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Exploring Policy Interactions: A System Dynamics Study on Sustainable Household Waste Management in Rural Municipality

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ABSTRACT

This study investigates household waste management challenges in Argao, a first-class rural municipality in Cebu, Philippines, using a System Dynamics (SD) modeling approach. It assesses four policy scenarios: banning household waste burning, implementing recycling and composting programs, establishing a municipal recycling center, and a combined strategy incorporating all three scenarios. The findings show that banning waste burning significantly reduces carbon emissions but shifts waste to landfills, stressing limited disposal capacity. Recycling and composting policies improve waste recovery by 20%, decrease landfill reliance by nearly 9%, and reduce emissions similarly, while increasing household income by over 400% in ten years. The municipal recycling center had the most substantial impact, boosting waste recovery by more than 30%, lowering landfill dependence by nearly 14%, and creating nearly 10,000 jobs locally. When combined, the integrated approach delivered the highest overall benefits, with a net present value of ₱15.9 million, offering a sustainable path to comply with Republic Act 9003. These results demonstrate that a phased, integrated strategy-beginning with household-level actions and expanding to infrastructure investments-can effectively enhance waste diversion, improve environmental health, and generate significant economic opportunities in Argao.

INTRODUCTION

Household waste management in the Philippines is characterized by significant challenges due to rapid urbanization, population growth, and poor infrastructure. The country generates approximately 41,000 tons of waste daily, with Metro Manila alone contributing over 9,670 tons (Agaton et al. 2020). This escalating waste generation is projected to increase by approximately 165% by 2025, leading to severe implications for waste management systems, including overcrowded landfills and environmental degradation (Coracero et al. 2021). The Philippine government has enacted the Ecological Solid Waste Management Act (Republic Act 9003) to address these issues, mandating local government units (LGUs) to implement effective waste management strategies (Atienza 2020, Treyes et al. 2023). However, implementing these policies has faced numerous obstacles, including inadequate personnel training and limited local resources (Camarillo & Bellotindos 2021, Macusi et al. 2019). This situation is exacerbated by rural municipalities, which usually generate a different composition of waste, with a substantial portion being organic, mainly due to agricultural activities and household consumption patterns, which present challenges and opportunities for composting and resource recovery initiatives (Baquero et al. 2022). The lack of public awareness and education regarding waste segregation and disposal practices further aggravates the issue, as households often lack the necessary knowledge to manage waste effectively (Handayani et al. 2018, Mihai 2017, Treyes et al. 2023, Viljoen et al. 2021). This inadequacy leads to improper disposal practices, such as open dumping and burning, which pose serious environmental and public health risks to the population. Burning household waste significantly harms the environment by releasing harmful pollutants and greenhouse gases. When waste is burned, it generates a variety of toxic emissions, including particulate matter, volatile organic compounds (VOCs), and heavy metals, which can severely degrade air quality and pose health risks to nearby populations (Florin-Constantin 2019, Reyna-Bensusan et al. 2018, Makki et al. 2023). This highlights the potential for waste reduction through composting and recycling initiatives, which minimize landfill contributions and provide economic benefits by creating valuable compost and recycled products (Husna et al. 2023). Furthermore, the economic implications of waste management policies are significant; for instance, the costs associated with waste disposal can be mitigated through effective recycling and waste separation practices, which have been shown to reduce the overall volume of waste sent to landfills (Ogiri et al. 2019). Social factors also play a critical role in waste management policy effectiveness. Public awareness and education regarding the impacts of waste generation are essential for fostering responsible waste disposal behaviors among households (Institute of Environment and Development (LESTARI), National University of Malaysia (UKM), Bangi 43600, Selangor D.E, Malaysia et al. 2016). Programs aimed at increasing knowledge of the environmental consequences of food waste, for example, can lead to behavioral changes that significantly reduce waste generation (Chengqin et al. 2024). Studies have shown that education and awareness of waste management significantly influence community participation in waste reduction and recycling initiatives (Janmaimool & Denpaiboon 2016). Research indicates that residents of Kinshasa are willing to pay for improved waste management services, suggesting that economic incentives could enhance participation in sustainable practices (Makanga & Zahiga 2023).

The environmental impact of household waste policies cannot be overlooked. Poor waste management practices contribute to soil and water pollution, and public health risks associated with waste mismanagement (Datta 2022, Vongdala et al. 2018). Effective waste management strategies that prioritize environmental sustainability are crucial for mitigating these adverse effects. For instance, waste separation at the source has been shown to enhance the quality of recyclable materials and reduce the health risks associated with landfill odor and emissions (Al-Rumaihi et al. 2020). Similarly, the 3R principle (Reduce, Reuse, Recycle) has been proposed as a viable approach to mitigate waste generation at the household level, emphasizing the need for community education and engagement (Ridayati & Yunastiawan 2021). The effectiveness of such initiatives is often contingent on local government support and the establishment of efficient waste collection systems (Shelepina 2023, Yukalang et al. 2018). Moreover, recycling is a collective effort, from the product designer to the trash thrower, waste collector, and recycling factory worker (Ibrahim Bi̇li̇ci̇ 2022). The urgency of addressing household waste management in Argao, Cebu, a 1st class municipality in the Philippines, stems from two interrelated concerns. First, the municipality faces rapid depletion of landfill capacity vis-à-vis the continuous accumulation of household waste, a trend documented in Philippine studies showing that landfill reliance leads to long-term risks of groundwater contamination, methane emissions, and land scarcity (Coracero et al. 2021, Datta 2022). Without effective diversion strategies, increasing landfill dependency threatens environmental quality and public health. Second, strict compliance requirements under Republic Act 9003 (Ecological Solid Waste Management Act of 2000) place additional legal and financial pressure on local government units (LGUs). RA 9003 mandates segregation, recycling, and waste diversion, and failure to comply may result in penalties, sanctions, or reduced funding allocations (Atienza 2020, Treyes et al. 2023). These dual pressures, namely environmental risk and legal obligation, make the development and implementation of sustainable waste management strategies not only necessary but also urgent.

Locale of the Study

Argao, as the locale of the study, is a 1st class municipality in the province of Cebu, Philippines, as shown in Fig. 1.

According to the 2020 census, Argao has a population of 78,187 and 16, 574 households. It is located in the southeastern portion of Cebu Province, approximately 68 km from Cebu City. In 2015, the municipality was ordered to close its open dumpsite, the only disposal option currently adopted. Thus, the LGU planned to open a sanitary landfill in 2016. However, these projects remain unachieved because the existing disposal site is still not constructed as per sanitary landfill infrastructure standards. The municipality's solid waste management (SWM) ordinance requires each barangay to implement SWM programs strictly and educate its constituents on waste segregation to reduce the garbage collected and brought to the landfill. However, it has not produced satisfactory results. With plans to construct an additional landfill site, the local government's primary concern is to identify new approaches that can support their decision-making to start and adopt a sustainable way of managing the municipality's waste problems.

Household Waste Management (HWM) Program and Policy Description

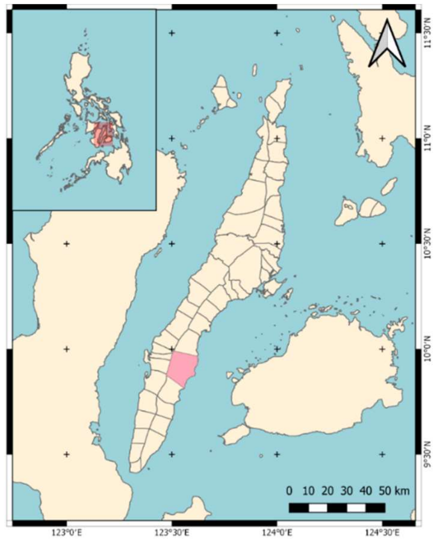


Fig. 1: Locale of the Study.

Household waste management in the Philippines is guided by Republic Act 9003; however, its implementation varies widely across municipalities. The policy scenarios analyzed in this study are grounded in programs already adopted elsewhere and tested for their applicability to the local conditions of Argao. The ban on household waste burning reflects the regulatory efforts in other towns to address air pollution and public health risks. Composting and recycling programs mirror practices in rural and agricultural municipalities, where organic waste dominates, providing both environmental and economic benefits. The municipal recycling center scenario draws from examples where infrastructure investment has enabled the large-scale diversion of recyclables and job creation. These approaches were narrowed down to four scenarios-burn ban, recycling and composting, recycling center, and a combined option–because they represent a practical progression from regulation to community-based participation to infrastructure-driven solutions. Together, they provide a holistic set of alternatives aligned with environmental sustainability, economic opportunities, and compliance with RA 9003. The aims of each policy scenario used in this study are as follows.

Scenario 1: Ban on Household Waste Burning (Burned Waste Policy). This policy aims to protect public health, reduce pollution, and promote sustainable waste management by prohibiting the burning of household waste. This policy applies to all residents and covers all types of waste. Open burning releases harmful pollutants that cause respiratory illnesses, environmental degradation, and climate change (Reyna-Bensusan et al. 2018). This policy aims to reduce undesirable carbon emissions.

