



POLICY BRIEF

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Towards Climate-Friendly Waste Management: The Potential of Integrated Municipal Solid Waste Management

Key Messages

- 📶 Greenhouse gas emissions from waste disposal in developing countries contribute significantly to global climate change.
- 📶 Moving towards integrated municipal solid waste management is a practical solution for mitigating these greenhouse gas emissions as well as for obtaining socio-economic and other environmental benefits at local level.
- 📶 By recovering materials and energy from waste, an integrated system can bring about additional reductions of greenhouse gas emissions that would otherwise have been generated by the production of equivalent amount of new materials and energy in conventional processes.
- 📶 Local governments play a key role in formulating and implementing appropriate policies and regulations in support of integrated waste management systems at the municipal level.



Nirmala Menikpura

Researcher
IGES Sustainable Consumption
and Production Group
menikpura@iges.or.jp



Janya Sang-Arun

Policy Researcher
IGES Sustainable Consumption
and Production Group
sang-arun@iges.or.jp



Magnus Bengtsson

Director
IGES Sustainable Consumption
and Production Group
bengtsson@iges.or.jp

I The present situation of waste management in developing Asian countries

Greenhouse gas emissions from conventional Municipal Solid Waste (MSW) management in developing countries contribute significantly to global climate change. Moving towards integrated waste management methods offers a practical solution for mitigating greenhouse gas emissions as well as for obtaining socio-economic and other environmental benefits. However, at the local authority level, there is very limited knowledge on the severity of environmental impacts from existing waste management including

greenhouse gas emissions and the effects on global climate change. Quantitative assessment of greenhouse gas emissions from different waste management options would be useful for the decision-making process when selecting climate-friendly waste management technologies at the local authority level. This policy brief provides such quantitative results while arguing why local authorities in developing countries should move towards more appropriate waste management options.

2 What is the contribution of existing waste management practices on greenhouse gas emissions?

Greenhouse gas emissions from waste management contribute significantly to global climate change issues. In fact, methane (CH₄) emissions from open dumping and landfilling are the third largest anthropogenic methane emissions source (IPCC, 2007). Worldwide, CH₄ emissions from the waste sector constitute approximately 18% of the global anthropogenic CH₄ emissions (Scheutz et al., 2009). Greenhouse gas effect and global warming potential is measured in terms of carbon dioxide equivalents (CO₂-eq) and methane is considered 25 times stronger than carbon dioxide (CO₂).

Landfilling is the most common waste disposal method in developing countries. Direct emissions of greenhouse gas from the landfill systems are up to about 1,000 kg CO₂-eq per tonne of MSW (Manfredi et al., 2009) and this figure may differ based on the waste composition.

In developing Asian countries, there is a growing interest in waste incineration as a solution to reduce the volume of waste and also to generate electricity. Even though methane emissions can be completely avoided using this technology, there is still the concern about emitting a substantial amount of fossil-based CO₂ due to burning plastics and synthetic textiles waste and combustion of fossil fuels like coal and diesel to enable the incineration.

Biological treatments can be identified as the most desirable approach in terms of greenhouse gas mitigation. However, small amounts of CH₄ and nitrous oxide (N₂O) can be formed during composting and mechanical biological treatment, mainly due to poor management and the initiation of semi-aerobic or anaerobic conditions (Forster et al., 2007). The amount of greenhouse gas emissions from individual treatment methods highly depends on the waste composition, technology type, management practices and the efficiency of resource recovery from waste.

However, by applying the appropriate technologies, there is a possibility for recovering a significant amount of materials and energy from waste and also reduce the amount of waste disposal at the landfill. Recovered materials and energy from waste can be used to replace the production of the equivalent amount of materials and energy from conventional processes. Therefore, greenhouse gas emissions that would otherwise occur from those conventional productions as well as organic waste landfilling can be reduced. In the absence of adequate policy actions on appropriate waste handling and treatment, these emissions are expected to increase due to growing waste generation. In order to overcome these problems, appropriate policies and legislations need to be formulated for sustainable waste management based on the concept of integrated management.

