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Analysis of Circular Waste Using a Causal Loop Diagram (CLD): A Case Study of Sukabumi City

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Abstract: This study examines the transition from linear to circular municipal solid waste management in Sukabumi City using a system dynamics approach. Utilizing a qualitative descriptive design, data were gathered through surveys of 400 residents across 33 villages, field observations of waste facilities, and stakeholder interviews. Results reveal significant "lost circularity" driven by low source separation, negative public perceptions, and the underutilization of community-based 3R facilities (TPS3R) and waste banks. The developed Causal Loop Diagram (CLD) identifies five reinforcing loops which are centred on 3R participation, institutional collaboration, and material value—and four balancing loops related to infrastructure limits, behavioural resistance, and funding constraints. The dominance of these balancing loops explains the stagnation of the circular transition. Findings suggest that the system remains trapped in a "take–make–dispose" model due to operational bottlenecks. The study concludes that the primary leverage points for accelerating circularity include intensive 3R education, the reactivation of upstream infrastructure, and enhanced multi-actor collaboration. These interventions are essential to shift the system dynamics toward sustainable resource recovery and reduced landfill dependency.

Keywords: Causal loop diagram; Circular waste; Environmental; System dynamic

Introduction

One of the factors contributing to air pollution that leads to increased greenhouse gas emissions and forms part of the triple planetary crises is poor waste management (Kasyfilham & Al Akbar, 2025; Rengganis et al., 2023). Waste has economic value when managed as a resource, yet in reality this potential remains largely untapped. Current waste management still follows a linear system (take–make–dispose), which continues to dominate in many countries and is a major cause of environmental degradation (Geng et al., 2012; MacArthur, 2015). This has resulted in increasing volumes of waste classified as residuals, while simultaneously eliminating the potential for recovering materials that should be returned to the production cycle.

At present, global development trends are shifting toward a circular economy that prioritizes reuse, recycling, and the extension of material lifespans (MacArtur, 2019; Meshram, 2024; Reddy et al., 2023). Indonesia has institutionalized this transition through the National Circular Economy Roadmap 2025–2045, utilizing the 9R framework to strengthen waste banks, TPS3R facilities, and material recovery systems (Prastya et al., 2025; Sadono, 2024). While these policies offer significant opportunities for value addition (Rahmi, 2024), implementation in secondary cities like Sukabumi remains fragmented, resulting in a persistent "circularity gap." This gap is evidenced by low waste reduction rates, minimal source separation, and a critical reliance on the Cikundul landfill (Diskominfo, 2024). Crucially, Sukabumi's management system currently lacks the infrastructure to capture specific high-impact waste streams—such as construction debris, textiles, and household medical waste—leading to "lost circularity" where potentially recoverable materials are permanently leaked from the system.

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Despite various initiatives in digitalization and public education, results remain marginal because these efforts are often implemented as isolated projects rather than integrated components of a complex system (Pires & Martinho, 2019). The primary novelty of this research lies in its departure from static, linear analysis to a dynamic, systemic approach specifically tailored to the socio-technical landscape of a secondary Indonesian city. By utilizing system dynamics, this study moves beyond mere description to expose the hidden "policy resistance," where cultural and institutional bottlenecks neutralize infrastructure improvements. This research is vital because, without a Causal Loop Diagram (CLD) to map the reinforcing and balancing feedback, interventions will continue to treat symptoms rather than root causes. Ultimately, this study provides the logical foundation required to identify strategic leverage points, ensuring that Sukabumi's transition toward a circular economy is not only conceptually sound but systemically resilient and measurable.

Method

This study utilizes a qualitative descriptive method integrated with a system dynamics approach to analyze waste management as a complex, non-linear ecosystem. While the qualitative framework explores individual perceptions and contextual meanings (Creswell & Creswell, 2022), system dynamics provides the tools to map feedback structures and variable interactions that define the city's waste behaviour (Meadows, 2008).

The study was centered in Sukabumi City, gathering data through a multi-stakeholder lens that included the Environmental Office, facility managers, and recycling actors. To ensure statistical representation, 400 respondents were proportionally sampled across 33 urban villages to measure 3R participation and waste-sorting habits. This primary data—collected via surveys, field observations at TPS/TPS3R sites, and expert interviews—were triangulated with secondary data from official technical reports and local regulations to build a comprehensive system model.

