IDRIS

Journal of Regional Development and Technology Initiatives
Vol. 3 (2025), pp. 145-160

Waste Management in the Circular Economy Framework: A Study on Biomass and Compost Potential Production in Payakumbuh City

Abdullah A. Afifi[1,4,*], Nor Anisa Arifin[2], Irwan Taslapratama[3]

[1]*Graduate School of Business, Universiti Kebangsaan Malaysia*
[2]*Decarbonization and Renewable Energy (DaRE) Research Centre, TNB Research, Malaysia*
[3]*Department of Agrotechnology, UIN Sultan Syarif Kasim Riau, Indonesia*
[4]*Darulfunun Institute for Development, Research and Initiatives (IDRIS) Payakumbuh, Indonesia*

Publication date: 4 February 2025

Abstract:
This study explores the potential of integrating waste management strategies with circular economy principles to enhance biomass and compost production in the greater Payakumbuh area. As regional urbanization and domestic waste levels continue to rise, there is an urgent need to shift from linear waste disposal systems toward resource-oriented waste valorization. This paper proposes a circular model that repositions organic household waste as a green input for local biomass energy and organic fertilizer production, thereby contributing to environmental sustainability, regional agricultural resilience, and green economic development. Drawing on interdisciplinary frameworks from circular economy theory, waste-to-resource models, and regional development planning, the study analyzes the feasibility of composting and anaerobic digestion as localized waste treatment technologies. It also examines governance challenges, infrastructure readiness, and community engagement in the region. The case of Payakumbuh, where agricultural productivity and urban waste generation are closely intertwined, illustrates both the opportunities and constraints of implementing circular economy strategies in smaller Indonesian urban centers. By conceptualizing a closed-loop system tailored to the socio-economic characteristics of Payakumbuh, this research provides a foundation for future empirical studies and policy interventions aimed at sustainable resource management and low-carbon regional transformation.

Keywords: *biomass production, co-creation, waste management, waste to value, circular economy*

1. Introduction

Indonesia faces significant challenges in managing municipal solid waste (MSW), with rapid urbanization and population growth contributing to increasing waste generation. In 2015, the per capita MSW generation in Indonesia was over 0.7-0.8 kg per day, with only 69% of this waste reaching landfills, while the remainder was often burned, dumped, or

[*]Correspondence: *abdullah@darulfunun.id*
https://doi.org/10.58764/j.jrdti.2025.3.93

managed informally. This situation underscores the urgent need for effective waste management strategies that can address both environmental and public health concerns (Kubota, Horita, & Tasaki, 2020; World Bank, 2018).

The concept of a circular economy (CE) offers a promising framework for addressing waste management issues. The Ellen MacArthur Foundation defines a circular economy as one that is restorative and regenerative by design, aiming to keep products and materials in use and regenerate natural systems. By shifting from a linear 'take-make-dispose' model to a circular approach, waste can be transformed into valuable resources, thereby reducing environmental impact and promoting sustainability (Ellen Macarthur Foundation, 2019).

Community-based waste management (CBWM) has emerged as an effective approach in Indonesia, leveraging local participation to enhance waste segregation and recycling efforts. For instance, in Yogyakarta, CBWM initiatives have successfully mobilized the community for waste separation and recycling, resulting in significant reductions in CO_2-equivalent emissions. Such models demonstrate the potential of community engagement in achieving sustainable waste management outcomes (Kurniawan et al., 2021; Mulasari, Husodo, Sulistyawati, & Tentama, 2024).

Biomass and compost production from organic waste are integral components of the circular economy, offering solutions for waste reduction and resource recovery. Organic waste, when properly managed, can be converted into compost or biogas, providing renewable energy sources and soil amendments for agriculture. This not only mitigates the environmental impact of waste but also contributes to energy security and sustainable agriculture practices (Vasileiadou, 2024).

The greater Payakumbuh area, characterized by its agricultural activities and growing urban centers, presents a unique context for implementing circular economy principles in waste management. The region's waste composition, predominantly organic, offers substantial potential for biomass and compost production. However, challenges such as limited infrastructure, inadequate policy support, and lack of community awareness hinder the effective implementation of such initiatives. One of the main issues faced by the Payakumbuh area is related to its landfill function on the regional scale, serving Payakumbuh, Lima Puluh Kota, Bukittinggi, and some of the Agam areas.

Integrating circular economy frameworks into regional waste management strategies requires a multi-faceted approach, policy development, technological innovation, and community engagement. The Ellen MacArthur Foundation emphasizes the importance of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems as core principles of the circular economy. Applying these principles at the regional level necessitates collaboration among stakeholders, including government agencies, private sector entities, and local communities.

Policy interventions play a critical role in facilitating the transition to a circular economy. Indonesia's national waste management policies, such as the Waste Management Law No. 18/2008, provide a legal framework for waste reduction, reuse, and recycling initiatives (World Bank, 2018). However, effective implementation at the local level requires capacity building, adequate funding, and enforcement mechanisms to ensure compliance and encourage innovation in waste management practices.

Technological advancements, particularly in waste-to-energy and composting technologies, can enhance the efficiency and scalability of biomass and compost production (UNEP, 2019). Investments in decentralized composting facilities, biogas digesters, and waste sorting technologies can facilitate the processing of organic waste at the community level, reducing transportation costs and promoting local resource utilization (Idilia, Ekayani, & Nuva, 2023; Seah et al., 2023). Moreover, digital platforms can support waste tracking, community engagement, and knowledge sharing among stakeholders (Afifi, Arifin, & Kiswanto, 2019).

Community engagement remains a cornerstone of successful waste management

initiatives. Educational campaigns, capacity-building programs, and participatory planning processes can empower communities to take ownership of waste management practices. By fostering a sense of responsibility and providing the necessary tools and knowledge, communities can play an active role in the transition to a circular economy.

This study aims to develop a conceptual framework for integrating circular economy principles into waste management strategies in the Payakumbuh area, focusing on biomass and compost production. By analyzing existing policies, technological options, and community-based initiatives, the study seeks to identify opportunities and challenges in implementing sustainable waste management practices. The findings are expected to inform policymakers, practitioners, and researchers in designing effective interventions that promote environmental sustainability and socio-economic development.

2. Methodology

This study adopts a conceptual research and case study approach, which is suitable for exploring complex and systemic topics such as the circular economy and integrated waste management (Abbas, 2010; Jaakkola, 2020; Yin, 2009). Besides collecting initial empirical data, this study also synthesizes and interprets existing theoretical frameworks, policy trends, and documented practices in the regions. By doing so, it aims to construct a conceptual model linking waste management, community participation, biomass, and compost production, and the broader objectives of sustainability and circular resource flows.

The Payakumbuh area is selected as the main regional case due to its representative characteristics of small and medium-sized urban-rural centers in Indonesia experiencing increasing waste challenges but also demonstrating the potential for community-led initiatives. Regional urban centers in Indonesia, especially those outside Java, are key sites for decentralized environmental innovation (Afifi, 2024a; Talitha, Firman, & Hudalah, 2020). This study thus uses Payakumbuh as a lens to examine localized potentials for integrating waste-to-resource strategies within a circular economy framework.