3 What is integrated municipal solid waste management (IMSWM)?

Integrated municipal solid waste management (IMSWM) systems incorporate all the technologies that are necessary to manage the waste streams while recovering useful materials and energy from waste (Kathiravale and Yunus, 2008; Koroneos and Nanaki, 2012). IMSWM systems should be designed after careful selections of technologies which best suit the waste characteristics and socio-economic conditions of a particular municipality. Therefore, the basic structure of the IMSWM systems can vary from one location to another.

IMSWM is not a new concept; it was initiated in developed countries to manage solid waste in ways that most effectively protect human health and the local environment. Initially, climate change was not the main driver for promoting IMSWM. However, current promotion of IMSWM is very important not only for obtaining the benefits mentioned above but also as a key option for climate-change mitigation.

Any IMSWM system should meet the following criteria to achieve a considerable reduction in greenhouse gas emissions as well as other social-economic and environmental benefits:

- Well-received contribution from the residents

for source-separation of organic waste and recyclables

- Availability of efficient collection and transportation service to transport the source separated waste without mixing with non-source separated waste (mixed MSW)
- Availability of appropriate technologies to treat the different fractions of waste, which have been designed based on municipal waste composition, the amount of waste generation, and the waste characteristics (e.g. moisture content, calorific value)
- Availability of properly designed disposal services to treat the residual waste

If an IMSWM system fulfill the above criteria, such a system has the capability to mitigate greenhouse gases to a considerable level, provide better services to the public, create income generation ways to the stakeholders, employ a sizable number of people and conserve a significant amount of resources, in addition to giving maximum protection to the environment. Therefore, if developing Asian countries can switch from current landfilling practices to an integrated system, it would solve the major dilemmas related to existing waste management.

4 How does the IMSWM system contribute to greenhouse gas mitigation from a Life Cycle Assessment (LCA) perspective?

LCA is a methodical approach for quantifying greenhouse gas emissions considering all phases of the life cycle such as transportation, operation (pre-processing, treatment) and disposal. It enables identification of issues of concern and possible policies for mitigating more effectively, taking into account the direct and indirect impacts associated with a particular waste management system. This policy brief explains the basic concept of LCA as shown in Box 1. All the waste treatment methods in an IMSWM system emit a considerable amount of direct greenhouse gas from waste transportation, operational activities and during waste treatment, as can be seen in Figure 1. Greenhouse gas emissions from transportation and operational

activities is generally not as high as from waste treatment. The treatment phase would be the major greenhouse gas “hotspot” along the waste management process chain.

By implementing an appropriate mix of technologies, organic waste disposal at landfills can be reduced or stopped and so methane emissions that would occur from organic waste degradation in landfills can be avoided. Furthermore, by adapting appropriate treatment methods, a significant amount of materials and energy can be recovered from waste. These recovered resources can replace an equivalent amount of materials and energy that would otherwise

need to be produced from virgin resources. Therefore greenhouse gas emissions from those virgin production processes can be avoided (see Figure 1). All in all, as a result of implementing an appropriate integrated system, greenhouse gas mitigation can be achieved due to both avoided landfilling and resource recovery.

technologies can be considerably lower than greenhouse gas savings potentials via both materials and energy recovery and avoided organic waste landfilling. Therefore, the net greenhouse gas emissions from a properly designed integrated system might reach zero or even a negative value. The definition of the net greenhouse gas emissions can be expressed as follows:

Greenhouse gas emissions from improved

$$\text{Net greenhouse gas emissions} = \text{Greenhouse gas emissions from the integrated system} - \text{Greenhouse gas avoidance via resource recovery and avoided landfill disposal}$$

