



Assessment of Greenhouse Gas Emission Reduction Potential from Decentralized Community-Based Solid Waste Management: A Case Study in Ban Non Sung, Sisaket, Thailand

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Abstract

Greenhouse gas (GHG) emissions from municipal solid waste (MSW) significantly contribute to climate change, particularly through methane (CH₄) and carbon dioxide (CO₂) emissions from landfills. This study evaluates the potential for GHG emissions reduction through improved solid waste management practices in Ban Non Sung, Khun Han district, Sisaket province, Thailand. Data was collected for 1 fiscal year, covering 1,586 residents across 340 households. Waste segregation at source included composting, bio-fermentation, animal feed conversion, and recycling. GHG emissions reductions were calculated based on national methodologies. Results showed that 69.27% of sorted waste was organic, with per capita sorted waste generation of 0.07 kg/day. The total estimated GHG emissions reduction was 41,111.78 kg CO₂eq/year (0.96 kg CO₂eq per kg sorted waste). Animal feed conversion was the most effective method, contributing 40.89% of the total reduction, primarily due to the dual benefit of methane avoidance and commercial feed displacement. Additionally, secondary national data from the Pollution Control Department (PCD) for 2020–2023 indicated a steady increase in source-sorted waste and corresponding GHG reductions, emphasizing the role of community-based waste initiatives in meeting national climate goals. The findings support the integration of sustainable waste practices to significantly mitigate GHG emissions in large communities.

Keywords : Community-based SWM; Decentralized waste management; Waste diversion; Methane mitigation; Ban Non Sung case study

Introduction

Greenhouse gas (GHG) emissions have become one of the most pressing global environmental issues due to their significant contribution to climate change and global warming. The Intergovernmental Panel on Climate Change (IPCC) reports that human activities, particularly in the energy, agriculture, and waste sectors, are the primary sources of GHG emissions worldwide. Methane (CH₄), carbon dioxide (CO₂), and nitrous oxide (N₂O) are the main greenhouse gases emitted into the atmosphere, with CH₄ having a global warming

potential approximately 25 times higher than CO₂ over a 100-year period [1]. Among these sources, solid waste management (SWM) has received increasing attention, especially in developing countries where rapid urbanization and population growth have intensified waste generation and its environmental impacts.

In Thailand, municipal solid waste (MSW) generation continues to rise annually, driven by increased economic activity, changing consumption patterns, and lack of effective waste segregation at the source. There are many open-dump landfill sites which still wait for the proper management [2]. According to the

Pollution Control Department (PCD), Thailand generated approximately 25.70 million tons of MSW in 2022, of which only a fraction was properly segregated and treated [3]. A significant portion of this waste, especially organic matter, ends up in landfills, where anaerobic decomposition results in the release of CH₄. Therefore, improving waste management practices, particularly at the community level, presents a practical and impactful opportunity for GHG emissions reduction.

Modern approaches to sustainable solid waste management focus on waste minimization, source segregation, recycling, composting, and energy recovery. These strategies not only extend the lifespan of landfills but also contribute to climate change mitigation through the reduction of GHG emissions. In particular, the diversion of organic waste from landfills to processes such as composting, bio-fermentation, and animal feed conversion has been proven to substantially reduce CH₄ emissions [4]. Recent literature emphasizes that the effectiveness of these practices relies heavily on decentralized governance and rigorous quantitative assessments at the implementation level [5-8].

The Ministry of Natural Resources and Environment (MNRE) of Thailand has acknowledged the critical role of SWM in achieving the targets set in the Thailand National Greenhouse Gas Reduction Plan (2021–2030), which aligns with the country's commitment under the Paris Agreement [9]. As part of this strategy, increasing the rate of waste segregation at source and promoting organic waste treatment technologies are key priorities. The Thailand Greenhouse Gas Management Organization (TGO) has also developed specific methodologies for calculating GHG reductions from waste management activities, providing a standardized framework for monitoring and evaluation [10].