The main research variables included 3R understanding, sorting behaviour, fleet capacity, TPS3R effectiveness, waste bank participation, public perception, economic value, secondary materials, landfill capacity, and specific waste categories. These variables were identified through surveys, observations, and literature studies and were then analyzed to determine causal relationships between variables (+/–).

Based on these causal relationships, a Causal Loop Diagram (CLD) was developed to map reinforcing and balancing loops in order to identify leverage points for policy intervention. Once the CLD was completed, a qualitative analysis was performed using thematic content analysis to synthesize field findings into a coherent model structure (Braun & V., 2021). Validation was conducted through source triangulation, expert discussions with the Environmental Office, and consistency checks of the model structure based on system dynamics theory.

Results and Discussion

Characteristics of Respondents and Field Conditions

Waste generation refers to the amount of waste produced from all human or natural activities within a specific period, expressed in units of weight (kg/ton) or volume (liters/m^3) (Aziz et al., 2022; Tchobanoglous et al., 1993). Understanding waste generation is the initial step in assessing the effectiveness of waste management. The recorded waste generation at the research site was 68,893.37 tons/year, while only 164.35 tons/year were managed, and 49,521.58 tons/year became residual waste at the landfill. This indicates a discrepancy between the total waste generated and the waste that is actually managed. The unmanaged portion is found as illegal waste scattered along roadsides, riverbanks and water bodies, and vacant land.

This study involved 400 respondents from 33 urban villages, selected proportionally using the Lynch method to represent social and technical conditions in the community. Respondents consisted of both male and female groups across diverse ages, allowing for varied perspectives on waste management behaviour. Their educational backgrounds ranged from elementary school to doctoral degrees. This diversity aligns with human capital theory, which emphasizes education level as a determinant of technical, managerial, analytical, and leadership capacities in resource management (Becker, 1993). Professionally, respondents represented the quadruple helix actors—academia, government, community, and business—who play key roles in driving waste management systems toward a circular economy (Carayannis & J, 2009).

Survey results show that most households (52.7%) generate less than 1 kg of waste per day. Another 38.7% generate 1–3 kg/day, and 4% produce 3–5 kg/day. This pattern indicates an urban waste generation profile. Households producing more than 1 kg/day require more serious intervention, including more regular collection services and partnerships with waste banks or TPS3R.

Regarding understanding of the 3R (Reduce, Reuse, Recycle) concept, 58.3% of respondents demonstrated basic understanding, while 9.8% claimed strong understanding. However, 31.9% did not understand 3R at all. This difference in comprehension directly influences waste management behavior. Those who understand 3R tend to practice waste sorting, while those who do not are more likely to produce mixed waste (Meadows, 2008).

This study also examined public perceptions of waste. Respondents largely did not view waste as a resource with economic value. Waste was instead perceived as a source of foul odor (67.8%), air pollution (21.7%), water pollution (13.5%), soil pollution (8.2%), disease (16.3%), and aesthetic disturbance (21%). These negative perceptions demonstrate that most Indonesians still view waste as something to be disposed of, rather than as a recoverable material. Such perceptions correlate with low adoption of circular economy practices, including low sorting rates and low utilization of secondary materials in developing countries (MacArtur, 2019). This aligns with people's habits of disposing of mixed waste directly at TPS. Only 26.1% of respondents consistently sorted waste, 55.9% did so occasionally, and 17.9% never sorted at all. Waste composition at the study site consisted of 54% organic waste and 46% inorganic waste, yet organic waste processing—via composting, maggot cultivation, biopores, or biogas—remained below 0.0001%, indicating ineffective waste reduction at source.

In terms of infrastructure, 10.3% of respondents rated the condition of TPS as good, 59.7% as adequate, and 30.1% as poorly maintained. Poorly maintained TPS indicated overcapacity, disposal outside operational hours, and inadequate infrastructure. Similarly, TPS3R facilities are intended to serve as the first processing point but are not widely known, with only 26.6% of respondents aware of their existence. This lack of awareness contributes to low participation in using these facilities. Field observations revealed that 50% of TPS3R units were non-operational or repurposed. A similar condition was found for waste banks, which were known by only 26.1% of respondents, with only 7.7% still actively depositing waste. These findings indicate that the primary causes of ineffective waste management are inadequate socialization and limited understanding of facility functions, resulting in suboptimal utilization of waste processing infrastructure.