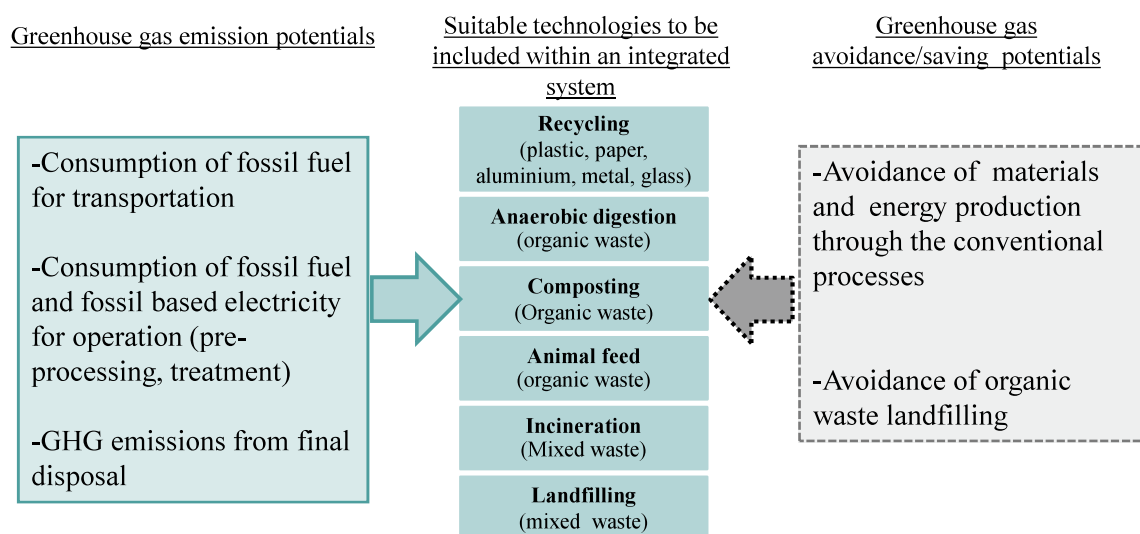


Figure 1 Greenhouse gas emissions and avoidance from different treatment options in an IMSWM system
(Note: Selection of the most appropriate technologies will depend on the capacity, availability of budget and the interest of the local authority.)

Box 1 The concept of LCA for quantification of greenhouse gas (GHG)

LCA is “a technique for assessing the environmental aspects and potential impacts associated with a product, service or function by compiling an inventory of relevant inputs and outputs” (McDougall et al., 2001). LCA is a useful technique for analysing current systems and alternatives in order to identify the consequences with respect to GHG mitigation in all the sectors such as waste, energy and transport. There are many studies that have been discussed about the application of LCA methodology in the waste sector, particularly for estimating the possible mitigation options of all the environment impacts via material and energy recovery from waste management (Koroneos and Nanaki, 2012; Poeschl et al., 2012). The LCA approach provides a meticulous data collection and calculations procedure to quantify the climate co-benefits from different waste management options and also to perform a quantitative assessment of optimising climate co-benefits by maximising resource recovery at the local authority level.

For instance, total GHG emissions from a particular waste management system throughout the life cycle can be calculated as follows:

$$\text{GHG}_{\text{Total emissions}} = \text{GHG}_{\text{Transportation}} + \text{GHG}_{\text{Operations}} + \text{GHG}_{\text{Treatment and disposal}}$$

The GHG mitigation and avoidance potential from individual treatment method can be estimated as follows:

$$\text{GHG}_{\text{Total avoidance}} = \text{Avoided GHG}_{\text{From resource recovery}} + \text{Avoided GHG}_{\text{From landfilling of organic waste}}$$

The overall climate impact or benefit of the waste management system will depend on net GHGs, accounting for both emissions and indirect, downstream GHG savings throughout the life cycle.

$$\text{GHG}_{\text{Net emissions}} = \text{GHG}_{\text{Total emissions}} - \text{GHG}_{\text{Total avoidance}}$$

By applying life-cycle approach, priorities can be identified more easily and policies can be targeted more effectively with respect to promotion of climate friendly waste management technologies.

Development of IMSWM systems would be a local initiative that can make meaningful contributions to global climate-change mitigation. In this brief, we

present the case of Muangklang in Thailand as an example for a well-functioning IMSWM system which has significant climate benefits.

5 An example: The IMSWM system in Muangklang

The Muangklang municipality is located in Rayong Province (190 km east of Bangkok). This municipality has initiated an IMSWM system as a sustainable solution by incorporating effective waste collection and transportation service, a waste sorting facility for recovery of recyclables, an anaerobic digestion facility, a composting facility and raising some farm animals, fed with the collected organic waste (see Figure 2). Due to all these ongoing initiatives, Muangklang waste management has been identified by national

governmental organisations as one of the best integrated waste management systems in Thailand.

