.

[31] O. E. Aro, "Circular Economy In Supply Chain Management: Leveraging Technology For Sustainability," ***Int. J. Res. Publ. Rev.***, Vol. 5, No. 10, Hlm. 4057–4057, Okt 2024, Doi: 10.55248/Gengpi.5.1024.3014.

[32] L. Batista, S. Seuring, A. Genovese, J. Sarkis, Dan A. Sohal, "Theorising Circular Economy And Sustainable Operations And Supply Chain Management: A Sustainability-Dominant Logic," ***Ijopm,*** Vol. 43, No. 4, Hlm. 581–594, Mar 2023, Doi: 10.1108/Ijopm-12-2022-0765.

[33] S. Ishaq, U. Tanveer, T. G. Hoang, Dan S. Seuring, "Circular Design Strategies Unleashed: Competitiveness And The Journey Towards Circular Manufacturing Businesses," *Bus Strat Env*, Hlm. Bse.70512, Jan 2026, Doi: 10.1002/Bse.70512.

[34] G. De Souza Andrade, M. T. Pereira, V. C. Pinto, L. M. Campos, Dan L. M. Fonseca, "Integrating Circular Economy Principles In The Electric Motor Industry: A Comprehensive Framework And Case Study For Sustainable Supply Chain Management," *Circ.Econ.Sust.*, Vol. 5, No. 2, Hlm. 1451–1470, Apr 2025, Doi: 10.1007/S43615-024-00467-2.

[35] C. F. A. Arranz, V. Sena, Dan C. Kwong, "Institutional Pressures As Drivers Of Circular Economy In Firms: A Machine Learning Approach," ***Journal Of Cleaner Production,*** Vol. 355, Hlm. 131738, Jun 2022, Doi: 10.1016/J.Jclepro.2022.131738.

[36] D. Ddiba, K. Andersson, S. H. A. Koop, E. Ekener, G. Finnveden, Dan S. Dickin, "Governing The Circular Economy: Assessing The Capacity To Implement Resource-Oriented Sanitation And Waste Management Systems In Low- And Middle-Income Countries," *Earth System Governance*, Vol. 4, Hlm. 100063, Jun 2020, Doi: 10.1016/J.Esg.2020.100063.

[37] E. D. R. Santibanez Gonzalez, L. Koh, Dan J. Leung, "Towards A Circular Economy Production System: Trends And Challenges For Operations Management," ***International Journal Of Production Research,*** Vol. 57, No. 23, Hlm. 7209–7218, Des 2019, Doi: 10.1080/00207543.2019.1656844.

[38] F. Husnatarina, "Circular Economy Practices And Profitability In Indonesian Manufacturing: Structural Enablers, Barriers, And Sectoral Divergence," *Nomico*, Vol. 2, No. 11, Hlm. 26–36, Des 2025, Doi: 10.62872/Jqqkw312.

[39] N. Bittner, N. Bakker, Dan T. B. Long, "Circular Economy And The Hospitality Industry: A Comparison Of The Netherlands And Indonesia," ***Journal Of Cleaner Production***, Vol. 444, Hlm. 141253, Mar 2024, Doi: 10.1016/J.Jclepro.2024.141253.

[40] E. Iacovidou, S. Gerassimidou, D. C. Wilson, J. Richter, S. Jobling, Dan E. Soedjono, "System-Wide Assessment Of Indonesia's Plastic Value Chain: Mapping Flows And Stakeholders Dynamics," ***Journal Of Cleaner Production***, Vol. 520, Hlm. 146082, Agu 2025, Doi: 10.1016/J.Jclepro.2025.146082.

[41] Maskun, Ratnawati, Wiranti, Asriyani, Dan Jamal Aslan, "Legal Framework Model For Sustainable Solid Waste Management In Indonesia: A Contemporary Environmental *Fiqh* Perspective," *Milrev*, Vol. 4, No. 2, Hlm. 1097–1122, Sep 2025, Doi: 10.32332/Milrev.V4i2.11104.