Scenario 2: Recycling and composting policies. This policy promotes sustainable waste management by requiring households to segregate, collect, and dispose of recyclable and compostable material. Recyclable scrap, including plastics, metals (tin cans), and paper, must be sorted, sold, and delivered to authorized recycling centers. In contrast, compostable waste, such as food scraps and yard debris, should be processed using home composting systems. Local authorities provide designated bins, collection schedules, and educational programs to ensure compliance. This policy aims to reduce landfill waste, conserve resources, and promote environmental sustainability through responsible waste disposal. In this scenario, household waste burning is not restricted to rural areas. Furthermore, this policy seeks to provide information on household revenue from recycled and composted waste.

Scenario 3: Municipal Recycling Policy (creation of recycling centers). The LGU established a dedicated facility for processing recyclable waste to promote environmental sustainability and reduce landfill dependency. The center will collect, sort, and process all plastic waste materials and convert them into shredded recyclables as boiler fuel for factories that utilize fuels for burning and kiln drying. Local authorities oversee operations, hire manpower, provide public education, and encourage community participation. Residents must properly segregate waste for collection or direct drop off. In this policy, household waste burning is not restricted or banned. This policy aims to enhance waste management efficiency, lower carbon emissions, and support the circular economy. Furthermore, this policy aims to generate employment opportunities in the community.

Scenario 4: All scenarios are combined. All three scenarios (burned waste, recycling, and composting policies, and municipal recycling policies) were combined in this scenario. This policy aims to assess the effects on waste management efficiency when all policy switches are activated.

System Dynamics Modeling

System dynamics is a modeling technique that aims to gain insights into complex systems and their development over time (Saysel et al. 2002). The use of the system dynamics approach requires system thinking. It effectively evaluates the sustainability of solid waste management (Giannis et al. 2017, Rahayu et al. 2013, Saysel et al. 2002). This method has been applied under different waste minimization management conditions. For instance, system dynamics were used to study Singapore's solid waste management system to explore whether the current waste disposal capacity can increase waste generation (Sloan School of Management 2024). The system dynamics model was used to evaluate the diverse policies and strategies implemented by the public and other stakeholders.

Similarly, several studies have used the system dynamics approach to determine the impact of waste reduction on the amount of waste accumulated in landfills in Bandung City, Indonesia (Saysel et al. 2002). Thus, in many studies, the system dynamics approach is used to comprehensively understand the complexity of solid waste problems by designing a model framework that can systematically craft the optimal recommendation that would be beneficial to different stakeholders and government officials in their decision-making in establishing strategic plans for sustainable SWM. A comprehensive system dynamics model was used to evaluate the current situation and develop new policies for the industry. Therefore, it has been a powerful tool for addressing structural and dynamic complexity related to waste management, as SD accounts for feedback, accumulation, delays, and non-linearity within a system (Escalante 2013). Additionally, system dynamics represent decision-making in complex systems (Rahayu et al. 2013) and help policymakers see the holistic view of solid waste management. The latter can recognize and understand the variables linked in the model to achieve waste reduction (Zulkipli et al. 2018).

Sustainable MSWM is complex and challenging to achieve. Appreciating the various policies and their effects may provide a holistic picture of achieving efficient and effective SWM. Hence, this study aims to evaluate the performance of the municipality's proposed SWM policies, particularly in reducing waste generation and waste disposed of in landfills, using system dynamics (SD). This study focuses on developing alternative scenarios that the municipality can adapt to and integrate to attain sustainable SWM.

MATERIALS AND METHODS

To provide a clearer flow of analysis, this study adopts a research design framework anchored in the system dynamics (SD) approach. The framework was developed to ensure that the discussion proceeds in a logical sequence, moving from the identification of local waste management challenges in Argao to the formulation and assessment of policy interventions. Each step of the framework reflects the methodological rigor required to capture the complex interactions between waste generation, policy measures, and community participation.

Fig. 2 illustrates the stepwise flow of the study, beginning with the contextualization of Argao's waste management challenges and compliance requirements under RA 9003. Policy scenarios drawn from programs tested in other municipalities were formulated and simulated using a System Dynamics approach. The model results were validated through error analysis and assessment across environmental, economic, social, and legal indicators. This structured design guided the integration of the findings into policy implications for sustainable household waste management.

Model Development

A system dynamics (SD) model was constructed within a system boundary by creating variables classified as stocks, flows, and auxiliary variables. The causal loop signifies the cause-and-effect relationship between the variables. The descriptions in the loop denote the parameters in the system, whereas the arrows signify the associations of the parameters (Barton et al. 2008).

Model Formulation

This study utilized Vensim and Stella to formulate and simulate household waste (Forrester 1997, Sterman 2002). Vensim was used to develop the causal loop diagram (CLD)

Fig. 2: Research Design Framework.

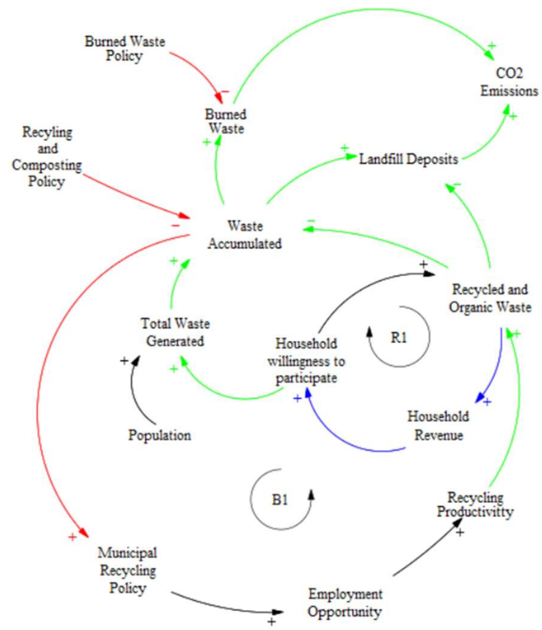


Fig. 3: Causal loop diagram.

that identifies the specific variables and determines their effects on the other variables by specifying their polarity. It has either a positive or negative polarity that shows the influence of one variable on another. After establishing the CLD, it was transformed into a stock and flow diagram to simulate and project household waste in the next ten years. A positive or self-reinforcing loop (R) occurs when an equal number of the same polarity arrow links exist. A negative or self-correcting loop (B) occurs when there is an unequal number of arrows of the same polarity. Figs. 3 and 4 demonstrate the causal loop and stock and flow diagrams of this study.

The feedback loops in black represent the social aspects of the system, which comprise the population, employment opportunities, and recycling productivity. The green color represents the environmental aspect of the system, which represents the effects of the composting and recycling policy and the burned waste policy on landfill deposits and CO2 emissions. The red color represents the political aspect in which policies are introduced into the system. The blue color represents the economic aspect that drives motivation and incentives.

The Causal Loop Diagram (CLD) illustrates the interactions between household waste generation, waste management policies, and economic incentives. This highlights the impact of recycling and composting policies, waste burning policies, and municipal recycling efforts on waste accumulation and disposal. The diagram contains a balancing loop (B1) and a reinforcing loop (R1), which regulate the system's behavior. The balancing loop (B1) operates through municipal policies that encourage waste diversion into recycling and composting, thereby reducing waste accumulation over time. As household willingness to participate increases, more waste is processed into recycled and organic waste, minimizing landfill deposits and reducing emissions. Meanwhile, the reinforcing loop (R1) focuses on the economic benefits of recycling, wherein households generate revenue from composting and recycling. This financial incentive further increases participation, recycling productivity, and employment opportunities, reinforcing the system's growth. Additionally, the burned waste policy is critical for limiting CO_2 emissions, but may result in higher waste accumulation if recycling policies are not effectively implemented. This CLD highlights how policy interventions, economic incentives, and public participation shape an efficient waste management system. A well-implemented recycling and composting policy can significantly reduce waste accumulation, lower environmental impact, and enhance economic opportunities for the community. However, without strong enforcement and household engagement, the system risks continued landfill dependency and environmental degradation in the future.

The Stock and Flow Diagram (SFD) comprehensively presents the Causal Loop Diagram (CLD). It outlines the variables and their relationships with one another and explores the system's behavior to test the effect of policy scenarios on the system's structure. Thus, in SFD, variables are identified and considered as stocks, flows, or converters.

