平成24年度新メカニズムの構築に向けた
アジア地域におけるMRV体制構築支援事業委託教務報告書(5/8)

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【添付資料 4.11-1】 Report: Developing a policy framework for NAMA on municipal solid waste management in developing countries based on a lifecycle and co-benefits approaches

Developing a policy framework for NAMA on municipal solid waste management in developing countries based on a lifecycle and co-benefits approaches

Project outline

According to research findings on the FY2011, the 3Rs and avoided direct landfill of organic waste are more climate friendly than the typical landfill gas recovery for energy production project. The policy framework of NAMA development is proposed to motivate inclusion or consideration of shifting from typical landfill gas recovery or final disposal site improvement to midstream and upstream approach. The framework is developed based on lesson learnt through the implementation of the 3Rs for material-sound cycle society in Japan, case studies that were carried out in FY2011 in Thailand, and pilot project in Cambodia.

Timeframe

1 August 2012 – 15 March 2013

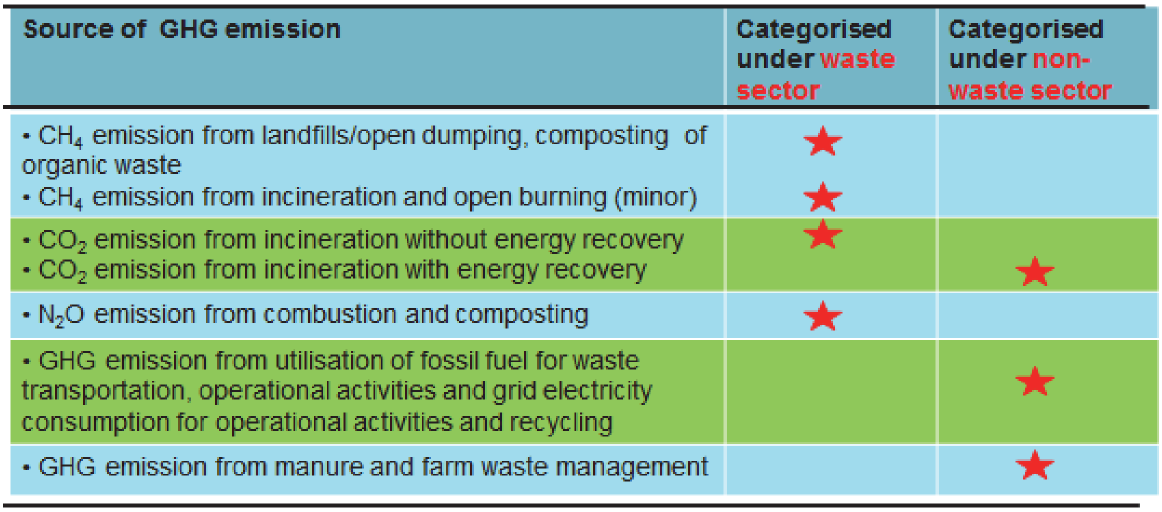
Result

1) Overview of GHG emissions from the waste sector

Municipal solid waste management includes waste collection, transport, treatment and disposal. All activities contribute, to some extent, greenhouse gas to the atmosphere. As shown in Table 4.11-1, the process of waste collection and transport emit GHGs through consumption of fossil fuels, landfill or open dumping emit methane through biological process, open burning and incineration emit methane and carbon dioxide through incomplete combustion, incineration and composting emit nitrous oxide, etc. However, the IPCC guidelines do not include all emissions from waste management activities in order to avoid double counting with other sectors. Unfortunately, many national and local governments mis-interpret this point and thus giving low priority on the waste sector and many of them focus on landfill gas recovery for climate change mitigation measures with less concerning on long term climate impacts and sustainable development goals.

There are many findings report that landfill gas recovery is not a sustainable solution for climate change mitigation because this technique can recover certain amount of methane but a large portion still releases to the atmosphere, especially in developing countries.