For analytical purposes, the study employs conceptual mapping and system logic modeling. Conceptual mapping is used to identify and visualize the key components of integrated waste systems (household behavior, collection practices, composting facilities, biomass energy potential) and their feedback loops (Turnheim et al., 2015). System logic modeling traces the transformation pathways of waste into usable resources, highlighting points where community participation, policy incentives, and technology investment interact to influence outcomes (Geels, 2002).

By combining conceptual design and empirical case contextualization, the methodology ensures that the proposed model is both theoretically grounded and practically relevant. The conceptual dimension strengthens the transferability of findings to other regional cities, while the Payakumbuh case provides concrete evidence of local governance structures, socio-economic dynamics, and environmental practices that shape implementation. This approach enhances the robustness of the study's contribution to both academic debates and policy discussions on the circular economy and waste management.

3. Literature review

3.1. Circular economy framework

The circular economy (CE) framework offers a transformative approach to sustainable development by emphasizing the continuous use of resources and minimizing waste. The Ellen MacArthur Foundation outlines three core principles of CE: eliminating waste and pollution, circulating products and materials at their highest value, and regenerating natural systems. These principles serve as a foundation for reimagining production and consumption patterns to achieve sustainability goals (Ellen Macarthur Foundation, 2019).

A pivotal concept within the CE is the cradle-to-cradle (C2C) design philosophy, which advocates for designing products and systems that enable materials to flow perpetually within biological or technical

cycles. This approach contrasts with the traditional linear model and aims to create systems where waste is eliminated by design (Braungart, McDonough, & Bollinger, 2007; Gong & Whelton, 2019). Implementing CE principles requires a systemic shift in how products are designed, used, and disposed of. It involves rethinking business models, supply chains, and consumer behavior to support resource efficiency and sustainability. This systemic approach is crucial for addressing environmental challenges and promoting economic resilience.

In the context of the Payakumbuh area, adopting CE principles can guide the development of sustainable waste management strategies. By focusing on resource recovery and regenerative practices, the region can transform waste challenges into opportunities for economic and environmental benefits.

3.2. Waste management perspectives

3.2.1. Community-based waste management

Community-based waste management (CBWM) emphasizes the role of local communities in managing waste through participatory approaches. In Indonesia, CBWM initiatives, such as waste banks, have been integrated into municipal waste management policies to enhance cooperation among community members and promote recycling activities (Kubota et al., 2020).

The success of CBWM relies on active community participation, education, and empowerment. By involving residents in waste segregation and recycling, CBWM fosters a sense of ownership and responsibility, leading to more effective and sustainable waste management practices. CBWM is particularly beneficial in urban and semi-urban contexts where centralized waste management systems may be inadequate. Decentralized approaches allow for tailored solutions that address specific local needs and conditions, enhancing the efficiency and effectiveness of waste management efforts (Ramadhanti, 2022; Wijayanti & Suryani, 2015).

In the Payakumbuh area, implementing CBWM can empower communities to manage their waste effectively, reduce environmental pollution, and create economic opportunities through recycling and composting initiatives.

3.2.2. Waste-to-value strategy

Transforming organic waste into biomass and compost represents a viable waste-to-value strategy within the CE framework. Composting biodegradable waste not only reduces the volume of waste sent to landfills but also produces nutrient-rich soil amendments that can enhance agricultural productivity (Hidalgo, Martin-Marroquin, & Corona, 2019; Sherwood, 2020).

The process of composting involves the aerobic decomposition of organic materials, resulting in a stable product that can improve soil structure, water retention, and nutrient content. This aligns with CE principles by returning valuable nutrients to the soil and supporting regenerative agricultural practices. In addition to composting, the production of biochar through pyrolysis of organic waste offers another avenue for waste valorization. Biochar can enhance soil fertility, sequester carbon, and reduce greenhouse gas emissions, contributing to both environmental sustainability and climate change mitigation (Duque-Acevedo, Belmonte-Ureña, Plaza-Úbeda, & Camacho-Ferre, 2020).

Implementing biomass and compost production in the Payakumbuh area can create a circular bioeconomy that supports local agriculture, reduces reliance on chemical fertilizers, and provides economic opportunities for communities engaged in waste processing activities (Ansar, Du, Javed, Adnan, & Javaid, 2025).

3.3. Sustainable development

Sustainable development in waste management emphasizes the integration of environmental, social, and economic dimensions to ensure that current needs are met without compromising the well-being of future generations. From an environmental perspective, effective waste management reduces pollution, conserves natural resources, and contributes to climate change mitigation through the reduction of greenhouse gas

emissions associated with landfills and incineration (Wan, Shen, & Choi, 2019). Socially, sustainable waste practices enhance community health by reducing exposure to hazardous waste, while also fostering social responsibility and awareness through community-based recycling and composting initiatives (Tanaka, 2007). Economically, the transformation of waste into resources, such as compost for agriculture or recyclable materials for industrial use, creates new market opportunities and generates employment across collection, processing, and recycling sectors (Guerrero, Maas, & Hogland, 2013).

In the case of Payakumbuh, adopting a sustainable waste management framework can strengthen local agricultural practices by integrating compost into farming, thereby reducing dependency on chemical fertilizers and enhancing food security. Furthermore, structured recycling systems decrease the demand for virgin raw materials, directly supporting resource efficiency. These efforts collectively align with the principles of sustainable development by balancing ecological protection, economic viability, and community welfare. Long-term success depends on coordinated action among local governments, private enterprises, and community organizations, supported by policies that encourage innovation, infrastructure development, and continuous monitoring of environmental and social outcomes (Ferronato & Torretta, 2019).

4. Payakumbuh area conditions

4.1. Demographic and waste generation

The Payakumbuh area, encompassing Payakumbuh City and its surrounding regions, has experienced steady population growth. As of 2023, Payakumbuh City had a population of approximately 146,730 residents, with an annual growth rate of 1.39% (Syafer & Putera, 2024). This growth contributes to increased waste generation, necessitating effective waste management strategies. Waste generation in