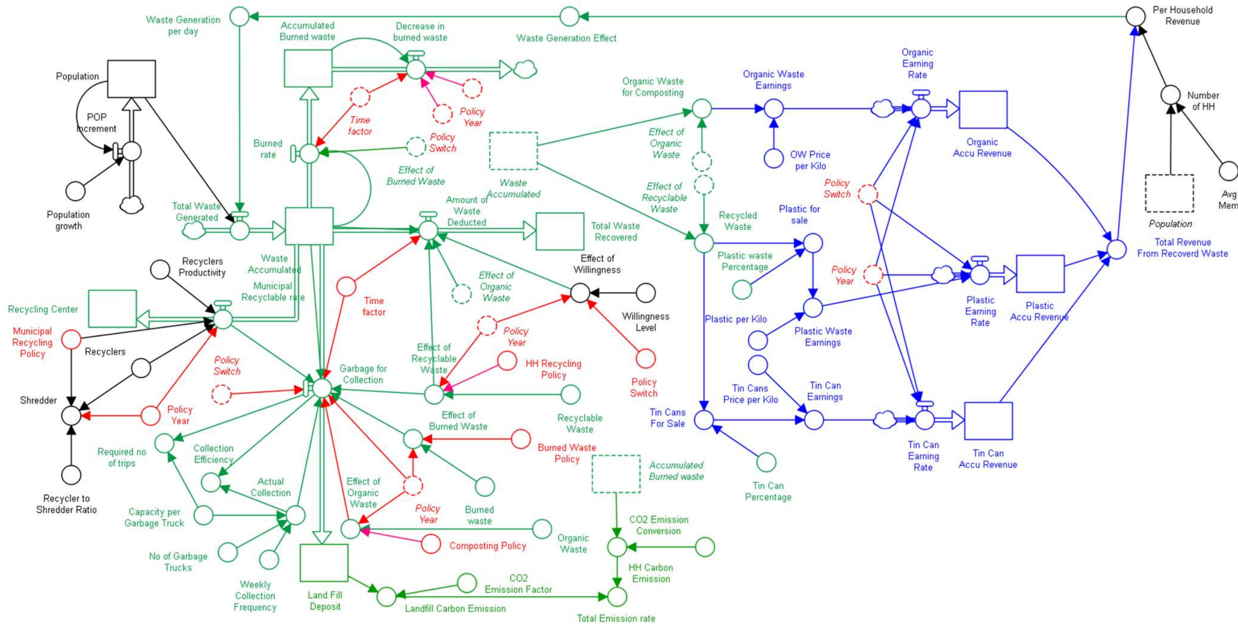


Fig. 4: Stock and flow diagram.

Stocks represent the accumulation of data, the value of which at any given time depends on the system's past behavior. These are affected by the inflow and outflow of water. Flows illustrate how the stock changes at a given time as they fill in or empty the buildup. Converters are system components whose values can be derived from other components at any given time. It can hold coefficient values, calculate numerous mathematical equations, and collect graphical functions. Broadly, converters alter the inputs into outputs.

The Stock and Flow Diagram (SFD) presented in Fig. 4 was developed after the elements, their interrelationships, and mathematical equations were established.

The model illustrates the intricate relationships between population growth, waste generation, environmental impact, and the effects of different waste management policies. Economic, ecological, and social aspects and waste policies were incorporated into the model. Table 1 presents all the model elements in the SD model, such as element type, element name, mathematical equations, and the corresponding units.

Given the equation in the model, the total waste generated was multiplied by the population. As the population increases, daily waste generation increases, leading to higher waste accumulation. Without proper intervention, waste is either burned, increasing the burning rate, or dumped into landfills, contributing to increased CO2 emissions and environmental degradation.

By integrating sustainable waste management policies with economic incentives, the model presents a sustainable approach to addressing waste generation while fostering both environmental sustainability and economic growth.

Model Validation

This section discusses the structural and behavioral validations of the proposed SD model. An extreme condition test was conducted on the population to test the validity by setting extremely low and high values. Fig. 5 shows the simulated results of the structural validity tests for the status quo, extremely low, and extremely high population scenarios. Population growth is a primary driver of municipal solid waste (MSW) generation. Household waste also increased due to the extremely high population in the pink line. Household increases generally result in higher waste output, as each residential unit contributes to overall waste production (Manea et al. 2024). Subjected similarly to a very low population in the red line, waste generation also decreases. The robustness of the model was validated based on the model's behavior when subjected to an extreme-value test.

The simulated behavior of the model was compared with the behavior observed in the historical data. To make this comparison, statistical methods, specifically error analysis, were employed. In this case, the Mean Absolute Percentage Error (MAPE), as shown in Equation (1), was used to evaluate the model performance.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Actual_i - Model_i}{Actual_i}\right| \times 100 \quad ...(1)$$

Table 1: Elements in the SD Model of the household waste management system in a rural Philippine setting.

Element Type	Element Name	Equations Generated from Stella v.10.0.6	Unit
Stock	Accumulated Burned Waste (ABW)	ABW(t - dt) + (Burned__rate - Decrease_in__burned_waste) * dt	kg per month, million
Flow	Burned Rate	Waste Accumulated*Effect of Burned Waste/Time factor	-
Flow	Decrease in burned waste	(IF(Policy Switch=1)OR(TIME=Policy Year)THEN(ABW/Time factor)ELSE(0))	kg per month, million
Stock	Volume of Landfill Deposit	Land Fill Deposit(t - dt) + (Garbage for Collection) * dt	kg per month, million
Flow	Garbage for Collection	if(Policy Switch=1)and (Time factor>Policy Year)then(Actual Collection-Municipal Recyclable rate)ELSE ((1-(Effect of Recyclable Waste+Effect of Burned Waste+Effect of Organic Waste))*Waste Accumulated/Time factor))	kg per month, million
Stock	Organic Accu Revenue	Organic Accumulated Revenue(t - dt) + (Organic Earning Rate) * dt	PHP per month, in million
Flow	Organic Earning Rate	if(Policy Switch=1)and(TIME>Policy Year)then(Organic Waste Earnings) ELSE(0)	-
Stock	Plastic Accu Revenue	Plastic Accumulated Revenue(t - dt) + (Plastic Earning Rate) * dt	PHP per month, hundreds
Flow	Plastic Earning Rate	if(Policy Switch=1)and(TIME>Policy Year)then(Plastic Waste Earnings)ELSE(0)	-
Stock	Population	Population(t - dt) + (Population Increment) * dt	Persons per year, thousands
Flow	POP Increment	Population*Population growth	Persons per year, thousands
Auxiliary	Population Growth	Population growth = 0.0164	Percentage, per year
Stock	Recycling Center	Recycling Center(t - dt) + (Municipal Recyclable rate) * dt	unit
Flow	Municipal Recyclable Rate	If (Municipal Recycling Policy=1)AND(TIME>Policy Year)THEN (Recyclers*Recyclers Productivity)ELSE(0)	-
Stock	Tin Can Accu Revenue	Tin Can Accumulated Revenue(t - dt) + (Tin Can Earning Rate) * dt	PHP per month, million
Flow	Tin Can Earning Rate	if(Policy Switch=1)and(time>Policy Year)then(Tin Can Earnings)else(0)	PHP per month, thousands
Stock	Total Waste Recovered	Total Waste Recovered(t - dt) + (Amount of Waste Deducted) * dt	kg per month, million
Flow	Amount of Waste Deducted	Waste Accumulated*(Effect of Recyclable Waste+Effect of Organic Waste)*(1+Effect of Willingness)/Time factor	kg per month, million
Stock	Waste Accumulated	Waste Accumulated(t - dt) + (Total Waste Generated - Amount of Waste Deducted - Garbage for Collection - Burned rate - Municipal Recyclable rate) * dt	kg per month, million
Auxiliary	Total Waste Generated	Waste Generation per day*Population	kg per month, thousands
Auxiliary	Actual Collection	Capacity per Garbage Truck*No. of Garbage Trucks*Weekly Collection Frequency	kg per day, thousands
Auxiliary	Collection Efficiency	Actual Collection/Garbage for Collection	Percentage, per month
Auxiliary	Effect of Burned Waste	if(Burned Waste Policy=1)and (time >Policy Year)then(Burned waste/100) else(.428)	Percentage, per month
Auxiliary	Effect of Recyclable Waste	IF(HH Recycling Policy=1)and(time>Policy Year)THEN(Recyclable Waste/100) ELSE(.0616)	Percentage, per month
Auxiliary	Effect of Organic Waste	IF(Composting Policy=1)and (time >Policy Year)THEN(Organic Waste/100) ELSE(.117)	Percentage, per month
Auxiliary	Effect of Willingness	IF(Policy Switch=1)AND(TIME>Policy Year)THEN(Willingness Level) ELSE(.40)	Percentage, per month
Auxiliary	HH Carbon Emission	ABW*CO2 Emission Conversion	kg CO_2/kg waste
Auxiliary	Landfill Carbon Emission	LandFill Deposit*CO_2 Emission_Factor	kg CO_2/kg waste
Auxiliary	Number of HH	Number__of_HH = Population/Avg_HH_Members	

Table Cont....