Table 4.11-1 GHG emissions from solid waste management



Source of GHG emission	Categorised under waste sector	Categorised under non-waste sector
• CH_4 emission from landfills/open dumping, composting of organic waste	★	
• CH_4 emission from incineration and open burning (minor)	★	
• CO_2 emission from incineration without energy recovery	★	
• CO_2 emission from incineration with energy recovery		★
• N_2O emission from combustion and composting	★	
• GHG emission from utilisation of fossil fuel for waste transportation, operational activities and grid electricity consumption for operational activities and recycling		★
• GHG emission from manure and farm waste management		★

Source: Sang-Arun and Menikpura, 2012

2) The 3Rs, a holistic approach to achieve sustainable solid waste management and climate change mitigation

The 3Rs (reduce, reuse, recycle) is a holistic approach to achieve sustainable solid waste management and climate change mitigation. The 3Rs approach is based on the idea of using resources efficiently before their final disposal. Hence, appropriate waste management through the 3Rs can reduce GHG emissions from the entire life-cycle of resources. Fig. 4.11-1 demonstrates climate benefits that can be achieved through the 3Rs and appropriate disposal practices.

During the production stage, the 3Rs aim to reduce the extraction of natural resources, reduce resource input for production without sacrificing product quality, as well as recycle resources for producing new products. This reduces emissions from land use change and forestry, agriculture, mining and industry sectors. During the consumption stage, the 3Rs aims to reduce the use of natural resources by reducing consumption and reusing resources - through refilling, repairing, and refurnishing - thus reducing emissions from the land use change and forestry and the energy sectors.

During the waste management stage, once separation at source is practiced, valuable waste can be recovered for energy, material and nutrient supply which could contribute to household, industry and agriculture. Recycling or recovery processes can cause GHG emissions, but in most cases lower than the use of virgin materials and landfill of organic waste. For these recycling process, GHG emissions from energy, agriculture, and land use change and forestry sectors can be reduced.

However, if separation at source is not practiced, there are other technical solutions available for recovering valuable nutrients and energy from organic waste, including mechanical biological treatment, sanitary landfill equipped with gas recovery, and thermal recovery from incineration. These high investment solutions can reduce GHG emissions to some extent, but they have disadvantages in resource circulation efficiency. Therefore, we recommend practicing waste separation at source before these end-of-pipe solutions.