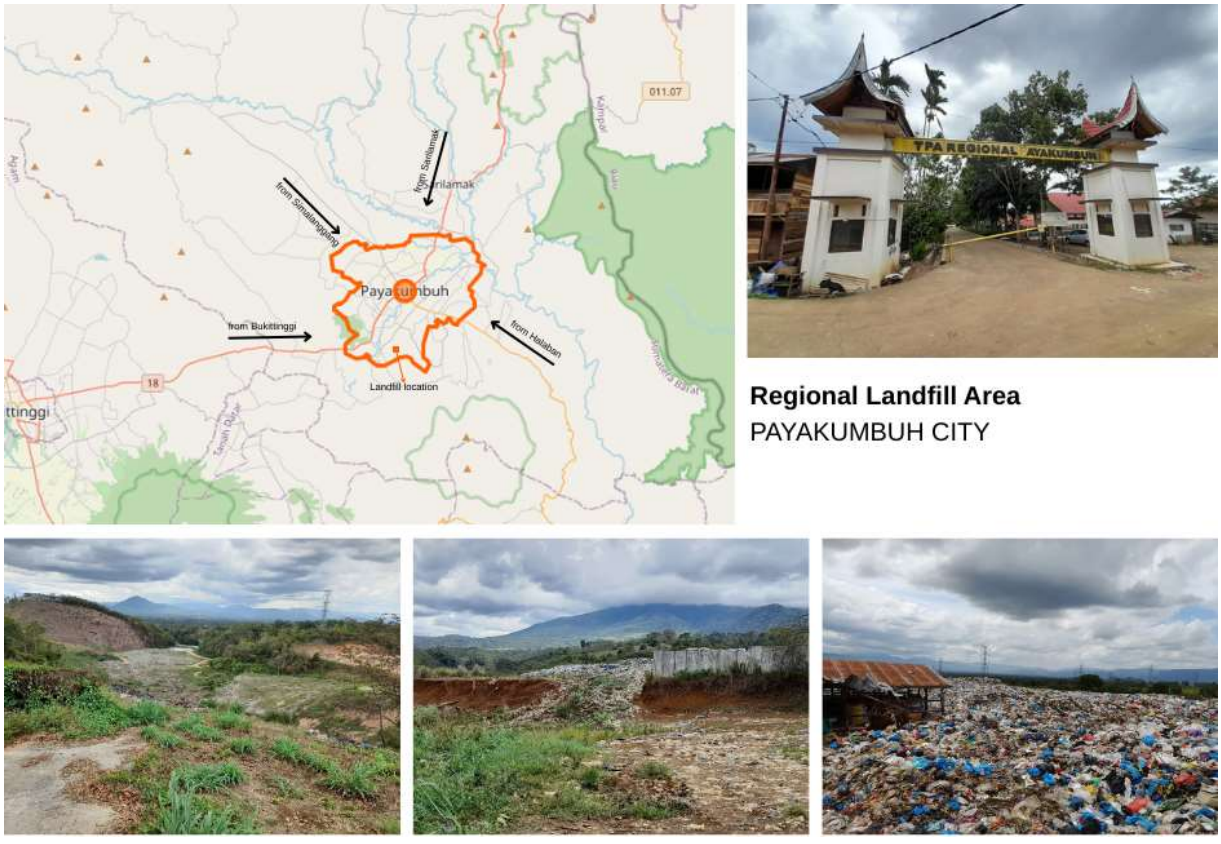

Figure 1. Landfill location (source: authors's)

Payakumbuh is significant, with an average per capita waste generation of 0.64 kg/day, totaling approximately 93.35 tons per day. The waste composition is predominantly organic waste, accounting for 92.58% of the total waste, with food waste constituting the largest portion at 48.25% (Hamdi, 2024). While combining the waste with the neighboring area, it is approximately 232,37 tons per day (Dinas Lingkungan Hidup Sumatera Barat, 2022). This high organic content presents both challenges and opportunities for waste management, particularly in composting and biomass production.

Figure 2. Landfill area (source: Google map)

The increasing waste generation correlates with urbanization and changing consumption patterns. Studies have shown that urban areas in Indonesia, including Payakumbuh, face mounting pressures in managing solid waste due to limited infrastructure and resources. Addressing these challenges requires integrated approaches that consider demographic trends and waste composition. The regional landfill serving Payakumbuh and neighboring areas is over its full capacity, highlighting the urgency for alternative waste management solutions (Putri, Raharjo, & Aziz, 2023). Implementing community-based waste management and promoting composting can alleviate the burden on landfills and contribute to sustainable waste practices.

4.2. Institutional and regulatory framework

Payakumbuh City's waste management is guided by several policies and regulations. The city has developed a Regional Strategic Policy (Jakstrada) for Household Waste and Household-like Waste Management, aiming to reduce waste generation and improve waste handling from 2018 to 2025. This policy aligns with national regulations, including the Minister of Environment and Forestry Regulation, which provides guidelines for regional waste management strategies (Anisa et al., 2021; Ditjen PSLB3, 2021).

Despite these frameworks, implementation challenges persist. A study analyzing the implementation of waste management policies in Payakumbuh identified issues such as limited public awareness, inadequate infrastructure, and insufficient coordination among stakeholders. These challenges hinder the effectiveness of existing policies and underscore the need for enhanced institutional capacity and community engagement (Okhtafianny & Ariani, 2023).

The city's waste management is overseen by the Environmental Agency, which is responsible for policy implementation, waste collection, and public education. However, resource constraints and limited technical expertise pose obstacles to achieving policy targets. Strengthening institutional frameworks and fostering partnerships with community organizations can enhance waste management outcomes. Payakumbuh has initiated alternative efforts to develop waste processing facilities and processes, such as the establishment of Temporary Waste Storage Sites (TPS3R) and Waste Processing Sites (TPST), to improve waste segregation and recycling. These initiatives reflect the city's commitment to advancing sustainable waste management

practices (Dinas Lingkungan Hidup Sumatera Barat, 2022; Kec. Payakumbuh Timur, 2024).

4.3. Waste management in Payakumbuh

Current waste management practices in Payakumbuh involve a combination of municipal services and community participation. The city has implemented waste segregation at the source, encouraging residents to separate organic and inorganic waste. However, adherence to this practice varies, with studies indicating that only about 60.78% of households consistently separate their waste (Anisa et al., 2021). Despite these efforts, challenges remain in achieving comprehensive waste management. Issues such as inadequate waste collection services, limited access to recycling facilities, insufficient public awareness, landfill overcapacity, and a lack of integrated planning hinder the effectiveness of existing practices. Even though there are some facilities present, such separator machine, husbandry, etc., it seems that more integrated planning needs to be implemented.

Organic waste, which forms over 60% of total household waste, is mostly unprocessed. Composting units remain limited to institutional pilot projects, and biomass valorization has yet to be scaled up. The limited infrastructure for composting and recycling demonstrates the need for strategic interventions aligned with circular economy principles. Local SMEs in Payakumbuh, particularly in the agricultural and food processing sectors, generate substantial organic residues and also represent potential users of compost and recycled products. Encouraging circular linkages between households, SMEs, and municipal waste services could create environmental and economic benefits. Studies on urban industrial symbiosis highlight that collaboration between municipalities and SMEs is essential for effective circular transitions (Velenturf & Purnell, 2017).

Institutional fragmentation also poses a significant barrier. Responsibility for waste management is spread across municipal, subdistrict, and community levels, creating inefficiencies in implementation. Studies on urban waste governance in Indonesia emphasize that clarity of roles and integrated policy execution are critical for success (Mesjasz-Lech, 2014). The implementation of the regional Jakstrada (Regional Policies and Strategies) requires streamlined inter-agency coordination to address these gaps.