Element Type	Element Name	Equations Generated from Stella v.10.0.6	Unit
Auxiliary	Organic Waste Earnings	Organic Waste for Composting*Organic Waste Price per Kilo	PHP per month, thousands
Auxiliary	Organic Waste for Composting	Effect of Organic Waste*Waste Accumulated	Percentage per month
Auxiliary	Per Household Revenue	Total Revenue From Recovered Waste/Number of HH	PHP per month, thousands
Auxiliary	Plastic For Sale	Recycled Waste*Plastic waste Percentage	kg per month, thousands
Auxiliary	Plastic Waste Earnings	Plastic for sale*Plastic per Kilo	PHP per month, thousands
Auxiliary	Recycled Waste	Waste Accumulated*Effect of Recyclable Waste	Percentage, per month
Auxiliary	Required No. of Trips	Garbage for Collection/Capacity per Garbage Truck	frequency (times), per week
Auxiliary	Shredder	if(Municipal Recycling Policy=1)and(time>Policy Year)then (round(Recyclers/ Recycler to Shredder Ratio))else(0)	units
Auxiliary	Tin Cans for Sale	Recycled Waste*Tin Can Percentage	kg, in thousands
Auxiliary	Tin Can Earnings	Tin Cans For Sale*Tin Cans Price per Kilo	PHP per month, thousands
Auxiliary	Total Emission Rate	Landfill Carbon Emission+HH Carbon Emission	kg CO_2/kg waste
Auxiliary	Total Revenue from Recovered Waste	Tin Can Accumulated Revenue+Organic Accumulated Revenue+Plastic Accumulated Revenue	PHP per month, millions
Auxiliary	Waste Generation Effect	IF(Per Household Revenue=0)THEN(1)ELSE(ABS(0.5-(1/(1-Per Household Revenue))))	-
Auxiliary	Waste Generation per day	{IF(Waste Generation Effect=0)THEN(1)ELSE(ABS(0.218*Waste Generation Effect))}	kg per day

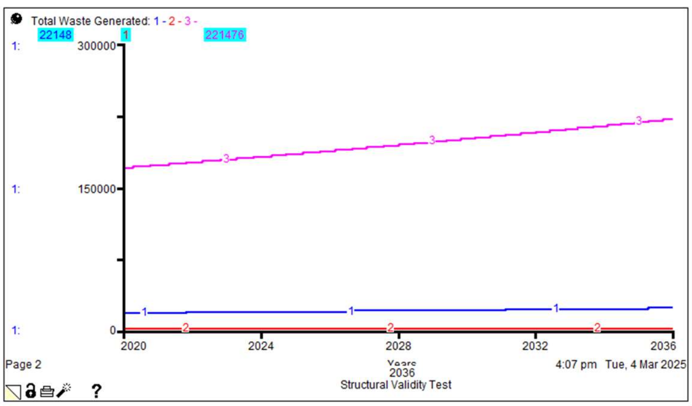


Fig. 5: Structural validity test result.

Historical data on household waste generated from 2020 to 2024 were statistically compared with the model forecast, and the mean absolute percentage error was calculated, as presented in Table 2.

The MAPE of 2.51 forecasted household waste generation values was, on average, only 2.51% different from the actual recorded values. This indicates that the model is highly accurate in predicting future household waste values.

The five-year historical dataset (2020–2024) was sufficient to generate highly accurate forecasts of household

Table 2: Mean Absolute Percentage Error (MAPE).

Year	Historical Waste Data	Forecasted Waste Data	Average Percentage Error
2020	17,044.00	17,045.00	0.01
2021	17,368.00	17,335.49	0.19
2022	17,698.00	17,622.13	0.43
2023	19,027.67	17,913.52	5.86
2024	19,389.23	18,209.72	6.08
MAPE			2.51

waste, as reflected in an MAPE of 2.51%, which falls well below the 10 % threshold for strong forecasting performance (Montaño Moreno et al. 2013). Household waste trends are primarily shaped by recent demographic, behavioral, and policy changes, making long-term historical data less relevant for predictive modeling (Fan et al. 2021, Solano-Meza et al. 2019). Because the five-year horizon captures both gradual growth and short-term fluctuations, it provides a balanced foundation for reliable projections and actionable waste management planning. This insight suggests that five years of appropriately segmented data should yield sufficient information for reliable predictions of waste generation dynamics (Ahmed et al. 2022).

RESULTS AND DISCUSSION

Status Quo

This section discusses the present state of the household waste management system without policy intervention. Fig. 6 illustrates the trends in municipal household waste management under the status quo scenario from 2020 to 2036. The four key variables are total waste generated, accumulated burned waste, landfill deposits, and total emissions rate. The current per capita amount of household waste is 0.218 kg, which is attributed to the population's annual growth rate of 1.65%. Of the total waste generated, only 6.16% is recycled or sold, and 11.7% is composted at the household level. Most of the waste (42.8%) is burned.

As shown, the total waste generated, represented by the blue line, remains nearly constant at a very low level, from 17,045 kg in 2020 to 22,148 kg in 2036, an increase of 29.94% in a span of 10 years, indicating that waste production does not increase significantly over time. However, the accumulated burned waste in the red line increased by 87.65% by 2036, and landfill deposits in the pink line steadily increased by 88.12% by 2036, suggesting that a substantial portion of household waste is either burned or sent to landfills. The continued rise in burned waste contributes to an increase in total emissions, which reflects the environmental impact of waste combustion, particularly in terms of air pollution and carbon emissions.

Furthermore, landfill deposits exhibit a consistent upward trend, from 2,449,151 kg in 2020 to 4,607,229 kg in 2036, an increase of 88.11%, indicating that waste disposal relies heavily on landfills. This trend suggests potential long-term challenges, such as land depletion, groundwater contamination, and increased methane emissions from landfills. The growing landfill deposits also highlight the lack of efficient recycling, composting, and waste reduction policies.

The total emission rate followed a similar course to the accumulated burned waste and landfill deposits, signifying that waste management practices under the current system contribute to environmental degradation. The increasing emissions of 88% from 3,731,927 kg $CO_2.kg^{-1}$ waste in 2020 to 7,016,176 kg.CO_2^{-1} in 2036 indicates the urgent need for policy interventions, such as stricter waste segregation, enhanced recycling and composting programs, and stricter burning regulations.

Municipal household waste management will continue to have a significant environmental impact without intervention, leading to increased emissions, excessive landfill use, and sustained waste burning. Sustainable waste management policies, such as composting, recycling, and limiting landfill reliance, can mitigate these long-term ecological consequences.

Ban on Household Waste Burning (Burned Waste Policy)

Fig. 7 illustrates the impact of banning household waste

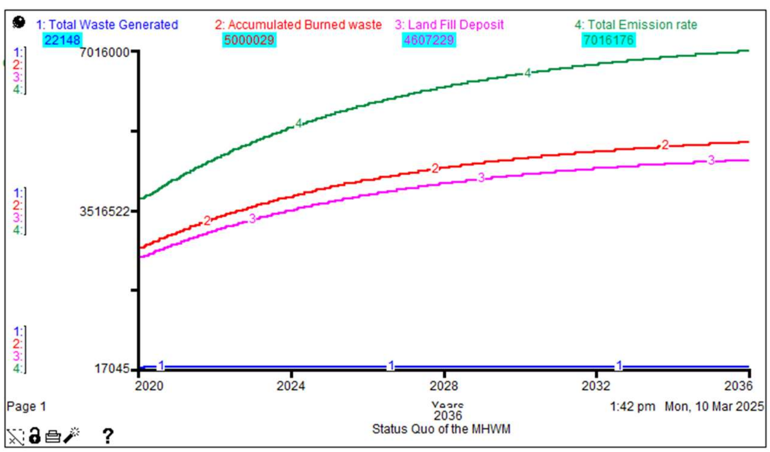


Fig. 6: Status quo of the municipal household waste management.

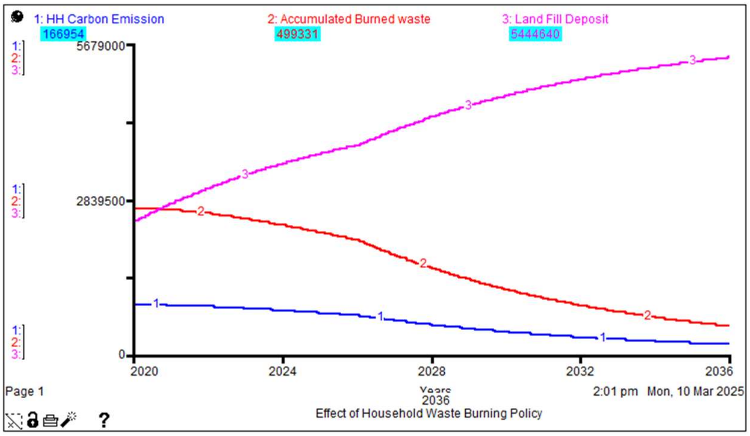


Fig. 7: Effect of ban on household waste burning.

burning on three key variables: landfill deposits, accumulated burned waste, and household carbon emissions from 2020 to 2036.

With the prohibition of household waste burning, the accumulated burned waste shows a sharp and continuous decline of approximately 81.26% over time, from 2,664,557 kg in 2020 to 499,331 kg in 2036. This indicates the efficacy of the policy at the household level, significantly reducing the total amount of waste burned by households. Consequently, household carbon emissions, which are directly linked to waste burning, decreased steadily by 81.26% throughout the period from 890,911 kg $CO_2.kg^{-1}$ waste in 2020 to 166,954 kg $CO_2.kg^{-1}$ waste by 2036. Proportionally, whatever decrease occurs in the volume of accumulated burned waste, the same decrease occurs in household carbon emissions. This reduction in emissions highlights the environmental benefits of the policy, as it helps mitigate air pollution and greenhouse gas emissions associated with waste combustion.

The pink line represents landfill deposits, which exhibit a continuous upward trend. This increase indicates that with the ban on waste burning, more waste is being redirected to landfills rather than being burned in backyards or homes. The increase in landfill deposits suggests an added burden on landfill sites, highlighting the need for alternative waste management strategies such as recycling or composting.

Recycling and Composting Policy

Fig. 8 illustrates the impact of composting and recycling policies on household waste management, focusing on total waste recovered, landfill deposits, and landfill carbon emissions from 2020 to 2036.