This study focuses on assessing the potential for GHG emissions reduction through community-driven solid waste management in Ban Non Sung, Khun Han district, Sisaket province, Thailand. The primary data for this study was collected from October 2019 to September 2020. While this period reflects the operational year of the program being evaluated, the methodology remains robust, and the analysis is contextualized using later national data (2020–2023) to assess ongoing trends. By

examining the composition of solid waste, identifying the proportion of recyclable and organic fractions, and calculating the GHG emissions reduction based on actual management practices, this research aims to provide data-driven insights for scaling similar initiatives across other communities in Thailand.

The research gap addressed by this study is the lack of a current, quantitative assessment focusing on the GHG mitigation benefits of a decentralized, multi-faceted, community-based SWM system in the Thai context. Most existing studies focus on national trends or centralized facilities; this research provides an essential data benchmark for local government organizations (LGOs) implementing source-segregation and alternative waste treatment programs.

Consequently, this study is expected to contribute to the growing body of knowledge on sustainable waste practices in the context of climate change mitigation. Furthermore, they can support policymakers and local governments in designing evidence-based programs that promote environmentally responsible behavior and community engagement in line with national and global sustainability goals.

Methodology

Case study area and SWM system

Ban Non Sung village, moo 1, Non Sung subdistrict, Khun Han district, Sisaket province, serves as a national model for community-based solid waste management and operates an exemplary waste-recycling bank system. The village waste management diagram is summarized as shown in **Figure 1**. The community separates waste at the source into four categories: organic, recyclable, general, and hazardous waste. A key strength of the village lies in its decentralized organic waste management: each household is encouraged to handle their organic waste on-site through composting, bio-fermentation, or by using it as animal feed. These practices help reduce the volume of waste needing external collection while promoting local food production, such as homegrown vegetables using composted fertilizer as shown in **Figure 2**. Recyclables are deposited monthly at the community waste-recycling bank as shown in **Figure 3**, with proceeds contributing to a

welfare fund. General waste is creatively made community products (as shown in **Figure 4**) or reused when possible or collected for disposal at an RDF facility. Hazardous waste is separated and managed responsibly. To improve waste logistics, the village has established 19 designated community drop-off points (as shown in **Figure 5**) where residents are encouraged to bring general and hazardous waste in sealed plastic bags at scheduled times. These points have replaced the previous door-

to-door collection system, fostering better waste segregation, community participation, and resource recovery. The village promotes strong waste discipline through regular community meetings, public announcements, local regulations, and incentive-based participation. This integrated system not only reduces environmental impact but also strengthens community engagement and social welfare through structured cooperation and shared responsibility.