The current rate (in 2012) of solid waste collection is 23 tonnes/day. The people in the community have taken the initiative to separate a part of the organic ratio at source. In addition, the biggest share of organic waste is generated at the Municipal Market. Approximately, 2 tonnes/day of source separated food waste and vegetable waste is collected and

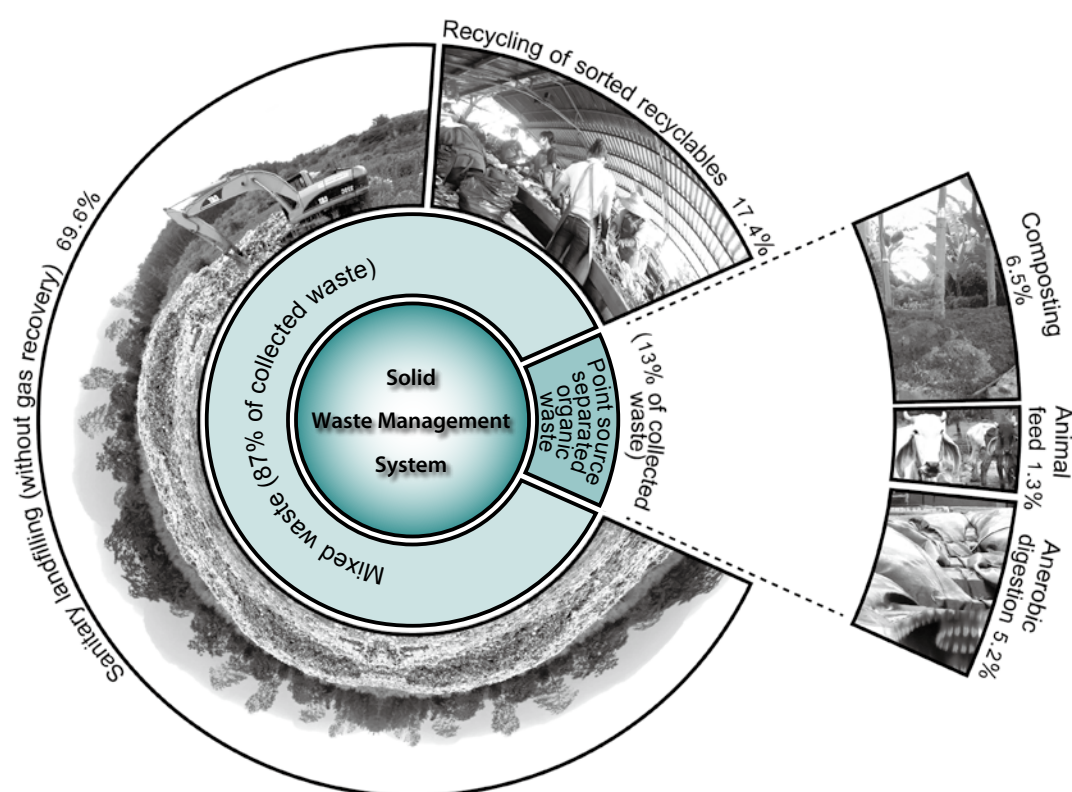


Figure 2 The existing IMSWM system in Muangklang municipality (percentages are calculated based on wet weight)

transported by light duty trucks. The collected organic waste is used for anaerobic digestion (approximately 200 kg/day), composting (1.5 tonnes/day) and as animal feed (300kg/day). The remaining 21 tonnes of mix solid waste is collected by compactor trucks. A low-cost, outdoor system of “two conveyor belts” have been set up to separate the recyclables from the collected mixed waste. Approximately, 4 tonnes

of recyclables are separated from 21 tonnes of collected waste. The wastewater drained (approximately 1 tonne) during the sorting of waste is collected and used for anaerobic digestion. The remaining mixed waste (16 tonnes/day) is transported and disposed of at the sanitary landfill site (without a gas recovery system) which is located 14 km away from the municipality.

6 What are the greenhouse gas emissions and avoidance potentials of individual treatment technologies and of the IMSWM system?

All waste treatment methods emit greenhouse gas from waste transportation, operation and during waste degradation. Greenhouse gas emissions from transportation and operation are relatively low compared to waste treatment. As an example, greenhouse gas emissions and avoidance potential from anaerobic digestion is shown in Figure 3. In this case, the greenhouse gas avoidance from anaerobic digestion are 25 times higher than the direct greenhouse gas emissions and more than 75% of the avoidance are due to avoided landfill disposal.