Causal Analysis in the Waste Management System

To understand the relationships among social, technical, institutional, and behavioral variables shaping the dynamics of Sukabumi's waste management system, a causal analysis was conducted. This analysis reveals that system performance is influenced by imbalances between service capacity, community behavior, and supporting facility effectiveness. These imbalances generate both reinforcing and balancing feedback loops (Meadows, 2008).

Differences in 3R understanding, public perception of waste, and behavioral variations create significant causal chains. Communities with strong 3R understanding tend to sort waste and act as reinforcing agents promoting positive environmental change. Conversely, communities with low 3R comprehension create balancing pressure, generating mixed waste, reducing service quality, and weakening TPS3R and waste bank performance. This condition highlights the need for interventions in education, environmental cadres, and social norm strengthening as leverage points (Ajzen, 1991; Becker, 1993).

Compliance with waste disposal schedules, preferences for facilities, and participation in TPS3R or waste banks also directly affect service quality. When facilities are suboptimal—such as in cases of uncollected waste or TPS overload—negative public perceptions emerge, decreasing community participation and creating balancing loops that weaken the system. Conversely, improved TPS performance, renewed fleets, and consistent TPS3R operations can trigger reinforcing loops that enhance sorting, reduce residuals, and build public trust. This two-way interaction demonstrates feedback between public perception and service quality.

Waste management infrastructure such as TPS, TPS3R, waste banks, and collection fleets creates dominant causal effects. Fleet shortages, TPS overload, suboptimal TPS3R operations, and irregular collection schedules generate balancing loops through increased uncollected waste, decreased public satisfaction, and reduced motivation to sort. Conversely, improving fleet capacity, upgrading TPS standards, and reactivating TPS3R can produce reinforcing loops that strengthen sorting and reduce residuals (Alyka & Andari, 2025; Prasetia et al., 2024). The lack of integration between upstream and downstream facilities forms the core structural barrier.

Institutionally, government acts as a balancing actor through policies, regulations, monitoring, and evaluation. However, weak socialization, limited fleet oversight, and inconsistent 3R programs delay government intervention, slowing the transition to a circular economy and creating policy resistance (Berenjkar et al., 2021; Senge, 1990). Nevertheless, quadruple helix collaboration has the potential to form reinforcing institutional loops that strengthen innovation, education, and recycling practices. When collaboration increases, social and technical capacities grow simultaneously, generating mutual reinforcement for behavioral transformation. Acceleration can be achieved through strengthened education, source sorting facilitation, recycling network development, and multi-actor collaboration (Kliem, 2021).

System Dynamics Model

The system dynamics model was designed to understand long-term behaviour through representations of nonlinear interactions among variables (Ma et al., 2022). In the context of Sukabumi's waste management, relationships can be better understood by mapping stocks, flows, supporting variables, and feedback mechanisms. Stocks represent accumulated system values over time, as shown in Table 1.

Table 1. System Stocks in Waste Management

System Stock	Description
Waste generation	Accumulated waste produced by the community
Sorted waste	Waste volume sorted at source
Unsorted waste	Waste not served by collection fleets
Residuals to landfill	Waste volume entering the landfill
Community participation	Degree of involvement in sorting and waste programs
Institutional performance (TPS/TPS3R/Waste Bank)	Effectiveness of upstream waste processing institutions

Flow variables represent changes in stocks and include waste generation rate, sorting rate, collection and transport rate, upstream processing rate (composting/maggot/TPS3R), and landfill residual rate. Supporting variables influence stock and flow dynamics, including 3R awareness, public perception, disposal schedule compliance, operational quality of TPS/TPS3R, fleet capacity and routes, waste bank functionality, quadruple helix collaboration, and government regulation and supervision.

Feedback Mechanisms

Feedback consists of reinforcing loops accelerating positive change (e.g., higher sorting and participation) and balancing loops resisting change due to technical limitations or behavioural barriers. In this case, balancing loops dominate, causing slow improvements despite government programs.

System Behaviour

Interpretation of stock–flow relationships show high dependence on the landfill, creating a stagnant state inhibiting movement toward circularity. Strengthened education and improved upstream facilities can increase sorting and reduce residuals, eventually improving participation. However, simultaneous intervention in both behavior and infrastructure is required to shift system dominance from balancing to reinforcing, making upstream improvements more strategic than expanding landfill capacity.