[42] P. Nurmalasari, Upn "Veteran" Yogyakarta, Dan K. Kusharyanti, "Implementation Of Circular Economy In Regional Public Service Agencies In Waste Management As A Waste Reduction Strategy In Indonesia," ***Jicp,*** Vol. 7, No. 4, Hlm. 862–871, Feb 2025, Doi: 10.32535/Jicp.V7i4.3556.

[43] A. Acevedo-De-Los-Ríos, F. R. Chumpitaz-Requena, D. R. Rondinel-Oviedo, Ú. Cárdenas-Mamani, Dan J. M. Redondo, "Exploring The Urban Systemic Scenarios Of Improving Socioecological Conditions In An Informal Settlement Of A Developing Country With A System Dynamics Model," *Environmental Science & Policy*, Vol. 169, Hlm. 104079, Jul 2025, Doi: 10.1016/J.Envsci.2025.104079.

[44] Ashutosh Deshpande, Vasanth Ramanathan, Dan Karthigaiselvan Babu, "Assessing The Socio-Economic Factors Affecting Household Waste Generation And Recycling Behavior In Chennai: A Survey-Based Study," ***Int. J. Sci. Res. Arch.***, Vol. 11, No. 2, Hlm. 750–758, Mar 2024, Doi: 10.30574/Ijsra.2024.11.2.0487.

[45] Y. Van Fan, J. J. Klemeš, C. T. Lee, Dan R. R. Tan, "Demographic And Socio-Economic Factors Including Sustainability Related Indexes In Waste Generation And Recovery," *Energy Sources, Part A: Recovery, Utilization, And Environmental Effects*, Vol. 47, No. 1, Hlm. 11100–11113, Jun 2025, Doi: 10.1080/15567036.2021.1974610.

[46] A. Q. Al-Amin, W. Leal Filho, Dan D.-M. Pociovalisteanu, Ed., *Sustainable Economic Development: Green Economy And Green Growth*, 1st Ed. 2017. Dalam World Sustainability Series. Cham: Springer International Publishing : Imprint: Springer, 2017. Doi: 10.1007/978-3-319-45081-0.

[47] S. Elsaid Dan E.-H. Aghezzaf, “A Progress Indicator-Based Assessment Guide For Integrated Municipal Solid-Waste Management Systems,” ***J Mater Cycles Waste Manag***, Vol. 20, No. 2, Hlm. 850–863, Apr 2018, Doi: 10.1007/S10163-017-0647-8.

[48] K. Z. Win, H. Yabar, Dan T. Mizunoya, “Analysis Of Household Waste Generation And Composition In Mandalay: Urban–Rural Comparison And Implications For Optimizing Waste Management Facilities,” *Waste*, Vol. 2, No. 4, Hlm. 490–509, Nov 2024, Doi: 10.3390/Waste2040026.

[49] Z. Papanikolaou Dan C. Karelakis, “A Path Analysis Of Behavioral Drivers Of Household Food Waste In Greece,” *Agriculture*, Vol. 15, No. 23, Hlm. 2481, Nov 2025, Doi: 10.3390/Agriculture15232481.

[50] A. Akther, F. Tahrim, L. C. Voumik, M. A. Esquivias, Dan D. C. Pattak, “Municipal Solid Waste Dynamics: Economic, Environmental, And Technological Determinants In Europe,” *Cleaner Engineering And Technology*, Vol. 24, Hlm. 100877, Feb 2025, Doi: 10.1016/J.Clet.2024.100877.

[51] E. A. Cavalheiro, R. H. Machado, A. S. Castro, Dan L. R. Falck, “Urban Solid Waste Generation And Gdp Per Capita: A Global Analysis Through The Lens Of The Environmental Kuznets Curve,” *Clcs*, Vol. 17, No. 3, Hlm. E5574, Mar 2024, Doi: 10.55905/Revconv.17n.3-012.