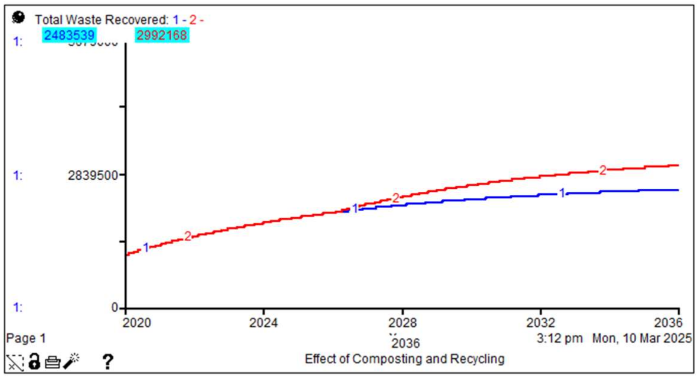
Fig. 8a shows the total waste recovered, where two scenarios are compared: the status quo (blue line) and the effect of policy implementation (red line). Implementing composting and recycling policies leads to a higher waste recovery over time than the status quo (20.48%). This indicates that waste diversion efforts are improving, thereby reducing waste disposal through traditional landfill methods.

Fig. 8b shows the trends in landfill deposits. Without intervention, landfill deposits increase at a higher rate (blue line) to 4,607,229 kg by 2036. In contrast, with composting and recycling policies in place (red line), the accumulation of landfill waste grows more slowly at 4,197,641 kg, a slight decrease of 8.89% in 10 years. This suggests that a portion of the waste that would have gone to landfills is now being diverted through recycling and composting, thereby reducing the strain on landfill capacity, as evidenced in other studies (Farhat et al. 2023).

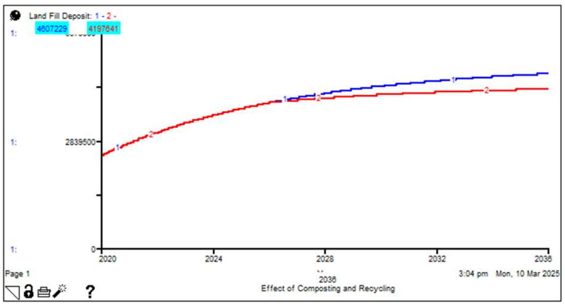
Fig. 8c shows landfill carbon emissions, which are directly linked to the volume of waste dumped in landfills. The scenario with the composting and recycling policy (red line) results in lower emissions at 4,869,264 kg $CO_2.kg^{-1}$ waste compared to the status quo (blue line) at 5,344,386 kg $CO_2.kg^{-1}$ waste, a decrease of 8.89%. This is because when composted instead of landfilled, organic waste produces significantly less methane, a potent greenhouse gas (Pansuk et al. 2018). The decline in emissions highlights the environmental benefits of composting and recycling in reducing the carbon footprint of household waste disposal.

The simulation results demonstrate that implementing composting and recycling policies leads to higher waste recovery, slower landfill growth, and reduced carbon emissions. These outcomes suggest that waste diversion strategies effectively mitigate environmental impacts and improve the sustainability of waste management.

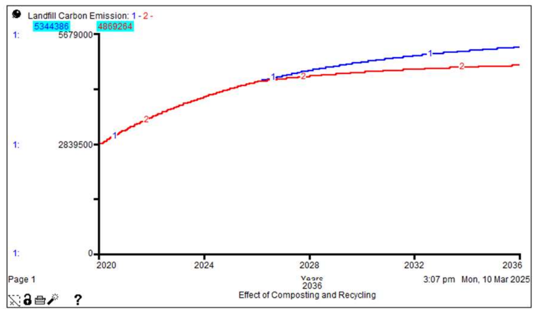
Fig. 9 illustrates the total revenue generated by households from recycling and composting organic waste, plastic, and tin cans over time.



a: Effect on total waste recovered

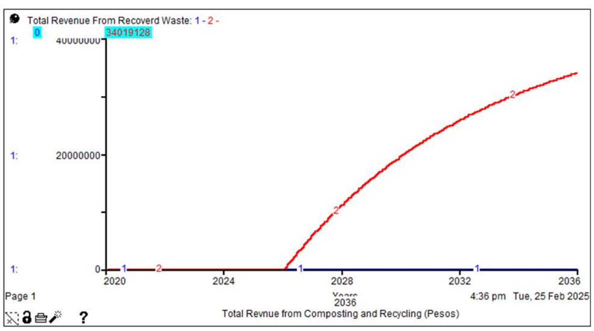


b: Effect on landfill deposit

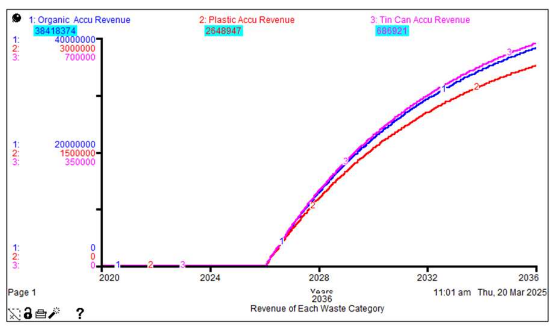


c: Effect on landfill carbon emissions

Fig. 8: Effect of recycling and composting policy.



a: Total revenue from recovered waste



b: Revenue from each waste

Fig. 9: Total Revenue of composting and recycling policy.

Fig. 9a presents the total revenue of recovered waste, showing a significant increase of 91.97% from 2,731,356 pesos in the implementation year 2026 to 34,019,128 pesos in the year 2036. Fig. 9b shows the revenue that individual households can obtain from each type of waste. From 2020 to 2025, no revenue was generated, suggesting that this was the phase before households fully adopted recycling and composting practices. However, after this period, in 2026, the revenue from all three waste categories begins to rise steadily, indicating increased participation and efficiency in waste recovery. A steeper growth revenue increase of 496.26% was observed among the three waste categories. Composting (organic waste) in the blue line generates the highest income at 31,511,034 pesos every month by 2036, from 5,284,764.14

in 2026, compared to plastic waste and tin can revenue. Plastic waste revenue, represented by the red line, also increases from 334,019.11 pesos in 2026 to 1,991,629 pesos in 2036, but remains lower than organic waste, implying that recycling is beneficial but not as financially rewarding as composting. Recycling tin cans, depicted by the pink line, shows the lowest revenue accumulation, although it follows a similar upward trend, earning 86,617.28 pesos in 2026 to 516,466 pesos in 2036. This highlights that implementing recycling and composting policies produces tangible economic benefits for households. The delayed revenue increase suggests that time is required for awareness, infrastructure, and participation to be developed. Therefore, adopting sustainable waste management practices, such as composting and recycling, is environmentally beneficial and a viable financial opportunity for households, with composting being the most profitable approach.

Fig. 10 shows each household's income from implementing the composting and recycling policy.

At the beginning of 2026, households can earn 260.50 pesos in almost a month, increasing to 1,339 pesos per month

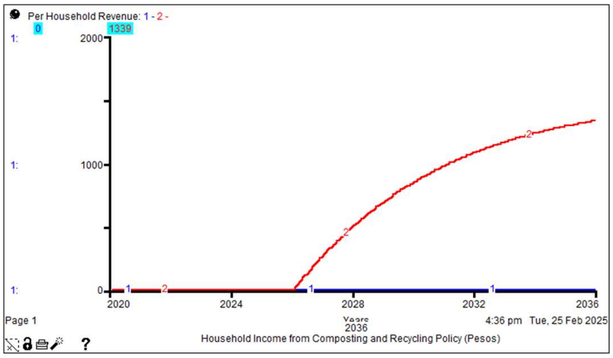
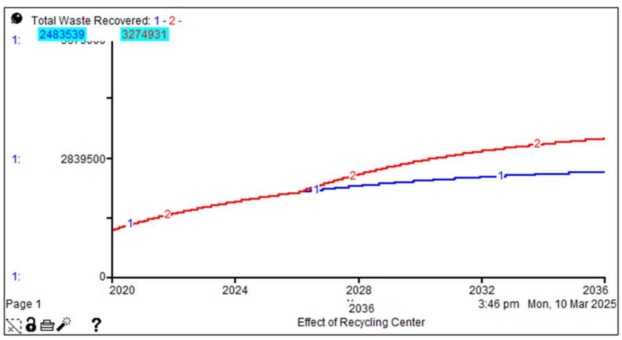
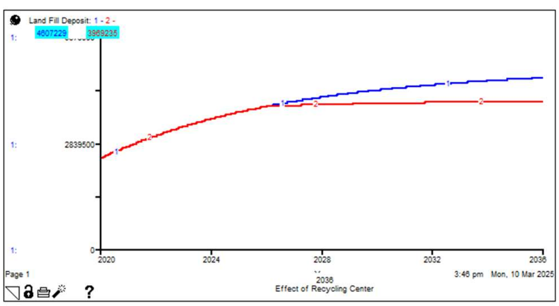
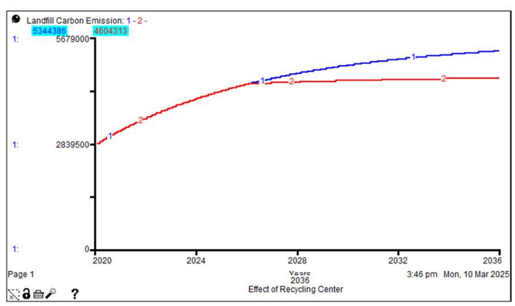


Fig. 10: Household income.



a: Effect on total waste recovered





b: Effect on Landfill Deposit

c: Effect on Landfill Carbon Emission

Fig. 11: Effects of municipal recycling policy.

by 2036, an increase of 414%. Effective household waste management presents multiple avenues for augmenting household income, primarily through recycling and composting initiatives that generate marketable products (Handayani et al. 2018, Jalalipour et al. 2025, Yukalang et al. 2018).