Causal Loop Diagram (CLD) Analysis

CLD analysis maps causal relationships among social, technical, institutional, and behavioural factors affecting waste management performance (Brereton & Jagals, 2021). The system contains five reinforcing loops (R1–R5) and four balancing loops (B1–B4) (Figure 1).

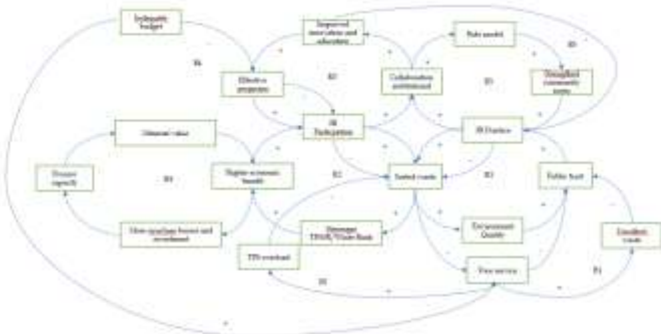

Figure 1. CLD Condition

Reinforcing loops include: R1 (3R Understanding): Higher 3R awareness → more sorting → lower residuals → cleaner environment → higher public trust → stronger 3R practice. R2 (TPS3R/Waste Bank Participation): Higher participation → more sorted waste → stronger TPS3R/bank operations → higher economic benefits → increased motivation → more participation. R3 (Quadruple Helix Collaboration): Stronger institutional collaboration → improved innovation and education → higher program effectiveness → enhanced public participation → stronger collaboration. R4 (Secondary Material Value): Higher economic value of recycled materials (compost, maggot feed, recycled plastics) → more circular businesses and investments → increased processing capacity. R5 (Social Recognition & Role Models): Role models practicing 3R influence their surroundings → strengthened community norms → mass adoption of sorting → more role models.

Balancing loops include: B1 (Fleet and Infrastructure Limitations): Waste increases → fleet capacity insufficient → uncollected waste → public complaints → pressure to improve services → temporary reduction in uncollected waste. B2 (TPS Overload): TPS overload → odor and pollution → declining participation → more mixed waste → further TPS overload. B3 (Behavioral Resistance): Low 3R understanding → mixed waste → poor service → public distrust → declining sorting motivation. B4 (Funding and Staffing Constraints): Larger programs → higher resource needs → inadequate budget → reduced program quality → lower participation.

Overall, the dominance of balancing loops shows that Sukabumi's system remains constrained by infrastructure, landfill dependence, and behavioural resistance. However, reinforcing loops related to education, institutional collaboration, and upstream facility utilization indicate strong potential for acceleration if strategic leverage points are targeted.

Transition Analysis Toward a Circular Economy

To achieve this transition, the city must focus on high-impact interventions that reshape the system from the ground up. This begins with strengthening 3R literacy through comprehensive community campaigns, school curricula, and household-level education led by environmental cadres. Simultaneously, the operational capacity of TPS3R (Waste Treatment Sites) and waste banks must be optimized through technical reactivation, equipment revitalization, and the introduction of incentive systems. On the logistics side, improving fleet performance through route digitalization and vehicle renewal will ensure more reliable collection services.

Beyond infrastructure, the strategy emphasizes reshaping public perception through environmental branding and the recognition of exemplary residents to foster a culture of sorting. This is supported by a "quadruple helix" collaboration model—engaging government, academia, business, and civil society—to drive green innovation and recycling consortia. To ensure longevity, regulatory consistency must be maintained through data-driven evaluation dashboards and standardized operating procedures. Ultimately, the goal is a fundamental shift in focus from downstream landfill dependence to upstream solutions, such as household composting, BSF maggot processing, and integrated waste bank networks.

Based on the CLD structure, system dynamics model, and field findings, the path toward sustainable waste management is defined by four distinct transition phases that mark the evolution from a reactive to a proactive system (Haydar, 2024). In the pre-transition phase, the system is dominated by balancing loops, characterized by limited social and technical readiness that keeps progress stagnant. As the system moves into the early transition, targeted education and upstream facility improvements begin to activate reinforcing loops R1 and R2, though significant resistance from balancing loops B1 and B3 remains a hurdle. This leads into the mid-transition phase, where institutional collaboration (R3) intensifies, creating a critical tipping point where reinforcing and balancing loops reach a relative equilibrium. Finally, the late transition is reached when reinforcing loops R1 through R5 become the dominant forces; at this stage, waste sorting is firmly established as a social norm, allowing the government to shift its role from being the sole driver of the system to acting as its primary stabilizer.