[52] C. H. Ng *Dkk.*, “Plastic Waste And Microplastic Issues In Southeast Asia,” *Front. Environ. Sci.*, Vol. 11, Hlm. 1142071, Apr 2023, Doi: 10.3389/Fenvs.2023.1142071.

[53] H. Wibisono, F. Firdausi, Dan M. E. Kusuma, “Municipal Solid Waste Management In Small And Metropolitan Cities In Indonesia: A Review Of Surabaya And Mojokerto,” *Iop Conf. Ser.: Earth Environ. Sci.*, Vol. 447, No. 1, Hlm. 012050, Feb 2020, Doi: 10.1088/1755-1315/447/1/012050.

[54] C. Ingrao, A. Bezama, A. Paiano, J. Hildebrandt, Dan C. Arcidiacono, “A Review Of The Key Findings From The Special Issue On ‘Life Cycle Sustainability Analysis Of Resource Recovery From Waste Management Systems In The Context Of Circular Models Of The Economy And The Bioeconomy,’” *Resources*, Vol. 14, No. 3, Hlm. 44, Mar 2025, Doi: 10.3390/Resources14030044.

[55] E. Octaviani, I. Masudin, A. Khoidir, Dan D. P. Restuputri, “Material Flow Analysis For Demand Forecasting And Lifetime-Based Inflow In Indonesia’s Plastic Bag Supply Chain,” *Logistics*, Vol. 9, No. 3, Hlm. 105, Agu 2025, Doi: 10.3390/Logistics9030105.

[56] J. Wang *Dkk.*, “Health Risk Of Heavy Metals In Drinking Water Sources Of Water-Carrying Lakes Affected By Retreating Polder: A Case Study Of Luoma Lake,” *Water*, Vol. 16, No. 18, Hlm. 2699, Sep 2024, Doi: 10.3390/W16182699.

[57] M. Sardarmehni, P. H. C. Anchieta, Dan J. W. Levis, “Solid Waste Optimization Life-Cycle Framework In Python (Swolfpy),” ***J Of Industrial Ecology***, Vol. 26, No. 3, Hlm. 748–762, Jun 2022, Doi: 10.1111/Jiec.13236.

[58] V. Bisinella, S. Schmidt, A. S. Varling, D. Laner, Dan T. H. Christensen, “Waste Lca And The Future,” *Waste Management*, Vol. 174, Hlm. 53–75, Feb 2024, Doi: 10.1016/J.Wasman.2023.11.021.

[59] R. Rabeiy, A. H. Birima, S. Almutairi, L. Kassem, Dan A. Nafady, “Waste Quantification, Characterization, And Potential For Recycling And Energy Production In Universities,” *Sustainable Environment*, Vol. 10, No. 1, Hlm. 2427514, Des 2024, Doi: 10.1080/27658511.2024.2427514.

[60] A. Iqbal *Dkk.*, “Empirical Analysis Of Cost-Effective And Equitable Solid Waste Management Systems: Environmental And Economic Perspectives,” *Environmental Research*, Vol. 244, Hlm. 117858, Mar 2024, Doi: 10.1016/J.Envres.2023.117858.

[61] Syafrudin, M. A. Budihardjo, I. F. S. Wahyuningrum, A. Chegenizadeh, A. S. Puspita, Dan S. A. Qadar, “Enhancing Waste Management In Batang Regency: Integrating Circular Economy Principles With Life Cycle Assessment And Material Flow Analysis,” ***Journal Of Open Innovation: Technology, Market, And Complexity***, Vol. 10, No. 4, Hlm. 100437, Des 2024, Doi: 10.1016/J.Joitmc.2024.100437.

[62] Y. Zahrah, J. Yu, Dan X. Liu, “How Indonesia’s Cities Are Grappling With Plastic Waste: An Integrated Approach Towards Sustainable Plastic Waste Management,” *Sustainability*, Vol. 16, No. 10, Hlm. 3921, Mei 2024, Doi: 10.3390/Su16103921.