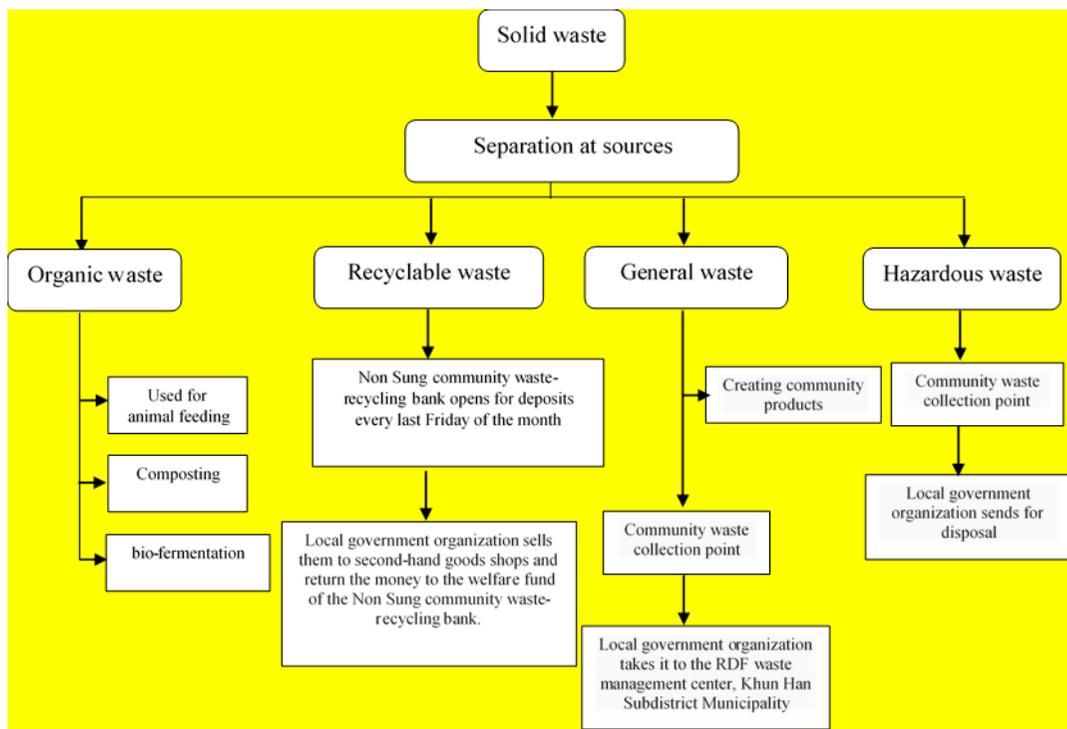


Figure 1 Waste management diagram of Ban Non Sung village, moo. 1, Non Sung subdistrict, Khun Han district, Sisaket province



Figure 2 Homegrown vegetables



Figure 3 Community waste-recycling bank



Figure 4 Community products from waste



Figure 5 Community drop-off point for general and hazardous waste

This study assesses waste composition and calculates the GHG emissions reduction achieved through different waste management practices. Data collection was conducted for 1 fiscal year, covering a population of 1,586 residents across 340 households. Waste segregation methods were analyzed, including organic waste processing through composting, bio-fermentation, and animal feed conversion, along with recycling efforts for glass, plastic, paper, and metals.

Data Collection and Waste Sampling Protocol

Primary data (activity data) for the Ban Non Sung case study was collected via direct measurement (weighing) over a continuous 12-month period (October 2019 to September 2020). This approach was chosen to capture seasonal variations and ensure data quality control.

The waste sampling protocol followed guidelines established by the Pollution Control Department (PCD) of Thailand. Waste weights were quantified daily/weekly at the community collection points and the waste bank. The measurement procedure involved the use of a calibrated scale, and the data was recorded by village volunteers with oversight from the local government organization (LGO). The total activity data represents the cumulative mass of waste successfully diverted from the baseline scenario (landfill disposal).

Waste segregation was performed at the source (household level) based on four predefined categories (Organic, Recyclable,

General, Hazardous). Household participation was tracked, with 340 households (1,586 residents) actively contributing data to the project. The recorded weights represent the actual performance achieved by this high-participation group.

GHG Emission Reduction Calculation

GHG emissions reductions were calculated based on the "Thailand Greenhouse Gas Management Organization (TGO) for waste diversion projects (TGO Methodology No. 04-2021)" [10]. The reduction in greenhouse gas (GHG) emissions resulting from the implementation of organic waste management activities can be calculated using a calculation program developed by the Office of the Permanent Secretary, Ministry of Natural Resources and Environment, Strategy and Planning Division [11], with the related equations shown as Equation 1:

$$\text{GHG Emission Reduction (kgCO}_2\text{eq)} = (\text{Activity Data} \times \text{Emission Factor})_{\text{before}} - (\text{Activity Data} \times \text{Emission Factor})_{\text{after}} \quad \text{Eq. 1}$$

Where:

- Activity Data (kg) refers to the amount of organic waste managed. The subscript "before" indicates the baseline scenario, while the subscript "after" indicates the management scenario as shown in **Table 1**.
- Emission Factor (kgCO₂eq/kg) refers to the greenhouse gas emission factor as shown in **Table 2** and **Table 3**.