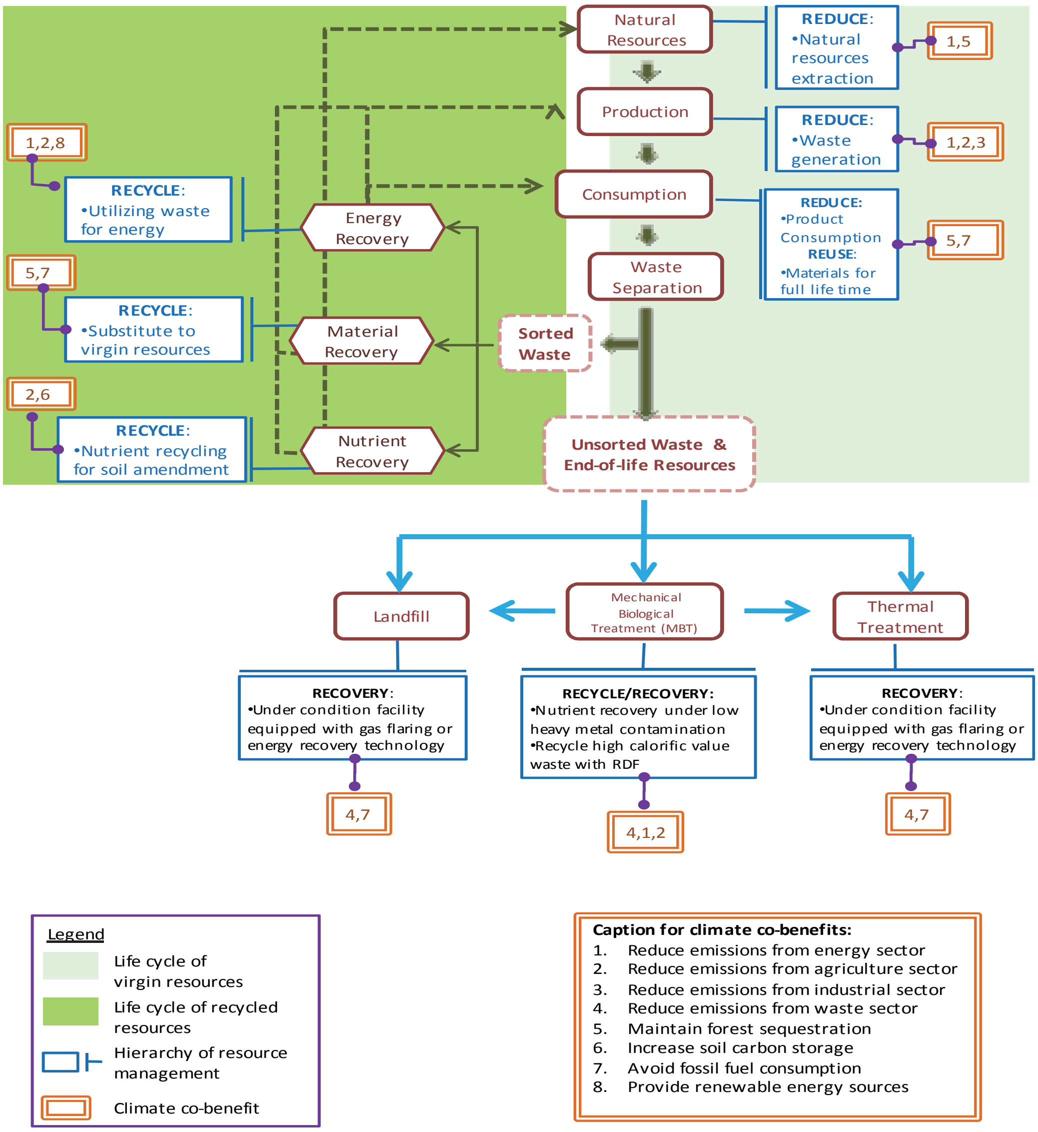


Fig. 4.11-1 3Rs practices at different life-cycle stages and their climate co-benefits (Sang-Arun et al, 2011)

The 3Rs for organic waste management can reduce the direct GHG emissions from the waste sector by reducing the amount of organic waste disposed in landfills (Table 4.11-2*)*. However, when regarded from a life-cycle perspective, when composted municipal solid waste is applied for soil fertilization, it can reduce GHG emissions from the agriculture sector, by reducing nitrous oxide emissions from the use of chemical fertilizer and increase soil carbon storage which available for soil improvement and plant growth. Additionally, it can reduce GHG emissions from the industrial sector by reducing the production of chemical fertilizer (Favoino and Hogg, 2008).

Table 4.11-2 Direct and indirect climate co-benefits of 3Rs application for organic waste management in main sectors.

Sectors	**Climate benefits, direct and indirect**
Waste	• Reduced methane emissions from landfill. • Once organic waste is separated, it could enhance separation of plastic waste for recycle (Schouw et al, 2002). Therefore, it could reduce carbon dioxide emissions from burning or incineration of plastic waste.
Energy and transport	• Reduced emissions from waste transportation and treatment, especially when community based and decentralized organic waste management is implemented. • Reduced emissions from energy use for production and distribution of products when reduced over consumption. • Reduced energy use for agriculture when compost is applied for soil improvement. • Reduced energy use for transportation and processing of agricultural and agro-industrial products when reduced over consumption. • Reduced emissions from fossil fuels by using energy recovered from waste.
Industry	• Reduced emissions from industrial processes by reducing product demand. • Reduced emissions from chemical fertilizer production (Favoino and Hogg, 2008).
Agriculture	• Avoided nitrous oxide emissions from farmland by reducing use of chemical fertilizer (Favoino and Hogg, 2008). • Increased soil carbon sequestration (Favoino and Hogg, 2008).
Land use change and forestry	• Reduced emissions from mining and deforestation.

Remark: The baseline for this comparison is that the waste would be either disposed in a landfill without gas recovery or incinerated without energy recovery and ineffective flue-gas cleaning.
: Interpreted from Fig. 4.11-1 which developed by authors.
Source: Sang-Arun et al, 2011

Organic waste is the major composition of municipal solid waste in developing countries. Table 4.11-3 presents potential GHG emissions from landfill disposal of food and paper wastes in the studied countries. This calculation is based on an assumption that all wastes are collected and disposed in landfill. Potential GHG emissions are generally depend on quantity of waste dumped, depth of landfill, and landfill management system. For this estimation, we use minimum and maximum default values for landfill depth which varied from unmanaged shallow landfill (lower range) to well managed sanitary landfill (upper range). Even though the content of organic contents is same, potential GHG emissions from the deep landfill is higher than the shallow landfill because aeration capacity of the deep landfill is lower than the shallow landfill.