Nevertheless, Payakumbuh possesses unique social capital that could accelerate waste governance improvements. The city's tightly-knit social structures, through RT and RW, mosques, and schools will provide strong community networks that can foster behavioral change. Localized knowledge and trust within communities are vital for sustainability transitions (Jasanoff et al., 2004). Mobilizing these networks could significantly enhance waste segregation and organic waste processing at the household level. Community-based initiatives such as waste banks and composting programs have also been introduced to promote recycling and reduce landfill dependency. These programs incentivize residents to sort and collect recyclable materials, which can then be exchanged for monetary rewards or other benefits. Such initiatives have shown promise in increasing participation and reducing waste volumes. However, their scale and coverage remain limited, and further institutional support is required to sustain them. Some schemes can be applied, such as the co-creation approach, by putting the municipality and local actors into the creation process (Eliza, Afifi, Arifin, & Azami, 2024; Prahalad & Ramaswamy, 2004).

A critical issue facing Payakumbuh is the saturation of its dedicated landfill, which has led to logistical challenges and scattered waste accumulation. Without immediate interventions, this situation risks escalating into a severe environmental and public health problem. Developing localized waste processing solutions, such as decentralized composting centers, community-based recycling facilities, and SME-driven waste-to-resource linkages, offers a more sustainable pathway to enhance the city's waste management capacity.

5. Discussion

5.1. Biomass and compost production

To start the discussion, instead of starting with the improvement of the process, we try to raise the idea of how this waste can become a precious product. The high organic content of Payakumbuh's waste stream presents significant opportunities for biomass and compost production. Organic waste, including food scraps, agricultural residues, and yard waste, can be transformed into valuable resources through composting and anaerobic digestion processes. These methods not only reduce waste volumes but also produce nutrient-rich compost and biogas, contributing to sustainable agriculture and energy generation.

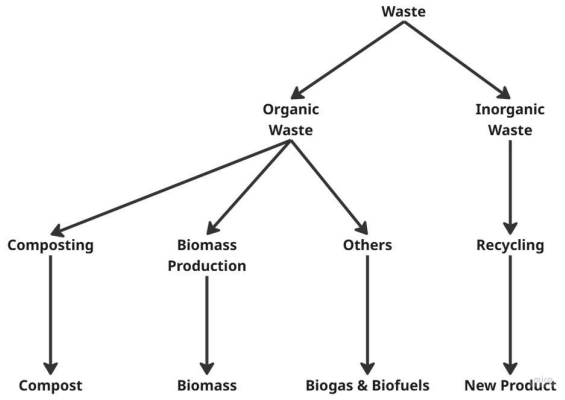

Figure 3. From waste production (compost, biomass, biogas, biofuels, and other new products

Agriculture plays a vital role in the local economy, generating substantial amounts of organic waste that can be utilized for composting. Integrating composting practices into agricultural operations can improve soil fertility, reduce reliance on chemical fertilizers, and enhance crop yields. Moreover, the adoption of composting aligns with circular economy principles, promoting resource efficiency and environmental sustainability (Sampaio et al., 2024). These organic agricultural residues (rice husk, cassava peel, wet market waste, livestock manure) represent a significant but underutilized biomass resource. The literature emphasizes the dual value of biomass as both an energy source and, soil fertility enhancer (Mekhilef, Saidur, Safari, & Mustaffa, 2011). Transitioning organic waste into biogas and compost, as part of the circular bioeconomy, can support local food systems, reduce fossil energy dependency, and even the next stage to be biogas production, which can be transformed into the next-generation of energy like hydrogen fuel cells (Arifin, Afifi, Kumar, Roslan, & Muchtar, 2024; Arifin, Afifi, Samreen, Hafriz, & Muchtar, 2023).

Community-based composting initiatives have the potential to engage residents in sustainable waste management practices. By establishing neighborhood composting centers and providing education on composting techniques, the city can foster a culture of environmental stewardship and reduce the burden on waste collection systems. Successful examples from other regions demonstrate the effectiveness of such approaches in managing organic waste.

To fully realize the potential of biomass and composting, investments in infrastructure, technology, and capacity-building are essential. Developing facilities for composting and biogas production, training personnel, and raising public awareness can create a robust system for organic waste management. These efforts can contribute to the city's sustainability goals and serve as a model for other regions facing similar challenges. As a start, the circular economy transformation demands upfront investment in infrastructure (composting units, biogas digesters), training, and monitoring systems. Public-private partnerships and blended finance mechanisms (e.g., waste credit schemes and green bonds), co-creation, and even involving waqf schemes should be explored (Afifi, 2024b; Dahan, Doh, Oetzel, & Yaziji, 2010; United Nations, 2022; Yi, Wang, & Chen, 2021). Fiscal incentives from provincial or national agencies may start and support the transition.

5.2. Circular economy transition

The transition from a linear to a circular economy necessitates a paradigm shift in waste management practices. In the context of the Payakumbuh area, integrating circular economy principles involves rethinking waste as a resource and designing systems that

facilitate the continuous use of materials. This approach aligns with the Ellen MacArthur Foundation's principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen Macarthur Foundation, 2019).

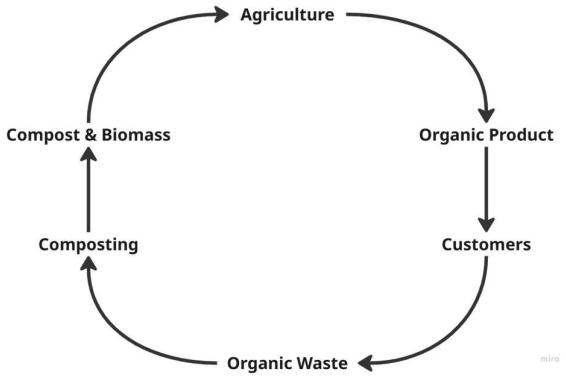

Figure 4. Circular economy for waste management – compost biomass production

Implementing circular economy strategies at the local level requires a comprehensive understanding of the existing waste management infrastructure, stakeholder engagement, and policy frameworks. Studies have highlighted the importance of localizing circular economy practices to address specific community needs and leverage local resources effectively. In Payakumbuh, this entails assessing the current waste streams, identifying opportunities for material recovery, and fostering collaboration among various stakeholders.

The integration process also involves capacity building and awareness campaigns to educate the community about the benefits of circular practices. By promoting behavioral changes and encouraging participation in waste segregation and recycling programs, the city can enhance the efficiency of its waste management system. Moreover, adopting circular economy principles can lead to economic opportunities through the development of new business models centered around resource recovery and reuse.

To facilitate this transition, it is essential to establish clear policy directives and provide incentives for sustainable practices. Local governments play a pivotal role in setting regulations, offering financial support, and creating an enabling environment for circular initiatives to thrive. In Payakumbuh, aligning municipal policies with national circular economy strategies can ensure coherence and effectiveness in implementation (Tanger, 2024).