[63] Ferdinan, “Optimizing Household Organic Waste Management In Support Of Sustainable Household Waste Management In Bekasi City, Indonesia,” *Wass*, Vol. 1, No. 1, Feb 2024, Doi: 10.61511/Wass.V1i1.2024.585.

[64] H. Khair, I. Rachman, Dan T. Matsumoto, “Analyzing Household Waste Generation And Its Composition To Expand The Solid Waste Bank Program In Indonesia: A Case Study Of Medan City,” ***J Mater Cycles Waste Manag***, Vol. 21, No. 4, Hlm. 1027–1037, Jul 2019, Doi: 10.1007/S10163-019-00840-6.

[65] M. Bigdeloo, T. Teymourian, E. Kowsari, S. Ramakrishna, Dan A. Ehsani, “Sustainability And Circular Economy Of Food Wastes: Waste Reduction Strategies, Higher Recycling Methods, And Improved Valorization,” *Mater Circ Econ*, Vol. 3, No. 1, Hlm. 3, Des 2021, Doi: 10.1007/S42824-021-00017-3.

[66] M. A. Fayshal, "Current Practices Of Plastic Waste Management, Environmental Impacts, And Potential Alternatives For Reducing Pollution And Improving Management," *Heliyon*, Vol. 10, No. 23, Hlm. E40838, Des 2024, Doi: 10.1016/J.Heliyon.2024.E40838.

[67] A. Maalouf Dan P. Agamuthu, "Waste Management Evolution In The Last Five Decades In Developing Countries – A Review," *Waste Manag Res*, Vol. 41, No. 9, Hlm. 1420–1434, Sep 2023, Doi: 10.1177/0734242x231160099.

[68] Abdul Hakim Zakkiy Fasya, Mursyidul Ibad, Kuuni Ulfah Naila El Muna, Shofi Futri Pratiwi, Dan Shofiyah Ajeng Sekar Arum, "A Systematic Review Of Solid Waste Management In Indonesia: Generation, Characteristics, Treatment, And Regulation," ***Jkl,*** Vol. 17, No. 4, Hlm. 333–342, Okt 2025, Doi: 10.20473/Jkl.V17i4.2025.333-342.

[69] R. D. A. Fariz, R. Muis, N. Anggraini, I. Rachman, Dan T. Matsumoto, "Good Environmental Governance Roles In Sustainable Solid Waste Management In Indonesia: A Review," ***Jcbeem,*** Vol. 8, No. 8, Hlm. 45–56, Mar 2024, Doi: 10.23969/Jcbeem.V8i1.12035.

[70] R. Muis, I. Rachman, Dan T. Matsumoto, "A Life Cycle Assessment Of Biological Treatment Scenario Of Municipal Solid Waste In Developing Country (Case Study: Makassar, Indonesia)," *Iop Conf. Ser.: Earth Environ. Sci.*, Vol. 1263, No. 1, Hlm. 012070, Nov 2023, Doi: 10.1088/1755-1315/1263/1/012070.

[71] H. P. Putra, E. Damanhuri, Dan E. Sembiring, "The Role Of Mrf In Indonesia's Solid Waste Management System (Case Study Of The Special Region Of Yogyakarta, Indonesia)," ***J Mater Cycles Waste Manag,*** Vol. 22, No. 2, Hlm. 396–404, Mar 2020, Doi: 10.1007/S10163-020-00979-7.

[72] S. U. Purba, S. Faradiba, Dan J. W. Sitanggang, "Tren Dan Distribusi Timbulan Sampah Serta Sumbernya Pada Kabupaten Dan Kota Di Indonesia," *Hc*, Vol. 14, No. 2, Hlm. 256–264, Jan 2026, Doi: 10.36763/57dzbk98.

[73] H. Gutama Dan F. M. Iresha, "Evaluation Of Solid Waste Management Effectiveness In Indonesia From 2019-2021: A Geographic Information System Analysis," *Iop Conf. Ser.: Earth Environ. Sci.*, Vol. 1263, No. 1, Hlm. 012067, Nov 2023, Doi: 10.1088/1755-1315/1263/1/012067.