Based on this estimation, the emissions from China were higher than those from other countries, followed by India, Indonesia, Thailand, Philippines, Malaysia, Viet Nam, Bangladesh, and Cambodia. These GHG emissions can be reduced once 3Rs for organic waste is applied.

Table 4.11-3 Potential GHG emissions from landfill of food and paper wastes in developing Asian countries

Country	Type of municipal solid wastes (million ton/yr)*			Potential GHG emissions from landfill of food and paper wastes ($MtCO_2eq/yr$)	
	Total	Food	Paper	Food	Paper
China	120	60	18	25.2-63.0	20.2-50.4
India	42	16.8	2.1	7.0-17.6	2.4-5.9
Indonesia	23	17.02	2.3	7.1-17.9	2.6-6.4
Thailand	15	9.6	1.2	4.0-10.1	1.3-3.4
Viet Nam	13	6.4	0.3	2.7-6.7	0.3-0.7
Philippines	11	3.6	2.1	1.5-3.8	2.3-5.8
Malaysia	9	4.4	1.5	1.8-4.6	1.7-4.3
Bangladesh	6	4.2	0.2	1.8-4.4	0.3-0.7
Sum	239.5	122.3	27.7	51.4-128.5	31.1-77.6

Remarks: Minimum value of potential GHG emissions from landfill reflects GHG emissions from landfill of organic waste under shallow-unmanaged condition and maximum value stands for deep well-managed landfill.
Source: Sang-Arun et al, 2011

The recycling processes used for recovering materials from waste generate GHG emissions in themselves. However, for most materials and under most circumstances, these emissions are lower than under a non-recycling scenario. In this study, potential GHG emissions from waste reduction, composting (degradation of organic matter under presence of oxygen), and anaerobic digestion (degradation of organic matter under absence of oxygen) was estimated using default values of the IPCC Guidelines. Default value of methane emissions based on wet weight was applied for food waste and that on dry weight for paper and grass. This calculation shows wide ranges of potential emissions reduction from waste reduction, composting and anaerobic digestion (***Table 4.11-4***). Reducing one kilogram of food waste can reduce methane emissions from landfill by 0.42 $kgCO_2eq$ compared to shallow landfill and 1.05 $kgCO_2eq$ compared to deep landfill without gas recovery practice.

Table 4.11-4 Potential GHG emissions from reduction, reuse and recycling of organic waste

Organic waste	Potential net GHG emissions reduction compared to landfill ($KgCO_2eq$ / kg of organic waste)					
	Waste reduction		Composting		Anaerobic digestion	
	Compare to shallow landfill	Compare to deep landfill	Compare to shallow landfill	Compare to deep landfill	Compare to shallow landfill	Compare to deep landfill
Food waste	0.42	1.05	0.07-0.40	0.70-1.03	0.25-0.42	0.88-1.05
Paper	1.12	2.80	0.20-1.06	1.88-2.74	-	-
Grass	0.48	1.19	-0.44-0.42	0.27-1.13	-	-

Remarks: Ranges of emissions reduction from composting and anaerobic digestion are highly depended on composting techniques and management practices.
: High emission in CO_2eq of composting, especially of grass, is caused by high global warming potential of nitrous oxide emitted from composting process, particularly vermicomposting. GHG emission savings from anaerobic digestion of grass and paper were not estimated due to its limitation on technology.
Source: Sang-Arun et al, 2011

Composting and anaerobic digestion can reduce net GHG emissions, but its efficiency depends on technology and management efforts. In general, anaerobic digestion has lower potential GHG emissions than composting. As shown in ***Table 4.11-5***, potential GHG emissions from anaerobic digestion is ranged from 0-8 gCH_4/kg of wet waste (1 gCH_4/kg in average), but the potential emissions from composting is ranged from 0.03 – 8 gCH_4/kg of wet waste (4 gCH_4/kg of wet waste in average). Therefore, anaerobic digestion can reduce GHG emissions as equal as reducing waste dumped into deep well-managed landfill if its management system is handling perfectly. However, it is worth noting that this estimation does not include GHG emissions from waste transportation and operation of the facilities.