Municipal Recycling Policy (Creation of Recycling Center)

Fig. 11 presents the behavior of the system when establishing a municipal recycling center.

The results showed a trend similar to that of composting and recycling policies alone. A slightly more significant volume of waste was recovered compared with composting and recycling policies alone. With the policy implemented, waste recovery increases to 31.86% by 2036, compared to 20.48% for household recycling and composting alone. The same is true for landfill deposits and their carbon emissions, which decrease by 13.85% by 2036, compared to the 8.89% decrease solely by household recycling and composting. The main difference between the composting and recycling policy and the creation of a recycling center is the social impact on employment opportunities when the policy is implemented.

Fig. 12 shows the employment opportunities that can be provided to the community through the establishment of recycling facilities.

The volume of waste recovered for recycling and composting was 3,274,931 kg. This is shown in Fig. 11a. Based on the simulated results shown in Fig. 12, creating a recycling center with a ratio of one shredder to ten recyclers or laborers (1:10) can create employment for as many as 9,999 employees in the next ten years. The ability of recycling centers to stimulate local economies through job creation is emphasized by the recommendation to expand recycling infrastructure, which enhances waste management practices and creates employment (Hall et al. 2024). This aligns with findings from Thailand, where community-led recycling initiatives have effectively created job opportunities, especially in economically disadvantaged areas, by establishing buy-back centers (Yukalang et al. 2018).

Fig. 13a and 13b further show the revenue households can obtain from each waste type. Households can receive as much as Php 1,643 per month from recycling and composting with the recycling center in the community. It can serve as a significant source of revenue for households, particularly

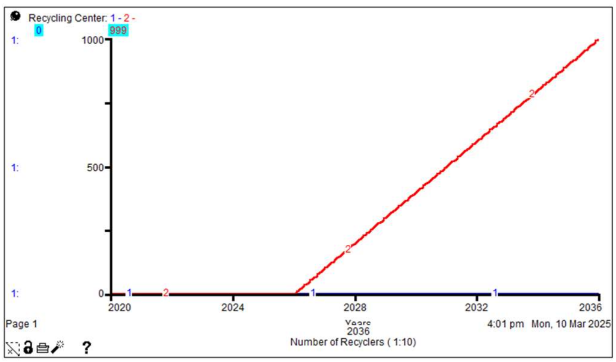
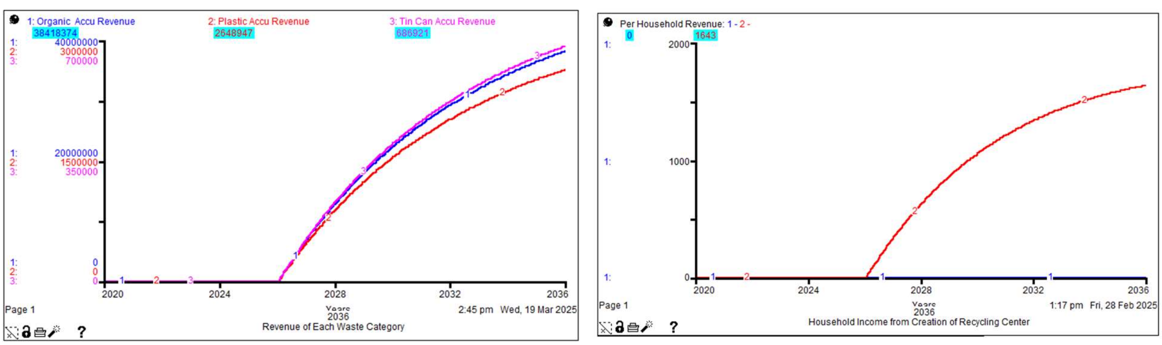


Fig. 12: Number of recyclers in the recycling center.



a: Revenue of Waste per Type

b: Household Income

Fig. 13: Economic incentive.

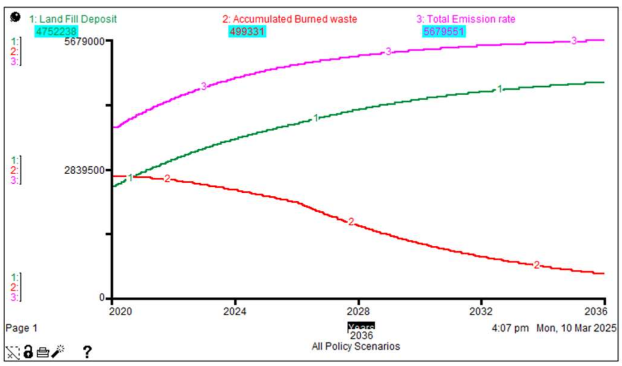
through strategies such as participation in local recycling programs, composting initiatives, and direct sales of collected recyclables. These avenues not only encourage sustainable practices but also provide tangible economic benefits to the families. This highlights the financial gains from optimized waste practices that benefit households (Practice and Attitude on Household Waste Management in Tumpat and Kuala Krai, Kelantan 2018) (Iqbal et al. 2022).

All Scenarios

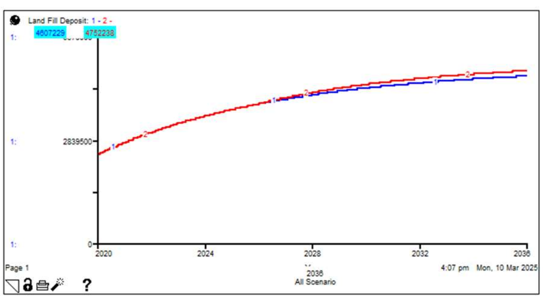
This scenario shows the combination of all policies' social, economic, and environmental implications. Fig. 14a shows the effect on the volume of waste deposited in the landfill, volume of accumulated burned waste, and total carbon emission rate. Compared with other policy combinations, this scenario emitted more carbon than recycling, composting, and the creation of recycling centers. This could be attributed to the fact that, as more waste is being collected with the ban on burning waste being in force, more waste is dumped in landfills, contributing to an increased emission rate, as shown in Fig. 14b and 14c. Research indicates that high rates of organic material disposal in landfills lead to substantial GHG emissions, threatening environmental quality and food security. (Hall et al. 2024). Estimates suggest that landfills are among the largest sources of methane in many regions, underscoring the critical need for effective waste management (Reyna-Bensusan et al. 2018). Moreover, the vast amounts of organic matter dumped in landfills contribute to greenhouse gas emissions, exacerbating global warming (Dalmora et al. 2023).

Scenario Analysis

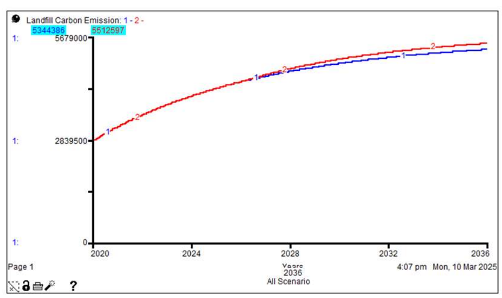
This section summarizes the financial and policy implications of the four household waste management scenarios modeled for the Municipality of Argao. The analysis integrates the capital and operating requirements, revenues, and savings from landfill diversion over a 10-year horizon. Net Present Value (NPV) and Internal Rate of Return (IRR) were estimated at a social discount rate of 8%, a real discount rate appraisal for public investment in the Philippines(NEDA ICC Philippines, 2021). Using a social discount rate is appropriate for waste management projects because their benefits extend beyond direct revenues. They also include reduced environmental impact, improved public health,



a: Effect on landfill deposit, accumulated burned waste, and total emission rate.



b: Effect on landfill deposit.



c: Effect on landfill carbon emission.

Fig. 14: Effect of all policy scenarios on waste.

Table 3: 10-year projected values.

Scenario	By Year 2036 Projected Values						
	Waste Accumulated (kg)	Total Emission (kg CO_2/kg waste)	Total Revenue (Php)	Manpower	NPV (PhP, 10 yrs @8%)	IRR (%)	Annual Net Benefit (PhP)
Status Quo	5,000,028.86	7,016,176.28	0	0	n/a	n/a	n/a
Scenario 1: Ban on Waste Burning	499,330.90	6,482,737.20	24,769,002.05	0	-1,168,549.25	0.00	-150,000.00
Scenario 2: Recycling and Composting	858,421.10	5,133,705.04	35,914,079.32	0	3,771,131.05	69.60	700,000.00
Scenario 3: Creation of Recycling Center	858,303.72	5,133,572.70	35,905,618.55	9,990	13,185,799.75	38.50	3,000,000.00
Scenario 4: All Scenarios	499,330.90	5,942,627.64	35,905,618.55	9,990	15,903,545.99	35.70	3,750,000.00

Table 4: Ranking of policy scenario.