Table 1 Baseline Scenario for MSW Management Operations Used in Emission Reduction Assessment

Category	Scenario
a) Organic Waste Baseline Management	Landfilling of organic waste in landfills Making bio-fermented liquid from vegetable and food scraps Making compost from vegetable and food scraps Using food or vegetable scraps for animal feeding
b) Recyclable Waste Baseline Management	Recyclable waste can be sorted for reuse Sorting of recyclable paper for reuse Sorting of recyclable glass bottles for reuse Sorting of recyclable plastics for reuse Sorting of recyclable steel/iron for reuse Sorting of recyclable aluminum for reuse

Table 2 Emission Factor for Assessing GHG Emissions from Organic Waste Management [11]

Type	Emission Factor (kgCO ₂ eq/kg)
Food scraps	2.53
Wood scraps	3.33
Food and vegetable scraps used for bio-fermented liquid	0.05
Food and vegetable scraps used for composting	0.43
Twigs and Grass used for Composting	0.43
Food and vegetable scraps used for animal feeding	0
Methane for Landfills and Open Dumps (< 5 meters deep)	0.45

Table 3 Emission Factor for Assessing GHG Emissions from Recyclable Waste Sorting [11]

Type	Emission Factor (kgCO ₂ eq/kg)
Paper/cardboard boxes	2.93
Glass bottles	0.49
Plastics	0.70
Sheet glass	0.63
Iron/steel	0.43
Aluminum	0.79

In addition, the potential GHG emissions reduction from municipal waste management was analyzed. This analysis was conducted at the national level, using actual secondary data from the Pollution Control Department (PCD) from 2020 to 2024 [12]. The aim was to estimate the broader potential impact of scaling up similar community-based initiatives across the country, thereby assessing their contribution to national GHG mitigation targets.

Results and Discussion

Waste Composition and Diversion Rate

The study found that the composition of total solid waste that has been sorted out at the source for a large community with a population of 1,586 people for the fiscal year 2020 had 42,715.65 kg including organic and food waste, representing 69.27 %, followed by recyclable waste accounting for 30.73 % (as shown in **Figure 6**). Figure 6 presents the composition of sorted waste in the studied community. Organic waste accounts for the highest proportion, followed by glass and plastic. The daily per capita sorted waste generation was 0.07 kg (~0.34 kg/household). This per capita sorted

waste rate (0.07 kg/day) is significant, especially when compared to the national average MSW generation rate of 1.15 kg/day [13], highlighting the effectiveness of the community's segregation effort. Total GHG emissions reduction from waste management activities was estimated at 41,111.78 kg CO₂eq per year (0.96 kg CO₂eq per kg sorted solid waste).

GHG Reduction Potential and Comparison

The total estimated GHG reduction of 41,111.78 kg CO₂eq/year resulting in an average reduction efficiency of 0.96 kg CO₂eq per kg sorted solid waste is significantly positive, especially when compared to the near-zero mitigation benefits of conventional landfilling (the baseline scenario). The most effective method for reducing GHG emissions was utilizing food and vegetable scraps for animal feed, contributing to a reduction of 16,812.09 kg CO₂eq (40.89%). Composting and bio-fermentation contributed to reductions of 7,733.82 kg CO₂eq (18.81%) and 7,414.60 kg CO₂eq (18.04%), respectively. **Table 4** summarizes the reductions in GHG emissions achieved through different waste management methods.