[74] M. R. Diani, D. Haniifah, Dan F. R. Dianty, "Analisis Proyeksi Pertumbuhan Penduduk Dan Volume Sampah Dki Jakarta Terhadap Dampak Yang Ditimbulkan," ***Jwsc,*** Vol. 1, No. 1, Hlm. 27–45, Feb 2024, Doi: 10.61511/Jwsc.V1i1.2024.691.

[75] D. Ardiatma, P. Lestari, Dan M. Chaerul, "Real Data Mapping Of Dki Jakarta Waste Generation Using The K-Mean Clustering Method At Final Disposal Bantargebang," *E3s Web Of Conf.*, Vol. 485, Hlm. 02015, 2024, Doi: 10.1051/E3sconf/202448502015.

[76] I. W. K. Suryawan Dan C.-H. Lee, "Achieving Zero Waste For Landfills By Employing Adaptive Municipal Solid Waste Management Services," *Ecological Indicators*, Vol. 165, Hlm. 112191, Agu 2024, Doi: 10.1016/J.Ecolind.2024.112191.

[77] S. Rochman, J. Ramdani, Dan L. I. Tampubolon, "The Dpsir (Driver, Pressure, State, Impact, Response) Approach In Analyzing The Case Of Waste Emergencies In Bandung City," ***Jassu,*** Vol. 2, No. 1, Jul 2024, Doi: 10.61511/Jassu.V2i1.2024.602.

[78] Y. Dhokhikah, Y. Trihadiningrum, Dan S. Sunaryo, "Community Participation In Household Solid Waste Reduction In Surabaya, Indonesia," *Resources, Conservation And Recycling*, Vol. 102, Hlm. 153–162, Sep 2015, Doi: 10.1016/J.Resconrec.2015.06.013.

[79] Amanda Putri Desynta, Reza Ardiansyah, Apria Yuvitar Devani Putri, Talitha Athaya Rahman, Gilang Amanda Puspanegara, Dan Ida Syamsu Roidah, "Peran Mahasiswa Dalam Mengatasi Permasalahan Sampah Di Kota Surabaya Melalui Pendampingan Program Zero Waste," *Manfaat*, Vol. 1, No. 3, Hlm. 15–25, Jun 2024, Doi: 10.62951/Manfaat.V1i3.65.

[80] D. Maulana, C. Nugroho, R. R. Wulan, Dan F. Habibi, "Developing Sustainable Waste Management In Urban Areas: Case Study Of Municipal Government Policy Strategies In Banten Indonesia," *Sage Open*, Vol. 15, No. 3, Hlm. 21582440251378799, Jul 2025, Doi: 10.1177/21582440251378799.

[81] Bintan Cakrawala Polytechnic *Dkk.*, "The Dynamics Of Tourism Development: Study Case Tourism Attributes In Penyengat Island," ***Ijaste,*** Vol. 5, No. 2, Hlm. 107–120, Des 2021, Doi: 10.31940/Ijaste.V5i2.107-120.

[82] Universitas Pertamina *Dkk.*, "Life Cycle Assessment Of Solid Waste Generation During And Before Pandemic Of Covid-19 In Bali Province," ***J. Sustain. Sci. Manage.,*** Vol. 16, No. 1, Hlm. 11–21, Jan 2020, Doi: 10.46754/Jssm.2021.01.002.

[83] M. Kedzierski, D. Frère, G. Le Maguer, Dan S. Bruzaud, "Why Is There Plastic Packaging In The Natural Environment? Understanding The Roots Of Our Individual Plastic Waste Management Behaviours," *Science Of The Total Environment*, Vol. 740, Hlm. 139985, Okt 2020, Doi: 10.1016/J.Scitotenv.2020.139985.

[84] I. W. K. Suryawan *Dkk.*, "Effect Of Sludge Sewage Quality On Heating Value: Case Study In Jakarta, Indonesia," *Desalination And Water Treatment*, Vol. 249, Hlm. 183–190, Feb 2022, Doi: 10.5004/Dwt.2022.28071.