Conclusion

This study concludes that the waste management system in Sukabumi City remains trapped in a dominant linear "take–make–dispose" model, resulting in significant "lost circularity". Although Indonesia has established a National Circular Economy Roadmap, its implementation at the local level is hindered by fragmented initiatives that fail to address the system's non-linear complexity. The application of a Causal Loop Diagram (CLD) reveals a critical imbalance: while five reinforcing loops (R1–R5)—such as 3R understanding, institutional collaboration, and material value—possess the potential to accelerate the transition, they are currently overwhelmed by four dominant balancing loops (B1–B4). These balancing loops, rooted in infrastructure constraints, deep-seated behavioral resistance, and funding limitations, create "policy resistance" that neutralizes isolated efforts such as digitalization or basic public education. System dynamics analysis identifies that the primary leverage points for a successful transition are not merely the expansion of landfill capacity, but rather a strategic shift toward upstream interventions. This includes the intensive reactivation of TPS3R and waste bank networks, coupled with a fundamental change in public perception through quadruple helix collaboration. Ultimately, accelerating the circular economy in Sukabumi requires an integrated approach in which behavioral transformation, reliable infrastructure, and consistent regulatory oversight work in tandem to shift the system's dominance from balancing resistance to reinforcing recovery.

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Author Contributions

Conceptualization, E.R.L.E.A; methodology, E.R.L.E.A; software, M.R.; validation, E.R.L.E.A; formal analysis, E.R.L.E.A.; investigation, Y.R.Y.R; resources, A.P.A.I.S.A.; data curation, T.H.; writing—original draft preparation, E.R.; writing—review and editing, E.R.L.E.A; visualization, M.R.; supervision, E.R.; project administration, E.R.; all authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alyka, F., & Andari, G. S. B. (2025). Analysis of the Operational Performance of TPS 3R and its Development Potential Towards Indonesia's Zero Waste 2050 Target. *Journal of Social Research*, *4*(7), 1495–1503. Retrieved from https://ijsr.internationaljournallabs.com/index.php/ijsr/article/view/2630

Aziz, H. A., Abu Amr, S. S., Vesilind, P. A., Wang, L. K., & Hung, Y.-T. (2022). Introduction to solid waste management. In *Solid waste engineering and management: Volume 1* (pp. 1–84). Springer. https://doi.org/10.1007/978-3-030-84180-5_1

Becker, G. S. (1993). *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. University of Chicago Press.

Berenjkar, P., L., L., Y., Y., & Yuan, Q. (2021). The application of system dynamics in different practices of a waste management system. *Environment, Development and Sustainability*, *23*(11), 15695–15724. https://doi.org/10.1007/s10668-021-01362-8

Braun, V. C., & V. (2021). *Thematic Analysis: A Practical Guide*. SAGE Publications, Inc. Retrieved from https://www.torrossa.com/it/resources/an/5282292

Brereton, C. F., & Jagals, P. (2021). Applications of systems science to understand and manage multiple influences within children's environmental health in least developed countries: a causal loop diagram approach. *International Journal of Environmental Research and Public Health*, *18*(6), 3010. https://doi.org/10.3390/ijerph18063010

Carayannis, E. G. C., & J, D. F. (2009). Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, *46*(3–4), 201–234. https://doi.org/10.1504/ijtm.2009.023374

Creswell, J. W., & Creswell, J. D. (2022). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Diskominfo, K. S. (2024). *Buku Data Statistik Sektoral Daerah Kota Sukabumi Tahun 2024* (E. Rahmi & Ed) (Eds.)). Diskominfo Kota Sukabumi. Retrieved from https://drive.google.com/file/d/1tr4I2bdItFEFAUOxPZf32zp7QAK883aA/view

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production*, *23*(1), 216–224. https://doi.org/10.1016/j.jclepro.2011.07.005

Haydar, S. (2024). A system dynamics model and analytical hierarchy process: an integrated approach for achieving sustainable solid waste management system. *Environmental Science and Pollution Research*, *31*(5), 6992–7007. https://doi.org/10.1007/s11356-023-31534-0