Some composting techniques (e.g. vermicomposting) can generate nitrous oxide which has higher global warming potent than methane[1] (Hobson et al. 2005). Therefore, composting of organic waste may contribute larger amount of GHG emissions compared to shallow-unmanaged landfill (Table 4.11-4). It is recommended that local governments should avoid promoting vermicomposting of organic waste and maintain aeration of the composting pile to reduce risk of GHG emissions contribution from composting.

Table 4.11-5 Default value for GHG emissions from biological waste treatment

Treatment	Methane emissions (gCH_4/kg waste treated)		Nitrous oxide emissions (gN_2O/kg waste treated)		Remarks
	Dry weight	Wet weight	Dry weight	Wet weight	
Composting	10 (0.08 – 20)	4 (0.03-8)	0.06 (0.2-1.6)	0.3 (0.06 – 0.6)	- 25-50% degradable organic carbon and 2% nitrogen - 60% moisture content
Anaerobic digestion	2 (0 – 20)	1 (0 – 8)	Assumed negligible	Assumed negligible	

Note: Numerical value in bracket refers to ranges of potential emissions.
Source: IPCC, 2006

As anaerobic digestion could also provide co-benefits of energy and nutrient recovery, it is more attractive than composting in terms of climate change mitigation, alternative energy source, and resource efficiency; but the cost is higher. Paper and grass contain more degradable organic carbon per unit of weight than food waste, and thus their potential GHGs emission reduction are higher than that of food waste.

Separation of organic waste from the rest of the waste stream for resource recovery could also make other recyclable materials cleaner and easier to handle (Schouw et al, 2002). Organic waste, particularly food waste, makes other materials dirty, smelly and wet, and it provides food source for microbes and pests. The India National Action Plan on Climate Change has

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[1] For the second national communication under the UNFCCC, the IPCC has suggested using the global warming potential for 100 years of nitrous oxide as 310 times stronger than carbon dioxide. However, the IPCC Fourth Assessment Report indicated that nitrous oxide is 298 times stronger climate impact than carbon dioxide (Forster et al, 2007).

also emphasized that increase organic waste separation for composting could also increase recycling of inorganic materials. Recycling of inorganic materials can sometimes reduce GHG emissions by up to 80-95% (Table 4.11-6) if virgin resources can be replaced. Effective recycling systems for these materials can therefore be very important for climate protection.

Table 4.11-6 Climate co-benefit of materials recycling

Products		GHG emissions ($kgCO_2eq.$/ton of product)			
Reference	Recycle	Reference product	Recyclable product	GHG Reduction	Reduction rate
Virgin plastic	Plastic profile	2,866	172	2,695*	94%
A mat made of virgin polypropylene	A mat made of recycled textile fiber	2,182	115	2,067*	95%
Virgin steel	Recycled steel	2,174	440	1,734*	80%
Steel	40% recycled steel	3,000	1,700	1,300**	43%
Aluminum	50% recycled aluminum	15,100-18,800	6,700	8,400-12,100**	56-64%
25% recycled glass	59% recycled glass	463	362	101*	22%

Sources: *Korhonen and Dahlbo, 2007
** Krauter and Rüther, 2004

3) Application of lifecycle approach for accounting GHG emissions

Life cycle approach should be used as a tool for evaluation of waste treatment technologies and selection of climate change mitigation measures to fully credited the contribution of improved solid waste management for climate change mitigation.

Life Cycle Assessment (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, transport. There is a growing interest of application of LCA methodology in waste sector particularly for estimating the possible mitigation options of all the environment impacts via material and energy recovery from waste (Koroneos and Nanaki, 2012). It enables to identify 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. Therefore life cycle approach has much to offer in terms of selection and application of suitable waste management technologies to achieve specific waste management objectives and goals.

By applying the life-cycle approach for Measurement" of GHG emissions from the entire lifespan of any Municipal Solid Waste (MSW) management system, "hotspots" of GHG emissions can be identified more easily since it helps with a thorough assessment comprising all the phases of the life cycle from "Cradle to Grave", including auxiliary material production (energy and raw materials), MSW collection and transportation, treatment and final disposal. Moreover, by applying LCA, potential of GHG emissions (directly or indirectly) from various waste management technologies and GHG savings can be quantified in a systematic way, and that would be very useful at the decision making stage.