The direct greenhouse gas emissions from each of the treatment methods used in the integrated system are shown as the upwards arrows in Figure 4. By aggregating the effects of all the possible avoidance (through resource recovery and avoided landfilling),

the total greenhouse gas avoidance from each technology was calculated and it is shown as the downwards arrows in Figure 4. The results show that greenhouse gas avoidance potential from all the technologies (except landfilling) is higher than direct emissions. Then by subtracting the avoided greenhouse gas emission potential from direct emissions, net greenhouse gas emissions from each technology can be estimated. Despite the potential for greenhouse gas savings from recycling, anaerobic digestion, composting and use of organic waste as animal feed, there are still emissions from the integrated system. This is mainly due to the high fraction of waste landfilling (69.6%) and the resulting methane emission. Net greenhouse gas emissions from the current integrated system amounts to 9 kg CO₂-eq/tonne of waste collected, as shown in the lower part of Figure 4.

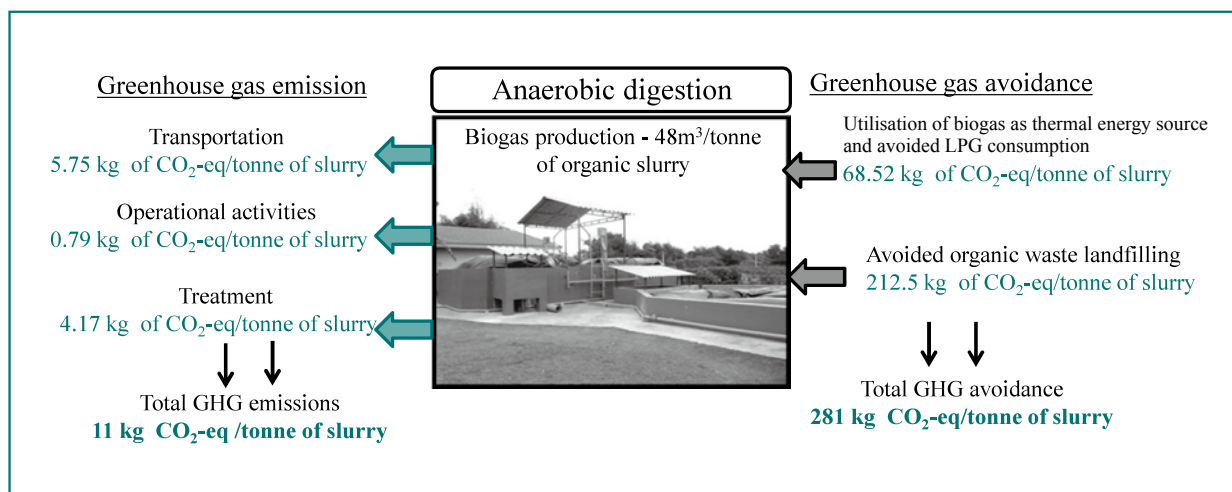


Figure 3 Greenhouse gas emissions and avoidance potential from anaerobic digestion in Muangklang (Note: Dry matter content of the organic slurry is maintained at 8.5%)