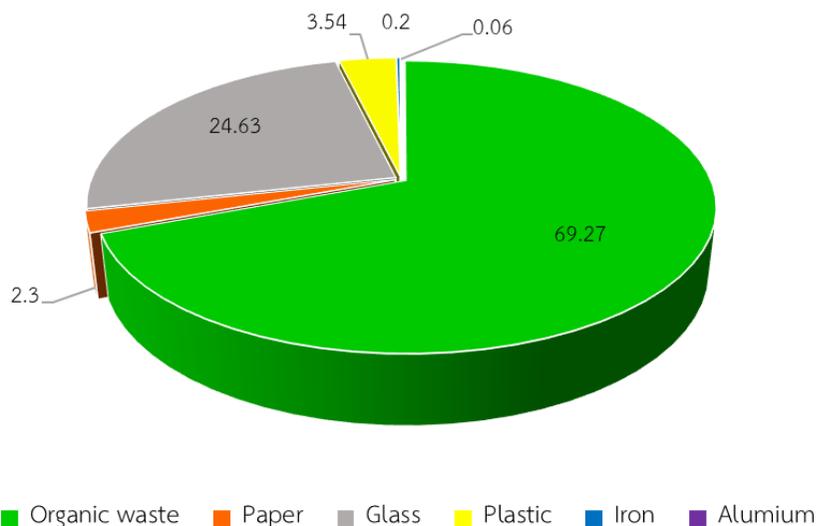


Figure 6 Weight Percentage Composition of Sorted Waste in Ban Non Sung Community

Table 4 Annual GHG Emissions Reduction from Waste Management Methods

Waste Management Method	GHG Reduction (kg CO ₂ eq)	Percentage Reduction (%)
Animal Feed Conversion	16,812.09	40.89
Composting	7,733.82	18.81
Bio-Fermentation	7,414.60	18.04

From Table 4, the high contribution from animal feed conversion (40.89%) can be attributed to its dual environmental benefit, making it the most effective option. Firstly, like composting and bio-fermentation, it avoids methane emissions that would otherwise be generated by the organic waste in a landfill. Secondly, and uniquely, using food scraps as animal feed (especially for livestock like pigs or chickens in the local community) acts as a displacement mechanism, reducing the demand and subsequent emissions associated with the production, processing, and transportation of commercial animal feed. The TGO methodology recognizes this displacement benefit, resulting in a zero-emission factor for this activity, leading to the highest net GHG reduction per kilogram of diverted waste compared to other treatments like composting and bio-fermentation. This preference for local, low-impact resource recovery (animal feed) over other recovery options is a key driver of the program’s success.

Trend Analysis and Policy Implications

To provide an updated assessment in Thailand, secondary data from 2020-2024 [12] was analyzed as shown in Table 5 revealing trends in calculated annual GHG emission reduction. The annual GHG emission reduction has been calculated to show that if community screening is successful, it can achieve significant annual GHG emissions reductions. In Table 5, the results indicate a gradual increase in waste generation, with a corresponding rise in calculated annual GHG emissions reduction due to improved waste management strategies. This highlights the importance of continued community-driven waste initiatives in achieving sustainability goals according to Thailand’s National Greenhouse Gas Reduction Plan (2021-2030) [9]. The Ban Non Sung model provides a crucial, quantified benchmark for LGOs nationwide to target their source segregation efforts, demonstrating a clear link between community participation and national climate commitments. This is consistent with other research [7-8], which can be confirmed

that the decentralized community-based solid waste management model is a good practice in reducing greenhouse gas emissions in Thailand.

Table 5 Generated and sorted solid waste during year 2020-2024 in Thailand [12]

Year	Solid Waste Generated (million-ton, Mt)	Sorted Solid Waste at Source (million-ton, Mt)	Calculated Annual GHG Emissions Reduction* (Mt CO ₂ eq)
2020	25.37	8.36	8.02
2021	24.98	7.89	7.57
2022	25.70	8.80	8.45
2023	26.95	9.31	8.94
2024	27.20	10.51	10.09

*Based on the GHG Emissions Reduction value of 0.96 kg CO₂eq per kg sorted solid waste obtained in this study of Ban Non Sung model.

Conclusions

Effective sorted solid waste management plays a crucial role in mitigating GHG emissions in large communities. This study quantified the performance of the decentralized community-based SWM model in Ban Non Sung, demonstrating a total annual GHG reduction of 41,111.78 kg CO₂eq, equivalent to 0.96 kg CO₂eq per kg of sorted solid waste. The key finding is the disproportionate effectiveness of animal feed conversion, which contributed 40.89% of the total reduction due to its dual benefit of methane avoidance and commercial feed displacement. These quantitative results provide the necessary performance benchmark for Local Government Organizations (LGOs) in Thailand to design and implement community programs that directly contribute to achieving the targets of the Thailand National Greenhouse Gas Reduction Plan (2021–2030) [9].

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