5.3. Socio-economic local participation

The circular economic transformation will both create opportunities and new challenges for society. The economic opportunities will create a new city transformation and the development of the downstream industry of agriculture. The local actors are instrumental in the successful implementation of circular economy initiatives. In Payakumbuh, neighborhood communities (rukun tetangga or rukun warga) can facilitate community engagement by organizing awareness campaigns, coordinating waste segregation efforts, and overseeing local composting projects. Their proximity to residents positions them effectively to influence behavior and encourage participation in waste management programs.

Educational institutions, particularly schools, play a vital role in instilling environmental values in the younger generation. Integrating waste management topics into the curriculum and involving students in recycling and composting activities can foster a culture of sustainability from an early age. Furthermore, schools can serve as collection points for recyclable materials, contributing to the overall efficiency of the waste management system.

Small and medium-sized enterprises (SMEs) have the potential to drive innovation in waste processing and resource recovery. By adopting sustainable business practices and investing in recycling technologies, SMEs can contribute to the local circular economy while creating employment opportunities. Collaborations between SMEs and community organizations can lead to the development of new products from recycled materials, adding value to waste streams (Afifi, Adrian, Azami, & Farid, 2024; Afifi et al., 2019).

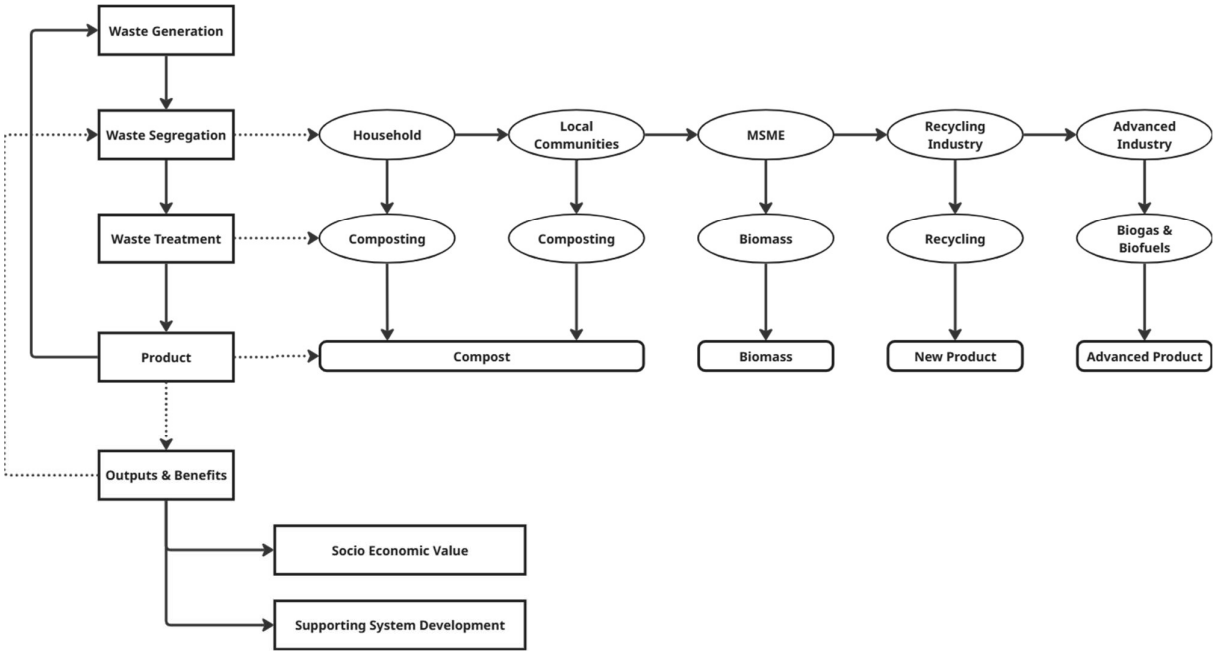

Figure 5. Socio-economic mapping for waste

Farmers stand to benefit significantly from the availability of compost derived from organic waste. Utilizing compost can improve soil health, increase crop yields, and reduce reliance on synthetic fertilizers. Engaging farmers in composting initiatives and providing them with training on sustainable agricultural practices can enhance the integration of circular economy principles in the agricultural sector. Waste banks, as community-based organizations, can facilitate the collection and exchange of recyclable materials, incentivizing waste segregation and promoting recycling habits among residents (Upadhyay et al., 2024; Wijayanti & Suryani, 2015).

A conceptual flowchart (Figure 5) illustrating the transformation of household and community waste into valuable resources can serve as a visual representation of the circular economy model in Payakumbuh. The process begins with waste generation at the household level, followed by segregation into organic and inorganic components that can be classified based on type and quantity in each level of area or community. Food leftovers and easy-to-compost organic waste can be processed by the community directly or in large quantities for composting at local facilities. The compost produced from organic waste can be utilized in local agriculture, enhancing soil fertility and reducing the need for chemical fertilizers. This not only supports sustainable farming practices but also contributes to food security in the region.

While the other non-easy-to-compost organic waste, such as a wood log, paddy straw, or organic waste in quantities like from harvest residue, crops, or market leftovers, can be processed through industry. These solid organic wastes can be processed into biomass. The biomass production needs to be done on an industrial scale, to make the process efficient and better technology used.

Figure 6. Recycle product segregation

For recyclable waste, inorganic materials are sent to recycling centers. The recycling products are the new products that are produced on an industrial scale. In our observation, the segregation of recyclable waste has not really become a problem, since these products still have value, at least in their material. The recycling industry has an impact on the scales and quantity. This is why, for regional circular economies, it's important to establish a recycling industry. The non-economic recycling industry will make the process inefficient and lost value in the transport and distribution. Recycling inorganic materials reduces the demand for virgin resources and minimizes environmental pollution.

The economic benefits of this model include job creation in waste collection, processing, and recycling sectors. Community-based composting programs have been shown to foster a sense of responsibility and collective action, promoting environmental awareness and stewardship. The segregation strategy and policy were made from the feedback on outputs and benefits to be reached, making it an integrated cycle. Additionally, the waste reduction sent to landfills leads to decreased greenhouse gas emissions, contributing to climate change mitigation efforts (Milan, 2024).

Implementing this requires coordinated efforts among various stakeholders, including multilevel local authorities, community organizations, and private enterprises. Establishing efficient logistics for waste collection and transportation, investing in composting and recycling infrastructure, and providing training for workers are critical components of the system. Monitoring and evaluation mechanisms should also be in place to assess the effectiveness of the model and identify areas for improvement. To make it more reliable and accountable, it is important to develop empirical and economical value-based approaches (Afifi, Andriyaldi, & Adrian, 2024; Jasanoff et al., 2004).

5.4. Smart waste management

The integration of smart technologies into waste management practices, such as web-based apps, IoT sensors, real-time tracking, and physical automated sorting, offers immense potential to improve efficiency, accuracy, and transparency throughout the waste cycle. For composting and biomass processes in particular, sensor-based monitoring can optimize moisture levels, temperature, and microbial activity, resulting in higher-quality compost and faster processing times. These benefits are especially critical in semi-urban regions like the Payakumbuh area, where community-based systems can suffer from variability in technique and limited technical oversight. Smart tools make it possible to standardize outputs and ensure the safety and marketability of compost products, which enhances their value in agricultural applications (Afifi, Adrian, et al., 2024; Fatimah, Govindan, Murniningsih, & Setiawan, 2020).