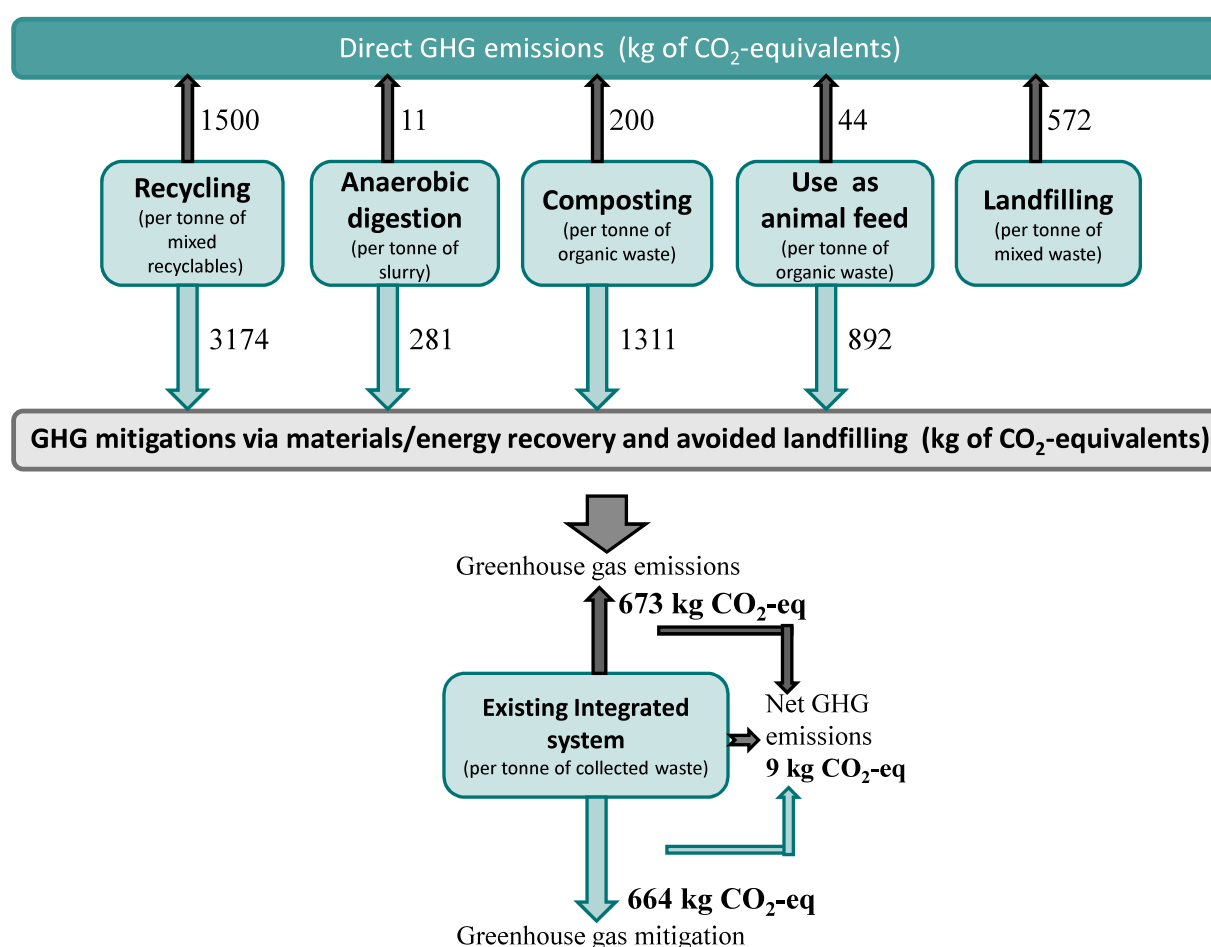


Figure 4 Greenhouse gas emissions and greenhouse gas avoidance potential of individual technologies and of the whole integrated system in Muangklang Municipality

7 Greenhouse gas emissions reduction from IMSWM system in Muangklang

If Muangklang had been like most of other municipalities in Thailand, its daily generated waste (without separation of organic waste and recyclables) would have been disposed of in an open dump or a sanitary landfill (without a gas recovery system). The current IMSWM system has achieved a very significant reduction in greenhouse gas emissions compared to the common practice of bulk collection and mass disposal. The net greenhouse gas emissions from the current

system is 97% and 99% lower than that of open dumping and sanitary landfilling (without gas recovery) respectively (see Figure 5). If Muangklang municipality improves the efficiencies of the source separation of organic waste and expands the capacity of anaerobic digestion, composting and animal feeding or sorting of recyclables, the municipality could reach “net zero greenhouse gas emissions” from its waste management system.