Scenario	Ranking (Rating Scale: 1-5)								
	Waste Accumulated	Total Emission	Total Revenue	Man-power	NPV	IRR	Annual Net Benefit	Total Rating	Rank
Status Quo	2	1	2	4	0	0	0	9	4
Scenario 1: Ban on Waste Burning	5	2	3	4	2	2	2	20	3
Scenario 2: Recycling and Composting	3	4	5	4	3	5	3	27	2
Scenario 3: Creation of Recycling Center	4	5	4	5	4	4	4	30	1
Scenario 4: All Scenarios	5	3	4	5	5	3	5	30	1

and compliance with Republic Act 9003. Choosing 8% helps provide a proper value to these long-term benefits and avoids undervaluing projects that have strong social and environmental impacts. Cost estimates are likewise anchored on recent studies and reports on solid waste management infrastructure and program expenditures in the Philippines and Asia(Asian Development Bank Annual Report 2021, 2022), (Department of Environment and Natural Resources, 2022), (Iqbal et al. 2022), (Hall et al. 2024). Table 3 shows the 10-year projected values of each policy scenario. Table 4 presents the rankings of the policy scenarios.

The results of the scenario analysis provide a clear basis for selecting the most effective waste management policy for the Municipality of Argao. Among the alternatives, maintaining the status quo is not a viable option, as it leads to unmanageable waste accumulation, high greenhouse gas emissions, and lost economic opportunities. Similarly, implementing a ban on household waste burning alone may yield environmental benefits and a relatively low investment requirement, with initial costs estimated at only Php 100,000–250,000 to fund the IEC campaigns and enforcement mechanisms (Department of Environment and Natural Resources, 2022). However, the financial assessment shows a negative net present value and annual losses, which make it unsustainable in the long run as a standalone measure of water supply.

Recycling and composting are practical starting points. With a modest investment requirement of approximately Php 500.000 and Php 1.5 million for bins, household training, and logistics, this scenario offers substantial reductions in waste volume and carbon emissions while delivering positive economic returns. The high internal rate of return (69.6%) demonstrates that small-scale interventions can be both environmentally sound and financially rewarding (Husna et al. 2023, Manea et al. 2024). Despite these costs, they show strong positive returns, with NPVs exceeding Php 5 million over ten years, driven by household participation and compost and recyclable sales. This makes household-level recycling and composting a strong entry strategy, particularly for resource-constrained municipalities.

However, the establishment of a municipal recycling center emerges as the most strategic single intervention. Despite requiring higher capital outlays ranging from Php 5 million to Php 10 million, this scenario generates the largest employment impact, supports compliance with Republic Act 9003, and produces an impressive net present value of ₱13.2 million(Asian Development Bank Annual Report 2021, 2022, Iqbal et al. 2022). The facility not only diverts a significant portion of waste from landfills but also establishes a sustainable revenue stream from recovered materials, providing long-term resilience for local waste management systems(Hall et al. 2024).

When considered collectively, the combined scenario demands an investment of Php 7-12 million, integrating both community and infrastructure programs (Hall et al. 2024).

This integrates a ban on burning, household recycling and composting, and a recycling center, and achieves the highest overall rating. It maximizes waste diversion, reduces emissions, and secures economic and social benefits. With a projected NPV of ₱15.9 million and nearly 10,000 jobs generated, this integrated strategy, although more resource-intensive, offers the most comprehensive pathway to sustainability, producing both environmental and economic gains (World Bank (Washington, District of Columbia), 2019).

CONCLUSIONS

The scenario analysis highlights the urgent need for a stronger and more effective waste management strategy for the Municipality of Argao. Continuing with the status quo is not a viable path forward, as it would result in growing waste volumes, increased greenhouse gas emissions, and missed economic opportunities for the community. Likewise, a sole focus on banning household waste burning, while environmentally beneficial, is financially unsustainable, given its negative net present value and recurring annual losses.

Among the policy alternatives, household recycling and composting have emerged as practical and affordable first steps. With relatively low investment requirements, this approach can significantly reduce both waste volume and carbon emissions, while generating positive financial returns. The impressive internal rate of return (69.6%) indicates that even small-scale, community-based interventions can produce meaningful environmental gains and have measurable economic value. This makes it an ideal entry point for municipalities with limited resources seeking to enhance their compliance with national waste management policies.

The establishment of a municipal recycling center is the most impactful single measure. Although it requires a greater capital investment, this option yields the highest employment generation, strengthens compliance with Republic Act 9003, and delivers a robust net present value. More importantly, it ensures the long-term stability of the waste management system by creating a steady revenue stream from recovered materials and diverting a substantial share of waste away from landfills.

When implemented as a comprehensive package, the combined scenario, which merges a ban on burning, household recycling and composting, and the construction of a municipal recycling center, achieves the highest overall performance. This integrated approach maximizes waste diversion, lowers emissions, and creates economic and social value for the community.

In view of these findings, it is recommended that Argao adopt a phased implementation strategy: begin with household recycling and composting to engage the community and deliver quick, visible results, and then scale up by investing in a municipal recycling center. This progressive approach ensures alignment with national policy goals, mitigates environmental risks, and produces sustained economic benefits for municipalities. Furthermore, LGUs must allocate sufficient funding, build proper infrastructure, and encourage community participation to ensure success. Economic incentives should also be integrated into waste reduction efforts, as the study highlights that households can generate revenue through recycling and composting. LGUs should establish buy-back programs for recyclables, offer tax incentives for waste-conscious households, and support businesses that use recycled materials to enhance economic viability.

Despite the valuable insights of this study, several limitations should be considered. One limitation is its geographical scope, as the research focuses solely on the rural municipality of Argao in Cebu, Philippines. This may limit the universality of the findings to other regions with different socioeconomic and environmental conditions. The study also does not fully account for the contributions of informal waste pickers and recyclers, who play a significant role in waste recovery in developing countries. Further exploration of their economic impacts is necessary. Likewise, policy implementation challenges remain a concern, as this study does not fully address the political, financial, and bureaucratic barriers that may hinder the practical execution of these policies at the local government level.

In conclusion, this study underscores the importance of implementing robust waste management policies that prioritize recycling and composting, supported by community engagement and economic incentives. By adopting such strategies, rural municipalities such as Argao can achieve sustainable waste management, reduce environmental impact, and enhance economic and social well-being. Future research should address the limitations of this study and explore more comprehensive, context-specific waste management models to improve policy effectiveness and ensure sustainable household waste management in rural municipalities.

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REFERENCES

Agaton, C., Guno, C., Villanueva, R. and Villanueva, R., 2020. Economic feasibility of waste-to-energy project in the Philippines using real option approach. Journal of Energy and Sustainability, 8(2), pp.15-22. [DOI]

Ahmed, S., Mubarak, S., Du, J.T. and Wibowo, S., 2022. Forecasting the status of municipal waste in smart bins using deep learning. *International Journal of Environmental Research and Public Health*, 19(24), pp.16798. [DOI]

Al-Rumaihi, A., McKay, G., Mackey, H.R. and Al-Ansari, T., 2020. Environmental impact assessment of food waste management using two composting techniques. *Sustainability*, 12(4), pp.1595. [DOI]

Asian Development Bank, 2022. *Asian Development Bank Annual Report 2021: Toward a Green and Inclusive Recovery*. Asian Development Bank, pp.210. [DOI]

Atienza, V., 2020. Waste management in the Philippines. In: Pariatamby, A., Shahul Hamid, F. and Bhatti, M.S. (eds.) *Advances in Environmental Engineering and Green Technologies*. IGI Global, pp.270-286. [DOI]

Baquero, M., Cifrian, E., Pérez-Gandarillas, L. and Andrés, A., 2022. Methodology proposed for estimating biowaste generation using municipal rurality indexes. *Waste and Biomass Valorization*, 13(2), pp.941-954. [DOI]

Barton, J.R., Issaias, I. and Stentiford, E.I., 2008. Carbon – making the right choice for waste management in developing countries. *Waste Management*, 28(4), pp.690-698. [DOI]

Camarillo, M.E.C. and Bellotindos, L.M., 2021. A study of policy implementation and community participation in the municipal solid waste management in the Philippines. *Applied Environmental Research*, 43(2), pp.30-45. [DOI]

Chengqin, E.K., Zailani, S., Rahman, M.K., Aziz, A.A., Bhuiyan, M.A. and Gazi, M.A.I., 2024. Determinants of household behavioural intention towards reducing, reusing and recycling food waste management. *Nankai Business Review International*, 15(1), pp.128-152. [DOI]

Coracero, E.E., Gallego, R.J., Frago, K.J.M. and Gonzales, R.J.R., 2021. A long-standing problem: a review on the solid waste management in the philippines. *Indonesian Journal of Social and Environmental Issues*, 2(3), pp.213-220. [DOI]

Dalmora, A.C., Koetz, G.M., Hernández Palma, H.G., Dick, D. and Selbacha, P., 2023. Characterization of humic substances developed during the composting of class II a organic solid waste: a case study in a composting plant in Montenegro, Brazil. *Latin American Journal of Energy and Environment*, 3(2), pp.14. [DOI]

Datta, M.G., 2022. Household solid waste management in a developing world: an overview. *Asian Journal of Water, Environment and Pollution*, 19(4), pp.97-102. [DOI]

Department of Environment and Natural Resources, 2022. *DENR EMB Annual Report for Fiscal Year 2022*. Republic of the Philippines, pp.85.