Digital platforms can also facilitate data-driven decision-making by tracking waste volumes, types, collection frequencies, and processing outcomes across neighborhoods. Mobile or web-based apps can be developed for households and waste collectors to log waste segregation practices, while community leaders and local waste banks can use dashboards to monitor overall system performance. This digital mapping helps identify inefficiencies, leakages, and improvement points in real-time. Pilot programs in Bandung and Denpasar have demonstrated that combining digital platforms with community incentives leads to greater household compliance and cleaner waste streams. Payakumbuh can replicate this model, starting with simple GIS mapping and gradually scaling toward full digital integration (Irsa, Budiarni, & Budiman, 2020; Parawangsa, Situmorang, & Suharto, 2020).

Schools and universities play a strategic role in supporting these technology transitions. Local institutions, such as Universitas Andalas, Universitas Negeri Padang, Universitas Muhammadiyah Sumatera Barat, STT Payakumbuh, and the Darulfunun Institute, can act as living laboratories for testing and refining waste-to-value innovations. Involving students and faculty in real-world composting experiments, sensor installations, or community education campaigns not only

enhances educational outcomes but also fosters a culture of environmental responsibility. Research shows that when waste education is embedded in curricula, long-term behavior change and technological innovation are more likely to be sustained (Gong & Whelton, 2019).

To move toward full Industry 4.0 adoption, an industrial maturity roadmap is recommended for Payakumbuh's waste management system. This roadmap would outline progressive stages, from manual and semi-automated collection to sensor-enabled sorting, to AI-driven forecasting of waste flows and resource recovery (Afifi et al., 2019). It can guide policymakers, community cooperatives, and private sector partners in planning capital investments, workforce training, and technological piloting. This structured transformation not only supports better environmental outcomes but also opens up new economic opportunities in green tech, agro-processing, and environmental services, aligning Payakumbuh's vision with national and global circular economy strategies.

5.5. Integrated regional strategy and policies

The transition toward circular waste systems in Payakumbuh requires an integrated regional development perspective, linking environmental, economic, and social policies. The city can develop a model for West Sumatra in embedding circular economy principles into local governance, bridging top-down planning with grassroots mobilization. The United Nations Sustainable Development Goals (SDGs) provide a global framework that aligns well with the Payakumbuh case. Implementation of circular economy strategies through compost and biomass use contributes to these targets by reducing methane emissions, improving urban waste systems, and promoting inclusive community development (Olczak & Piebalgs, 2023).

While the Jakstrada offers strategic direction, it lacks operational depth. Regulatory gaps exist around community composting standards, incentive systems for biomass use, and SME support. Learning from Bali's plastic policy, Payakumbuh could implement local regulations (Perda) to strengthen mandatory segregation and support waste entrepreneurship (Lestari, Fitri, & Hikmawan, 2021). Effective policy and governance frameworks are essential for the successful implementation of circular economy models. In Payakumbuh, aligning local regulations with national policies on waste management and circular economy can provide a coherent direction for stakeholders. Establishing clear guidelines for waste segregation, recycling, and composting, along with enforcement mechanisms, ensures compliance and accountability. The success of circular waste management models depends significantly on sustained political will and transparent governance. Payakumbuh's leadership must champion these innovations through inclusive policy processes, clear communication, and long-term capacity building (Schroeder, Anggraeni, & Weber, 2019).

Programs in Yogyakarta and Surabaya have demonstrated that engaging women's groups and youth organizations enhances project sustainability. Women are often primary actors in household waste management, while youth can drive digitalization and innovation in community-based solutions. Targeted empowerment programs could be tailored for the Payakumbuh context. Surabaya is often highlighted as a successful example of community-based waste management in Indonesia. Through its integrated waste bank system, the city has managed to significantly reduce household waste while empowering local communities (Dhokhikah, Trihadiningrum, & Sunaryo, 2015). The approach fosters social engagement by incentivizing waste sorting and recycling, providing valuable insights for Payakumbuh. A similar system could be adapted to suit the scale and socio-cultural dynamics of the Payakumbuh area, leveraging its dense community structures.

Yogyakarta has pioneered localized composting through community-based infrastructure, especially in urban kampungs. Studies show that these initiatives result in improved soil quality and reductions in landfill dependence (Kurniawan et al., 2021). For Payakumbuh, the success of Yogyakarta offers

a pathway to develop urban-scale organic waste reuse. The use of simple technology and community training in composting should be explored at multiple levels of the municipality. To face a severe plastic pollution crisis, it has implemented multi-stakeholder initiatives combining community awareness, youth activism, and government policies banning single-use plastics. While Payakumbuh has different waste typologies, the community mobilization model and policy enforcement mechanisms can inform local regulation and civil society collaboration.

Financial incentives, such as subsidies for composting equipment or tax breaks for recycling businesses, can encourage investment in circular economy initiatives. Public-private partnerships can mobilize resources and expertise, fostering innovation and expanding the reach of waste management programs. Moreover, integrating circular economy objectives into urban planning and development strategies can institutionalize sustainable practices across various sectors. Engaging citizens in policy development processes ensures that initiatives are responsive to community needs and garner public support. Participatory approaches, such as public consultations and feedback mechanisms, can enhance transparency and trust in governance structures. By fostering a collaborative environment, Payakumbuh can build a resilient and inclusive circular economy that benefits all stakeholders.

Lastly, capacity building for local government officials and community leaders is crucial to enhancing their understanding of circular economy concepts and their ability to implement relevant programs. Training sessions, workshops, and knowledge exchange platforms can facilitate the dissemination of best practices and lessons learned from other regions. Involving the education sector in the local curriculum is also important in building a paradigm and societal culture about sustainable waste management and the circular economy. Additionally, establishing monitoring and evaluation systems enables the assessment of program effectiveness and informs policy adjustments.

6. Conclusion

This study contributes to academic discourse by advancing a conceptual understanding of waste management and circular economy transitions in small urban centers like Payakumbuh. By integrating comparative insights from other Indonesian cities and aligning them with the Sustainable Development Goals, the paper highlights how systemic thinking can enrich the literature on environmental governance and urban resilience. Scholars benefit from a framework that situates local practices within broader debates on sustainability, circular economy, and policy innovation.

For practitioners, the findings emphasize the practical value of adopting circular economy principles in regional waste management. Local governments, businesses, and community organizations can use this framework to design integrated waste management systems that prioritize composting, biomass technology, and community training. The discussion also underscores the necessity of aligning local policies with Indonesia's Circular Economy Roadmap, which provides clear pathways for practical interventions that enhance efficiency, reduce environmental risks, and improve quality of life in urban areas.