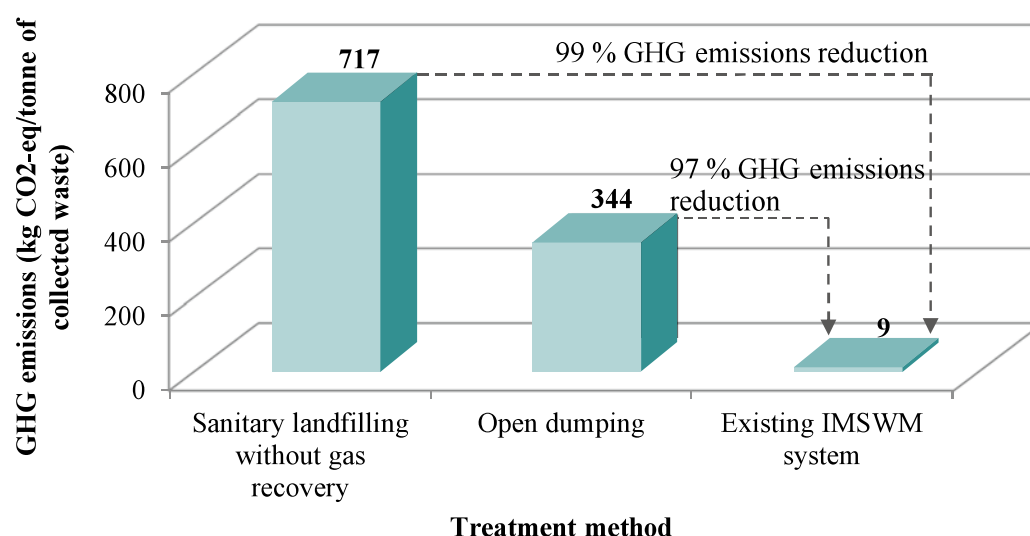


Figure 5 Comparison of greenhouse emissions of two Business as Usual scenarios and the existing IMSWM system in Muangklang municipality

8 Further improvements for achieving “net zero greenhouse gas emissions” in Muangklang municipality

Even though the existing IMSWM system in Muangklang municipality has not yet reached the level of “net zero greenhouse gas emissions”, remarkable emissions reduction has been achieved as explained in the pervious section. However, there is a very likely possibility that Muangklang could achieve net zero greenhouse gas emissions from the current IMSWM system by offsetting the direct greenhouse emissions from greenhouse gas savings.

By improving either the recycling rate or organic waste utilisation rate up to a certain level, the entire integrated system would drive towards net zero greenhouse gas emissions since improvements in avoidance of greenhouse gas emissions via energy and material recovery could easily compensate the greenhouse gas emissions from the current system (9 kg CO₂-eq/tonne of waste). Improvement of the recycling rate has the highest potential for reducing greenhouse gas emissions from the IMSWM system. However, expanding the individual technologies depends on

the priorities and the capacities of the municipality. Furthermore, upgrading the capacities of more than one technology would drive the entire system beyond the net zero greenhouse gas emissions level. Under that situation, the result would be a negative value as the net impact from the overall integrated system which indicates the possible greenhouse gas savings. All in all, the initiation of IMSWM methods by targeting net zero greenhouse gas emissions would shift the entire waste management from being part of the key problem to being part of the solution in sustainable development.

This case study demonstrates that it is fully possible for municipalities in developing Asia to achieve climate-friendly waste management by adapting the appropriate IMSWM system. However, local authorities play a key role in formulating and implementing the IMSWM systems. The role of local authorities in promoting and implementing appropriate IMSWM systems is discussed in the following section.

9 What should local authorities do to replace existing poor waste management practices with IMSWM?

Most local governments in developing Asian countries are claiming that existing budget constraints act as the major barrier to sustainable waste management. According to the mayor of Muangklang municipality, money is not the most important matter for establishing an effective waste management system, rather it is the correct use of available resources and the collaborative working power of the people in the community. Without much concern about the budget constraints, Muangklang's mayor took the lead to improve the overall waste management system, with the available resources within the municipality. Therefore we believe that the integrated system implemented by this municipality would be a practical model for demonstrating and promoting IMSWM systems elsewhere in Thailand and neighbouring countries.

Most of the municipalities in Thailand as well as in neighbouring countries fall into the small-to medium scale. Therefore, similar to Muangklang's initiative, there is a high possibility for these municipalities to also apply this type of low cost, locally adapted IMSWM system as a sustainable waste management option. Furthermore, in these countries, there is a high demand for the recovered resources from waste (e.g. compost, biogas) since it is the most economical way to meet the increasing demand for energy and organic fertiliser. However, the application of IMSWM practices in large administrative bodies would be a challenging issue due to the need to handle the massive amount of waste generated daily. The initiation of an effective waste separation programme at source would be the key driving force for the implementation of IMSWM in such large administrative bodies.