[85] A. (Anya) Phelan, H. Ross, N. A. Setianto, K. Fielding, Dan L. Pradipta, "Ocean Plastic Crisis—Mental Models Of Plastic Pollution From Remote Indonesian Coastal Communities," *Plos One*, Vol. 15, No. 7, Hlm. E0236149, Jul 2020, Doi: 10.1371/Journal.Pone.0236149.

[86] M. M. Sari *Dkk.*, "Comparison Of Solid Waste Generation During And Before Pandemic Covid-19 In Indonesia Border Island (Riau Islands Province, Indonesia)," *Ecol. Eng. Environ. Technol.*, Vol. 24, No. 2, Hlm. 251–260, Mar 2023, Doi: 10.12912/27197050/157170.

[87] A. Heidari *Dkk.*, "Youth And Sustainable Waste Management: A Sem Approach And Extended Theory Of Planned Behavior," ***J Mater Cycles Waste Manag***, Vol. 20, No. 4, Hlm. 2041–2053, Okt 2018, Doi: 10.1007/S10163-018-0754-1.

[88] M. Struk, "Distance And Incentives Matter: The Separation Of Recyclable Municipal Waste," *Resources, Conservation And Recycling*, Vol. 122, Hlm. 155–162, Jul 2017, Doi: 10.1016/J.Resconrec.2017.01.023.

[89] S. Lee-Geiller Dan G. Kütting, "From Management To Stewardship: A Comparative Case Study Of Waste Governance In New York City And Seoul Metropolitan City," *Resources, Conservation And Recycling*, Vol. 164, Hlm. 105110, Jan 2021, Doi: 10.1016/J.Resconrec.2020.105110.

[90] R. Diaz-Ruiz, M. Costa-Font, F. López-I-Gelats, Dan J. M. Gil, "Food Waste Prevention Along The Food Supply Chain: A Multi-Actor Approach To Identify Effective Solutions," *Resources, Conservation And Recycling*, Vol. 149, Hlm. 249–260, Okt 2019, Doi: 10.1016/J.Resconrec.2019.05.031.

[91] A. Prabawati Dan E. Frimawaty, "Assessing Plastic Waste Management Performance: Insights From The Waste Management Performance Index," *Whem*, Vol. 2, No. 1, Feb 2025, Doi: 10.61511/Whem.V2i1.2025.1320.

[92] R. Aprilia, E. Noerhayati, Dan A. Rahmawati, "Characterization Of Waste Composition As A Basis For Developing A Community-Based 3r Tps System In Waste Management Efforts In Pandansari Lor Village, Malang Regency," *Ajteoh*, Vol. 2, No. 1, Hlm. 1–12, Jul 2024, Doi: 10.61511/Ajteoh.V2i1.2024.1010.

[93] J. Semilu Rosesar Dan G. Andari Kristanto, "Household Solid Waste Composition And Characterization In Indonesia Urban Kampong," *Iop Conf. Ser.: Mater. Sci. Eng.*, Vol. 909, No. 1, Hlm. 012077, Des 2020, Doi: 10.1088/1757-899x/909/1/012077.

[94] D. A. Kusumaningtiar Dan G. Vionalita, "Household Solid Waste Management And Composition In Bekasi, Indonesia," ***Open Access Maced J Med Sci***, Vol. 10, No. E, Hlm. 1472–1475, Jul 2022, Doi: 10.3889/Oamjms.2022.9884.

[95] M. S. Hakim, I. Baihaqi, Dan A. Kunaifi, "Value Chain Development As Alternative Method For Mapping Waste Management," *Jibe*, Vol. 1, No. 01, Hlm. 11, Jun 2017, Doi: 10.22219/Jibe.Vol1.No01.11-18.