Future research should empirically test the conceptual model presented here by examining the actual performance of waste management strategies in Payakumbuh and comparable cities. Quantitative and qualitative studies could assess the effectiveness of community training programs, the economic feasibility of compost and biomass technologies, and the long-term social acceptance of circular economy initiatives. Further inquiry into governance mechanisms, financing models, and behavioral change strategies will also be crucial for scaling sustainable waste management practices in Indonesia and beyond.

References

Abbas, A. F. (2010). *Metode Penelitian, cet. I*. Jakarta: Adelina Bersaudara.

Afifi, A. A. (2024a). How Indonesia Should Go Further with Decentralization : Revisiting the Views and the Visions. *Perwakilan: Journal of Good Governance, Diplomacy, Customary Institutionalization and Social Networks*, *2*, 93–104.

Afifi, A. A. (2024b). Waqf Business Model (WBM): Towards A Sustainable Social Business Model on The Mainstream Economics. *Journal of Regional Development and Technology Initiatives*, *2*, 63–78.

Afifi, A. A., Adrian, H., Azami, E., & Farid, M. (2024). Re-Viewing Sumitro's Policy and Industrial Maturity: Powering Downstream and Manufacturing Industries for Economic Growth and Sustainable Society. *Journal of Regional Development and Technology Initiatives*, *2*, 79–102.

Afifi, A. A., Andriyaldi, A., & Adrian, H. (2024). Reconstructing the Concept of Bela Negara: From Excessive Jargon to an Empirical Civic-based Approach. *Perwakilan: Journal of Good Governance, Diplomacy, Customary Institutionalization and Social Networks*, *2*(2), 81–92.

Afifi, A. A., Arifin, N., & Kiswanto, G. (2019). Industrial Maturity Development Index: An Approach from Technology-driven Resources. *International Colloquium on Research Innovations & Social Entrepreneurship (Ic-RISE) 2019*. https://doi.org/10.58764/conf.icrise2019.1

Anisa, L., Sherra, B. El, Irvanda, R., Maulana, Y., Iswandi, Barlian, E., & Erianjoni. (2021). *Waste Reduction and Handling Management in Payakumbuh City*. (c), 193–201.

Ansar, A., Du, J., Javed, Q., Adnan, M., & Javaid, I. (2025). Biodegradable Waste in Compost Production: A Review of Its Economic Potential. *Nitrogen*, *6*(2). https://doi.org/10.3390/nitrogen6020024

Arifin, N. A., Afifi, A. A., Kumar, N., Roslan, N. N., & Muchtar, A. (2024). Influence of Metal Dopant (Cu, Co, Sm, Sn) on Ni/ScSZ Thin Film Anode in Solid Oxide Fuel Cell. *Journal of Regional Development and Technology Initiatives*, *2*, 103–117.

Arifin, N. A., Afifi, A. A., Samreen, A., Hafriz, R. S. R. M., & Muchtar, A. (2023). Characteristic and challenges of scandia stabilized zirconia as solid oxide fuel cell material – In depth review. *Solid State Ionics*, *399*, 116302. https://doi.org/10.1016/J.SSI.2023.116302

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, *15*(13), 1337–1348. https://doi.org/https://doi.org/10.1016/j.jclepro.2006.08.003

Dahan, N. M., Doh, J. P., Oetzel, J., & Yaziji, M. (2010). Corporate-NGO Collaboration: Co-creating New Business Models for Developing Markets. *Long Range Planning*, *43*(2), 326–342. https://doi.org/10.1016/j.lrp.2009.11.003

Dhokhikah, Y., Trihadiningrum, Y., & Sunaryo, S. (2015). Community participation in household solid waste reduction in Surabaya, Indonesia. *Resources, Conservation and Recycling*, *102*, 153–162.

Dinas Lingkungan Hidup Sumatera Barat. (2022). *Laporan RKL-RPL TPA Sampah Regional Payakumbuh Semester II Tahun 2022*.

Ditjen PSLB3. (2021). *Penyusunan Kebijakan Strategi Daerah dalam Pengelolaan Sampah Rumah Tangga Dan Sampah Sejenis Sampah Rumah Tangga*.

Duque-Acevedo, M., Belmonte-Ureña, L. J., Plaza-Úbeda, J. A., & Camacho-Ferre, F. (2020). The management of agricultural waste biomass in the framework of circular economy and bioeconomy: An opportunity for greenhouse agriculture in Southeast Spain. *Agronomy*, *10*(4), 489.

Eliza, M., Afifi, A. A., Arifin, N. A., & Azami, E. (2024). Digital Learning Co-Creation: A Conceptual Study between University and Learning Hub in Underdeveloped Urban Areas. *Journal of Regional Development and Technology Initiatives*, *2*, 119–130.

Ellen Macarthur Foundation. (2019). The circular economy in detail. Retrieved from https://www.ellenmacarthurfoundation.org/the-circular-economy-in-detail-deep-dive

Fatimah, Y. A., Govindan, K., Murniningsih, R., & Setiawan, A. (2020). Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia. *Journal of Cleaner Production*, *269*, 122263.

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health*, *16*(6), 1060.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274.

Gong, Y., & Whelton, J. (2019). In Conversation: Ellen MacArthur: From Linear to Circular. *She Ji*, *5*(3), 247–256. https://doi.org/10.1016/j.sheji.2019.08.001

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1), 220–232.

Hamdi, F. (2024). *Studi Timbulan, Komposisi, Potensi Daur Ulang dan Guna Ulang Sampah Kota Payakumbuh*.

Hidalgo, D., Martin-Marroquin, J. M., & Corona, F. (2019). A multi-waste management concept as a basis towards a circular economy model. *Renewable and Sustainable Energy Reviews*, *111*, 481–489.

Idilia, C. F., Ekayani, M., & Nuva, N. (2023). Study of Waste Generations and Potential Implementation of Community-Based Waste Management in Residential Area. *Geosfera Indonesia*, *8*(3), 216. https://doi.org/10.19184/geosi.v8i3.38690

Irsa, R., Budiarni, R., & Budiman, A. (2020). Pemetaan tempat pembuangan sampah di kota payakumbuh menggunakan mobile gis. *Jurnal SIMTIKA*, *3*(2), 13–20.

Jaakkola, E. (2020). Designing conceptual articles: four approaches. *AMS Review*, *10*(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Jasanoff, S., Miller, C. A., Thompson, C., Waterton, C., Wynne, B., Storey, W. K., … Ezrahi, Y. (2004). *States of Knowledge: The co-production of science and social order*. Routledge London.