Kasyfilham, F., & Al Akbar, N. (2025). Evaluasi Tata Kelola Sampah Yogyakarta Pasca-Piyungan: Studi Komparatif dengan Model Ekonomi Sirkular Banyumas. *Jurnal Administrasi Dan Kebijakan Publik*, *10*(1), 152–181. https://doi.org/10.25077/jakp.10.1.152-181.2025

Kliem, D. (2021). *System Dynamics in Transition Management: Participative modeling for transitioning towards a circular construction material industry*. Retrieved from https://nva.sikt.no/registration/0198f23a9204-fccbeaa3-1eb6-44ef-bb29-ff1a72925b28

Ma, W., Yuan, H., & Hao, J. L. (2022). A bibliometric visual analysis of the system dynamics approach for construction and demolition waste management. *Cleaner Waste Systems*, *1*, 100004. https://doi.org/10.1016/j.clwas.2022.100004

MacArthur, D. E. (2015). Growth within: a circular economy vision for a competitive europe. *Ellen MacArthur Foundation*. Retrieved from Retrieved from https://content.ellenmacarthurfoundation.org/m/3d4eba36b0311c08/original/Growth-within-A-circular-economy-vision-for-a-competitive-europe.pdf

MacArtur, D. E. (2019). *City governments and their role in enabling a circular economy transition an overview of urban policy levers*. Retrieved from www.ellenmacarthurfoundation.org/our-work/activities/circular-economy-in-cities

Meadows, D. H. (2008). *Thinking in systems a primer* (D.

Wright (Ed.); 1st ed.). Chelsea Green Publishing.

Meshram, K. K. (2024). The circular economy, 5R framework, and green organic practices: pillars of sustainable development and zero-waste living. *Discover Environment*, *2*(1), 147. https://doi.org/10.1007/s44274-024-00177-4

Pires, A., & Martinho, G. (2019). Waste hierarchy index for circular economy in waste management. *Waste Management*, *95*, 298–305. https://doi.org/10.1016/j.wasman.2019.06.014

Prasetia, A. P., Yusron, M. A., & Izzhati, D. N. (2024). Design of a Plastic Waste Shredder Machine for the Processing of Inorganic Waste at TPS3R in Kudus Regency. *Journal of Advances in Information and Industrial Technology*, *6*(2), 173–182. https://doi.org/10.52435/jaiit.v6i2.615

Prastya, I. Y., Putranti, I. R., Yuniningsih, T., & Priyadi, B. P. (2025). Sustainability of Co-Production in Waste Management: Exploring Waste Banks and TPS3R in Semarang City. *Acta Innovations*, 1–12. Retrieved from https://www.ceeol.com/search/article-detail?id=1324390

Rahmi, E. (2024). Tackling Organic Waste with a Circular Economy. In *Case Study in Sukabumi City* (pp. 151–159). https://doi.org/10.2991/978-94-6463-406-8_26

Reddy, V. V., Kumar, P., Rao, A. L. N., Kumar, R., Singh, S., Asha, V., & Kareem, S. H. (2023). Waste to wealth generation: Innovative methodologies in resource utilization and minimization in circular economy. *E3S Web of Conferences*, *453*, 1035. https://doi.org/10.1051/e3sconf/202345301035

Rengganis, S. I., Zannaria, N. D., Pratiwi, R., Kartikasari, I. B., Munanto, G. B., & Oktavia, E. (2023). Economy Circular Pengelolaan Sampah Organik Pasar di Peternakan Sapi dari Hulu hingga Hilir (Studi Kasus di Kelompok Tani Sumber Makmur, Gunung Tembak Kota Balikpapan). *Jurnal Rekayasa Tropis, Teknologi, Dan Inovasi (RETROTEKIN)*, *1*(2), 1–12. https://doi.org/10.30872/retrotekin.v1i2.752

Sadono, E. D. (2024). Recent Developments of 3R Activities in Indonesia. *Circular Economy and Sustainable Development: A Necessary Nexus for a Sustainable Future*, 601–617. https://doi.org/10.1007/978-3-031-66007-8_32

Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organization*. Doubleday.

Tchobanoglous, G., Theisen, H., & Vigil, S. A. (1993). *Integrated Solid Waste Management: Engineering Principles and Management Issues*. McGraw-Hill.