[96] L. N. Fujianti, M. Munawir, I. Rachman, Dan T. Matsumoto, "Analyzing Community Perspectives On Bsf-Based Organic Waste Treatment: Evidence From Survey Data And Text Mining In Bandung, Indonesia," ***Multidiscip. Sci. J.***, Vol. 8, No. 1, Hlm. 2026116, Jul 2025, Doi: 10.31893/Multiscience.2026116.

[97] N. P. D. S. Astiti, I. P. K. T. Frandika, I. W. Suwardika, I. M. R. Adileo, Dan I. P. M. A. Susena, "Organic Waste Processing Based On A Circular Economy As An Environmentally Friendly Solution," ***Wicaksana: Jurnal Lingkungan Dan Pembangunan***, Vol. 9, No. 1, Hlm. 1–10, Mar 2025, Doi: 10.22225/Wicaksana.9.1.2025.1-10.

[98] I Made Gunamantha, I Gede Astra Wesnawa, Ni Made Oviantari, Ni Wayan Yuningrat, Putu Lilik Pratami Kristiyanti, Dan Komang Widiadnyana, "Estimating Circular Economic Potential Of Organic Fraction Of Municipal Solid Waste In Small City," ***Jescae***, Vol. 2, No. 4, Hlm. 80–96, Des 2023, Doi: 10.56556/Jescae.V2i4.683.

[99] B. Indra Maulana, A. Suryamiharja, P. C. Wisesa, Rendy Munadi, Dan S. Sussi, "Utilization Of Household Organic Waste Into Biogas And Integrated With Iot," ***J. Resti (Rekayasa Sist. Teknol. Inf.)***, Vol. 8, No. 6, Hlm. 839–845, Des 2024, Doi: 10.29207/Resti.V8i6.5906.

[100] N. P. Alifa, A. Adelia, Dan A. A. Mufti, "Material Flow Analysis Of Plastic Waste For Circular Economy Potential: A Case Study Of Wijaya Kusuma And Sidomakmur Waste Banks In Metro City," *Jist*, Vol. 5, No. 10, Hlm. 4076–4088, Okt 2024, Doi: 10.59141/Jist.V5i10.5325.

[101] F. Fatmawati, I. Ilham, S. Saleh, Dan A. R. Razak, "Waste Management System: A Case Study Of Waste Bank Management Toward A Circular Economy In Maros Regency," ***J. Borneo Adm.***, Vol. 20, No. 1, Hlm. 1–14, Apr 2024, Doi: 10.24258/Jba.V20i1.1206.

[102] N. A. Arisman, S. W. Utomo, B. Yanuwiadi, Dan M. Ahmad, “Plastic Pollution And Extended Producer Responsibility Policy: Views From Industry In Bandung City,” ***Ijbpscm,*** Vol. 14, No. 4, Hlm. 399–420, 2023, Doi: 10.1504/Ijbpscm.2023.136607.

[103] R. Ardi, S. Nurkamila, D. L. Citraningrum, Dan T. N. Zahari, “Reverse Logistics Network Design For Plastic Waste Management In Jakarta: Robust Optimization Method,” ***Ijtech,*** Vol. 14, No. 7, Hlm. 1560, Des 2023, Doi: 10.14716/Ijtech.V14i7.6681.

[104] E. Antriyandarti *Dkk.*, “Pengembangan Ekonomi Sirkular Untuk Pengelolaan Sampah Organik Di Desa Senden, Kabupaten Magelang,” *Warta*, Hlm. 1–10, Mar 2025, Doi: 10.23917/Warta.V27i1.7049.

[105] S. Song *Dkk.*, “Upcycling Food Waste Using Black Soldier Fly Larvae: Effects Of Further Composting On Frass Quality, Fertilising Effect And Its Global Warming Potential,” ***Journal Of Cleaner Production,*** Vol. 288, Hlm. 125664, Mar 2021, Doi: 10.1016/J.Jclepro.2020.125664.