Kec. Payakumbuh Timur. (2024). Tidak Miliki Lagi TPA, Payakumbuh Konsepkan TPST dan TPS3R. Retrieved from https://kecpyktimur.payakumbuhkota.go.id/2024/07/10/tidak-miliki-lagi-tpa-payakumbuh-konsepkan-tpst-dan-tps3r/

Kubota, R., Horita, M., & Tasaki, T. (2020). Integration of community-based waste bank programs with the municipal solid-waste-management policy in Makassar, Indonesia. *Journal of Material Cycles and Waste Management*, *22*(3), 928–937. https://doi.org/10.1007/s10163-020-00969-9

Kurniawan, T. A., Avtar, R., Singh, D., Xue, W., Dzarfan Othman, M. H., Hwang, G. H., … Kern, A. O. (2021). Reforming MSWM in Sukunan (Yogjakarta, Indonesia): A case-study of applying a zero-waste approach based on circular economy paradigm. *Journal of Cleaner Production*, *284*, 124775. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.124775

Lestari, G. P., Fitri, T. A., & Hikmawan, M. D. (2021). The Role of Bye-Bye Plastic Bags in Realizing Bali Provincial Government Policy Regarding the Restriction of Plastic Bags in 2013-2018. *Ijd-Demos*, *3*(1).

Mekhilef, S., Saidur, R., Safari, A., & Mustaffa, W. (2011). Biomass energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, *15*(7), 3360–3370.

Mesjasz-Lech, A. (2014). Municipal waste management in context of sustainable urban development. *Procedia-Social and Behavioral Sciences*, *151*, 244–256.

Milan, Y. (2024). *Social and Economic Benefits of Community-Based Composting Programs : Lessons from Global Initiatives*. *14*(1000578), 1–2. https://doi.org/10.35248/2252-5211.24.14.578.Citation

Mulasari, S. A., Husodo, A. H., Sulistyawati, S., & Tentama, F. (2024). *Community-driven Waste Management : Insights from an Action Research Trial in Yogyakarta , Indonesia*. 1–13. https://doi.org/10.2174/0118749445334410241122102430

Okhtafianny, T., & Ariani, R. (2023). Analisis Implementasi Kebijakan Pengelolaan Sampah Di Kota Payakumbuh. *Jurnal Ekonomi Bisnis, Manajemen Dan Akuntansi (JEBMA)*, *3*(2), 537–550. https://doi.org/10.47709/jebma.v3i2.2837

Olczak, M., & Piebalgs, A. (2023). Methane emission in a circular economy. In *Law in the EU's Circular Energy System* (pp. 160–180). Edward Elgar Publishing.

Parawangsa, S. R., Situmorang, R., & Suharto, B. (2020). Site Selection for Regional Solid Waste Final Disposal in Bangka Island Based on Geography Information System (GIS). *International Journal on Livable Space*, *5*(2), 76–80.

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of Interactive Marketing*, *18*(3), 5–14.

Putri, V. T., Raharjo, S., & Aziz, R. (2023). Strategi Pengelolaan Sampah Menggunakan Analisis SWOT : Studi Kasus TPA Regional Payakumbuh. *Jurnal Serambi Engineering*, *8*(3), 6697–6706. https://doi.org/10.32672/jse.v8i3.5788

Ramadhanti, F. (2022). Developing Community-Based Solid Waste Management (CBSWM) Model: Case of West Nusa Tenggara, Indonesia. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, *5*(1), 578–586.

Sampaio, I. C. F., da Silva Quinto, A. S., de Moura, I. V. L., Cezar, K. S., Franco, M., & de Almeida, P. F.

(2024). *The Role of Composting in Sustainable Agriculture and Waste Management BT - Progress in Hydrogen Energy, Fuel Cells, Nano-Biotechnology and Advanced, Bioactive Compounds* (C. A. Taft & S. R. de Lazaro, Eds.). https://doi.org/10.1007/978-3-031-75984-0_18

Schroeder, P., Anggraeni, K., & Weber, U. (2019). The relevance of circular economy practices to the sustainable development goals. *Journal of Industrial Ecology*, *23*(1), 77–95.

Seah, C. C., Tan, C. H., Arifin, N. A., Hafriz, R., Salmiaton, A., Nomanbhay, S., & Shamsuddin, A. H. (2023). Co-pyrolysis of biomass and plastic: Circularity of wastes and comprehensive review of synergistic mechanism. *Results in Engineering*, *17*, 100989.

Sherwood, J. (2020). The significance of biomass in a circular economy. *Bioresource Technology*, *300*, 122755.

Syafer, E., & Putera, R. E. (2024). *Analisa Partisipasi Masyarakat dalam Pengelolaan Sampah di Kota Payakumbuh*. *4*, 4568–4583.

Talitha, T., Firman, T., & Hudalah, D. (2020). Welcoming two decades of decentralization in Indonesia: a regional development perspective. *Territory, Politics, Governance*, *8*(5), 690–708.

Tanaka, M. (2007). Waste management for a sustainable society. *Journal of Material Cycles and Waste Management*, *9*(1), 2–6.

Tanger, K. (2024). To Shift to a Circular Economy, Act, Advocate, Advance. Retrieved from https://deloitte.wsj.com/sustainable-business/to-shift-to-a-circular-economy-act-advocate-advance-62410ea4

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., & van Vuuren, D. (2015). Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. *Global Environmental Change*, *35*, 239–253.

UNEP. (2019). *Waste-to-Energy: Considerations for Informed Decision-Making*.

United Nations. (2022). The Sustainable Development Goals Report 2022. *United Nations Publication Issued by the Department of Economic and Social Affairs*, 64.

Upadhyay, S. K., Singh, G., Rani, N., Rajput, V. D., Seth, C. S., Dwivedi, P., … Khoo, K. S. (2024). Transforming bio-waste into value-added products mediated microbes for enhancing soil health and crop production: Perspective views on circular economy. *Environmental Technology and Innovation*, *34*(February), 103573. https://doi.org/10.1016/j.eti.2024.103573

Vasileiadou, A. (2024). From Organic Wastes to Bioenergy, Biofuels, and Value-Added Products for Urban Sustainability and Circular Economy: A Review. *Urban Science*, *8*(3), 121. https://doi.org/10.3390/urbansci8030121

Velenturf, A. P. M., & Purnell, P. (2017). Resource recovery from waste: Restoring the balance between resource scarcity and waste overload. *Sustainability*, *9*(9), 1603.

Wan, C., Shen, G. Q., & Choi, S. (2019). Waste management strategies for sustainable development. In *Encyclopedia of sustainability in higher education* (pp. 2020–2028). Springer.

Wijayanti, D. R., & Suryani, S. (2015). Waste Bank as Community-based Environmental Governance: A Lesson Learned from Surabaya. *Procedia - Social and Behavioral Sciences*, *184*(August 2014), 171–179. https://doi.org/10.1016/j.sbspro.2015.05.077

World Bank. (2018). Indonesia's Marine Debris Hotspot. In *Synthesis Report*. Retrieved from https://documents.worldbank.org/en/publication/documents-reports/documentdetail/983771527663689822/indonesia-marine-debris-hotspot-rapid-assessment-synthesis-report%0A

Yi, Z., Wang, Y., & Chen, Y. J. (2021). Financing an Agricultural Supply Chain with a Capital-Constrained Smallholder Farmer in Developing Economies. *Production and Operations Management*, *30*(7), 2102–2121. https://doi.org/10.1111/poms.13357

Yin, R. K. (2009). *Case study research: Design and methods*. Sage.