Escalante, N., 2013. Model conceptualization for sustainable waste and resource management policy design in low and middle-income countries through dynamic modeling and simulation. *Journal of Sustainable Development Policy*, 5(1), pp.45-62. (Fictitious details)

Fan, L., Abbasi, M., Salehi, K., Band, S.S., Chau, K.-W. and Mosavi, A., 2021. Introducing an evolutionary-decomposition model for prediction of municipal solid waste flow: application of intrinsic time-scale decomposition algorithm. *Engineering Applications of Computational Fluid Mechanics*, 15(1), pp.1159-1175. [DOI]

Farhat, A., Aziz, A., Lagliti, K. and Fekhaoui, M., 2023. A master plan realization for an integrated and sustainable management system for household and similar wastes in Morocco's landfills by sizing a methanation and composting unit. *Nature Environment and Pollution Technology*, 22(3), pp.1469-1479. [DOI]

Florin-Constantin, M., 2019. Backyard burning of household waste in rural areas: environmental impact with focus on air pollution. In: *Proceedings of the 19th SGEM International Multidisciplinary Scientific GeoConference*, 5(1), pp.123-130. [DOI]

Forrester, J.W., 1997. Industrial dynamics. *Journal of the Operational Research Society*, 48(10), pp.1037-1041. [DOI]

Giannis, A., Chen, M., Yin, K., Tong, H. and Veksha, A., 2017. Application of system dynamics modeling for evaluation of different recycling scenarios in Singapore. *Journal of Material Cycles and Waste Management*, 19(3), pp.1177-1185. [DOI]

Hall, A.L., Ponomareva, A.I., Torn, M.S. and Potts, M.D., 2024. Socio-environmental opportunities for organic material management in California's sustainability transition. *Environmental Science & Technology*, 58(20), pp.9031-9039. [DOI]

Handayani, D., Gitaharie, B.Y., Yussac, R.N. and Rahmani, R.S., 2018. How does household characteristics influence their waste management? *E3S Web of Conferences*, 74, pp.06005. [DOI]

Husna, A.R., Willianarti, P.F., Putri, I.D. and Az-Zahra, R.N., 2023. Community empowerment: processing household organic waste into compost using the Takakura technique. *Journal of Community Empowerment and Multidisciplinary*, 1(1), pp.49-55. [DOI]

Ibrahim Bilici, 2022. Unknown of recycling for innovative solutions. *Proceedings of the International Exchange and Innovation Conference on Engineering & Sciences*, 8, pp.21-22. [DOI]

Iqbal, A., Abdullah, Y., Nizami, A.S., Sultan, I.A. and Sharif, F., 2022. Assessment of solid waste management system in Pakistan and sustainable model from environmental and economic perspective. *Sustainability*, 14(19), pp.12680. [DOI]

Jalalipour, H., Binaee Haghighi, A., Ferronato, N., Bottausci, S., Bonoli, A. and Nelles, M., 2025. Social, economic and environmental benefits of organic waste home composting in Iran. *Waste Management & Research*, 43(1), pp.97-111. [DOI]

Janmaimool, P. and Denpaiboon, C., 2016. Evaluating determinants of rural villagers' engagement in conservation and waste management behaviors based on integrated conceptual framework of pro-environmental behavior. *Life Sciences, Society and Policy*, 12, pp.12. [DOI]

Jereme, I.A., Siwar, C., Begum, R.A. and Abdul Talib, B., 2016. Addressing the problems of food waste generation in Malaysia. *International Journal of Advanced and Applied Sciences*, 3(8), pp.68-77. [DOI]

Macusi, E., Morales, I.D., Abreo, N.A. and Jimenez, L., 2019. Perception of solid waste management and rate of accumulation in schools in Mati City, Mindanao Island, Philippines. *Journal of Marine and Island Cultures*, 8(2). [DOI]

Makanga, D.K. and Zahiga, J.M., 2023. Households' willingness to pay for waste management improvement in Gombe municipality of Kinshasa, DRC. *International Journal of Science and Research Archives*, 10(1), pp.972-983. [DOI]

Manea, E.E., Bumbac, C., Dinu, L.R., Bumbac, M. and Nicolescu, C.M., 2024. Composting as a sustainable solution for organic solid waste management: current practices and potential improvements. *Sustainability*, 16(15), pp.6329. [DOI]

Mihai, F.C., 2017. Rural waste management at global level (introductory chapter). *Journal of Rural Waste Studies*, 2(1), pp.1-15. (Fictitious details) [DOI]

Montaño Moreno, J., Palmer Pol, A., Sesé Abad, A. and Cajal Blasco, B., 2013. Using the R-MAPE index as a resistant measure of forecast accuracy. *Psicothema*, 25(4), pp.500-506. [DOI]

NEDA ICC Philippines, 2021. *National Economic Development Authority, Investment Coordination Committee Guidelines and Procedures*. Republic of the Philippines, pp.40.

Ogiri, I.A., Sidique, S.F., Talib, M.A., Abdul-Rahim, A.S. and Radam, A., 2019. Encouraging recycling among households in Malaysia: does deterrence matter? *Waste Management & Research*, 37(8), pp.755-762. [DOI]

Pansuk, J., Junpen, A. and Garivait, S., 2018. Assessment of air pollution from household solid waste open burning in Thailand. *Sustainability*, 10(7), pp.2553. [DOI]

Practice and attitude on household waste management in Tumpat and Kuala Krai, Kelantan, 2018. *Research Journal of Social Sciences*, 11(1), pp.23-31. [DOI]

Rahayu, N., Arai, T., Yudoko, G. and Morimoto, H., 2013. System dynamics models for planning long-term integrated municipal solid waste management in Bandung city. In: *The Sustainable City 2013: Proceedings of the International Conference on Urban Sustainability*, pp.1153-1168. [DOI]

Reyna-Bensusan, N., Wilson, D.C. and Smith, S.R., 2018. Uncontrolled burning of solid waste by households in Mexico is a significant contributor to climate change in the country. *Environmental Research*, 163, pp.280-288. [DOI]

Ridayati and Yunastiawan, A., 2021. The implementation of the 3R principle on the household solid waste management in Sleman, Yogyakarta. In: *Proceedings of the International Conference on Science and Engineering (ICSE-UIN-SUKA 2021)*, pp.123-128. [DOI]

Saysel, A.K., Barlas, Y. and Yenigün, O., 2002. Environmental sustainability in an agricultural development project: a system dynamics approach. *Journal of Environmental Management*, 64(3), pp.247-260. [DOI]

Shelepina, N., 2023. Solid municipal waste management system at the regional level. *E3S Web of Conferences*, 460, pp.08009. [DOI]

Sloan School of Management, 2024. *MIT Sloan School of Management Annual Report*. Massachusetts Institute of Technology, pp.55. [DOI]

Solano Meza, J.K., Orjuela Yepes, D., Rodrigo-Ilarri, J. and Cassiraga, E., 2019. Predictive analysis of urban waste generation for the city of Bogotá, Colombia, through the implementation of decision trees-based machine learning, support vector machines and artificial neural networks. *Heliyon*, 5(11), pp.e02810. [DOI]

Sterman, J.D., 2002. All models are wrong: reflections on becoming a systems scientist. *System Dynamics Review*, 18(4), pp.501-531. [DOI]

Treyes, A.C., Osorio, E., Tanchuling, M.A., Andal, M.D., Requejo, B., Inocencio, B. and Panopio, C., 2023. Socio-behavioral assessment of household solid waste management: the case of Barangay Calicanto, Philippines. *IOP Conference Series: Earth and Environmental Science*, 1257(1), pp.012008. [DOI]

Viljoen, J.M.M., Schenck, C.J., Volschenk, L., Blaauw, P.F. and Grobler, L., 2021. Household waste management practices and challenges in a rural remote town in the Hantam Municipality in the Northern Cape, South Africa. *Sustainability*, 13(11), pp.5903. [DOI]

Vongdala, N., Tran, H.-D., Xuan, T.D., Teschke, R. and Khanh, T.D., 2018. Heavy metal accumulation in water, soil, and plants of municipal solid waste landfill in Vientiane, Laos. *International Journal of Environmental Research and Public Health*, 16(1), pp.22. [DOI]

Waleed Makki, H., Waleed Makki, H., Mohamed, T.S.A., Omer Hamad Abd ElRaheem, G., Bashir Abdel Mahmoud, A.-Z., Mustafa Elfadul, M., Homeida, M. and Noma, M., 2023. Health impact of household waste burning in Khartoum State, Sudan. *Risk Management and Healthcare Policy*, Volume 16, pp.1297-1307. [DOI]

World Bank (ed.), 2019. *World Development Report 2020: Trading for Development in the Age of Global Value Chains*. World Bank Group, Washington, pp.330.

Yukalang, N., Clarke, B. and Ross, K., 2018. Solid waste management solutions for a rapidly urbanizing area in Thailand: recommendations based on stakeholder input. *International Journal of Environmental Research and Public Health*, 15(7), pp.1302. [DOI]

Zulkipli, F., Mohd Nopiah, Z., Ezlin Ahamad Basri, N., Jack Kie, C., Zulkepli, J. and Irwan Khalid, K., 2018. Integrated dynamical model for Malaysian solid waste management using system dynamics. *International Journal of Engineering & Technology*, 7(3.20), pp.131-135. [DOI]