[106] D. Novianti, E. Rimbawati, Dan J. Judiono, “Pemanfaatan Bsf Dalam Pengelolaan Sampah Di Kawasan Permukiman Perkotaan,” *Cakrawala*, Vol. 18, No. 2, Hlm. 307–318, Des 2024, Doi: 10.32781/Cakrawala.V18i2.720.

[107] S. Wainaina *Dkk.*, “Resource Recovery And Circular Economy From Organic Solid Waste Using Aerobic And Anaerobic Digestion Technologies,” *Bioresource Technology*, Vol. 301, Hlm. 122778, Apr 2020, Doi: 10.1016/J.Biortech.2020.122778.

[108] T. R. Yasin, I. D. Y. Yusuf, Dan A. Rahmanissa, “Anaerobic Biodigester As A Community-Based Food Waste Processor (Case Study: Canteen Area Of Pt Pln Nusantara Power Up Muara Karang),” *E3s Web Of Conf.*, Vol. 485, Hlm. 05003, 2024, Doi: 10.1051/E3sconf/202448505003.

[109] V. Azteria *Dkk.*, “Penerapan Teknologi Pengolahan Sampah Organik Dengan Metode Komposter Untuk Mewujudkan Lingkungan Zero Waste,” *Pelitamasyarakat*, Vol. 7, No. 1, Hlm. 1–10, Sep 2025, Doi: 10.31289/Pelitamasyarakat.V7i1.14836.

[110] M. P. Nurani, “Mengoptimalkan Potensi Sampah Organik Untuk Mendorong Pertanian Berkelanjutan Pada Review Sistematis,” *Bistek-Journal*, Vol. 10, No. 1, Hlm. 36–50, Jun 2023, Doi: 10.37832/Bistek.V10i1.65.

[111] R. Hamdani, J. S. Ash Shidiqie, U. Priyadi, U. Dinurri’anah, Dan A. I. H. Adli, “Optimization Of Organic Waste Management With A Circular Economy Approach : The Case Of Food Recycling In Bantul Regency, Indonesia,” ***J. Pengabdi. Has. Pemberdaya. Masy.,*** Vol. 6, No. 2, Hlm. 278, Mei 2025, Doi: 10.33394/Jpu.V6i2.14238.

[112] Fathurrahman, F., Irawan, A. ., & Fridayanti, sri . (2023). Effectiveness Of Regional Regulation Number 20 Of 2001 Regarding Regulation Of Street Traders And Seasonal Street Traders In Tarakan City. *International **Journal of Educational Research &Amp; Social Sciences***, *4*(3), 429–434. https://doi.org/10.51601/ijersc.v4i3.652.

[113] Sulaiman, S., Halim Soebahar, A. ., & Mundir, M. (2023). Madrassa Diniyah Curriculum Transformation In Pesantren: A Study Of Wali Songo Mimbaan And Salafiyah Syafi’iyah Sukorejo Pesantren In Situbondo. ***International Journal of Educational Research &Amp; Social Sciences***, *4*(3), 444–453. https://doi.org/10.51601/ijersc.v4i3.659.

[114] Mutiara Cipta, D. ., & Alvin, S. (2023). Safeguarding Personal Information: Communication Privacy Management By Gen-Z Influencers. ***International Journal of Educational Research &Amp;*** *Social Sciences*, *4*(3), 465–471. https://doi.org/10.51601/ijersc.v4i3.653.

[115 Mohammad Solekhan, Kunarto, & Mahmuda Pancawisma Febriharini. (2022). Forest And Land Fire Management Strategies : Prevention And Law Enforcement. ***International Journal of Educational Research &Amp; Social Sciences***, *3*(2), 567–580. https://doi.org/10.51601/ijersc.v3i2.306.

[116] D. Yuliana Sinaga. (2022). The Effect Of Ralistic Mathematics Learning Model And Project-Based Learning Model On Problem Solving Ability And Motivation Of Students In Class V Private Sd Markus Medan Helvetia. ***International Journal of Educational Research &Amp; Social Sciences***, *3*(2), 590–600. https://doi.org/10.51601/ijersc.v3i2.268.