10 Recommendations: enabling the adoption of IMSWM

Target setting and institutional setup: According to the lessons learnt from Muangklang, local governments should play a key role, setting waste management targets. Municipalities are based on the council-mayor form of local governments and therefore, the attitude and the continue efforts of the council-mayors and the municipal staff play a significant role in commencement and successful operation of IMSWM systems. Among the responsibilities of the municipal bodies, sustainable waste management should be taken into account as one of the priority issues.

Awareness raising and capacity building: Well-received contributions from key stakeholders (public, private and informal sectors) within the municipality are the key to the success of Muangklang's waste management system. It is necessary to strengthen capacity at all levels for stakeholders and conduct awareness raising programmes on a range of issues including: the seriousness of existing waste management systems and their contribution to local hazards as well as global climate change; the benefits of source separation; the existence of low-cost and

climate friendly technologies; and the multiple benefits of resource recovery. Most importantly, periodical awareness programmes should be conducted to facilitate and encourage residents to separate waste at the source since this is potentially the key driving force for the success of IMSWM systems. Learning from the examples in practice would be the most effective way of knowledge dissemination and capacity building. For instance, Muangklang municipality has been recognised by other municipalities in Thailand and neighbouring countries as a learning centre. The mayor and his staff are providing a dedicated training course for the visitors and learners about the technological, management information on the existing IMSWM system.

Selection of simple, low-cost technologies and their effective integration: Sustainability of any waste management method in developing countries depends on the total cost of the facility and its level of simplicity. Therefore, selection and incorporation of high-end technologies within an IMSWM system would not be a wise decision since such technologies require high investment and operation costs as well

as high technical skills for operation and maintenance with the limited municipal budget. Identification and selection of low-cost solutions which are best suited to local conditions, (e.g. match with the availability of municipal budget and technical skills) and which have the potential for generating an income would be a very important consideration at the design phase of the IMSWM system. There should be a market for the recovered resources from waste at the local or regional level so that the system is feasible financially. Careful planning, designing and combining of appropriate technologies within an integrated system would facilitate net revenue generation potential to the municipality. For instance, total monthly expenditure (costs for labour, vehicle, fuel and electricity) to run the IMSWM system in Muangklang is THB200,000 (THB30 = 1USD) whereas the monthly revenue generation by

selling the recovered materials and avoided land filling amount to THB240,000.

Creation of multiple-benefits to the local community: Stakeholder participation, appreciation, coordination and commitment on waste management would be a powerful driving force for the continuity of an integrated system. A municipality's effort on building effective interconnections and trustworthiness amongst the people is important. For instance, the waste management system in Muangklang created a win-win situation for both the municipality and the people in the community. In fact, 42 workers are operating the waste-management schemes, and they contribute to saving costs to the municipality whilst making enough money to cover their salary.

• Note to readers:

The estimated greenhouse gas emission/avoidance values are only valid for Muangklang Municipality in Thailand with respect to the following waste characteristics:

- Estimated value for recycling reflects the recyclable mix in Muangklang which consist of 40% paper, 40% plastics, 5% aluminium, 5% metal and 10% glass.
- GHG emissions from anaerobic digestion have been quantified for "per tonne of organic slurry." Dry matter content of the organic slurry is 8.5% and therefore, the biogas production potential is low.
- Mixed waste disposed at the landfill consists of food waste 15.3%, wood 6.8%, plastics 24.4%, paper 4.1%, textile 4.1%, leather 2.7%, glass 27.7%, metal 4.4% and others 13.5%.
- Direct GHG emissions from the integrated system (kg CO₂-eq/tonne of collected waste) = GHG emissions from recycling (kg CO₂-eq/tonne of sorted recyclables)×17.4/100 + GHG emissions from anaerobic digestion (kg CO₂-eq/tonne of organic slurry)×5.2/100 + GHG emissions from composting (kg CO₂-eq/tonne of organic waste)×6.5/100 + GHG emissions from use of organic waste as animal feed (kg CO₂-eq/tonne of organic waste)×1.3/100 + GHG emissions from landfilling (kg CO₂-eq/tonne of mix waste landfilling) × 69.6/100.

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Institute for Global Environmental Strategies

2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115 Japan
TEL : +81-(0)46-855-3700 FAX : +81-(0)46-855-3709 E-mail: iges@iges.or.jp <http://www.iges.or.jp>

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