All the waste treatment methods emit a considerable amount of GHG directly or indirectly. For instance, the direct GHG emissions may be caused due to waste transportation, treatment and final disposal. Indirect GHG emissions may occur due to energy and material production, which is required for operation of the MSW management systems. Direct and indirect GHG emissions from various waste treatment technologies are highlighted in Figure 4.11-2. As an example, life cycle framework for assessing GHG emissions from an integrated waste management system is presented in Figure 4.11-3 which includes all the phases of life cycle and the life cycle inputs and outputs with respect to GHG emissions.

Total GHG emissions from a particular waste management system can be calculated as follows;

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

In contrast, organic waste disposal at the landfills can be stopped by implementing appropriate technologies like composting, anaerobic digestion. Therefore, methane emissions that would otherwise 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 the waste. These recovered resources would be useful to replace an equivalent amount of materials and energy that would have otherwise produced through the virgin production processes. Therefore, the associated GHG emissions from those virgin production processes can be avoided. By implementing appropriate waste treatment technologies for maximum resource extraction, GHG mitigation can be achieved due to avoided organic waste landfilling as well as resource recovery, (see Figure Figure 4.11-2). The GHG mitigation and avoidance potential from individual treatment method can be estimated as follows;

$$\mathrm{GHG}_{\text{Total avoidance}} = \text{Avoided } \mathrm{GHG}_{\text{Resource recovery}} + \text{Avoided } \mathrm{GHG}_{\text{Landfilling}}$$

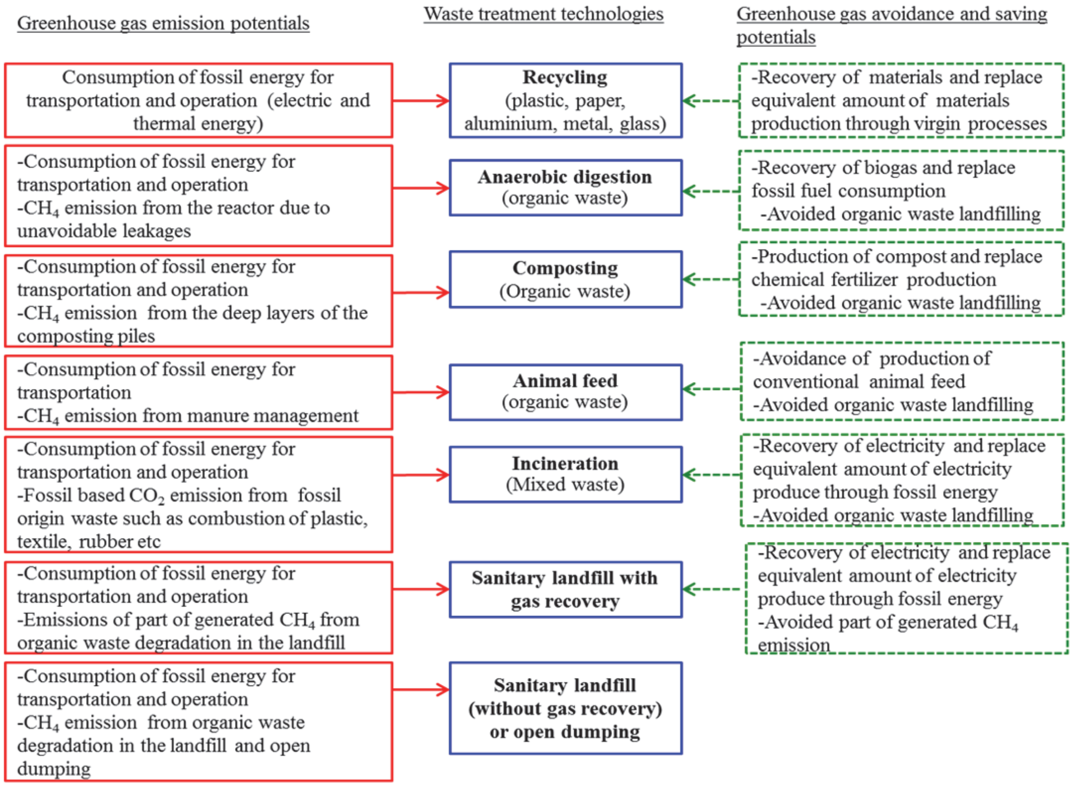


Figure 4.11-2: The potential of GHG emissions and GHG savings from different type of treatment technologies in LCA perspective

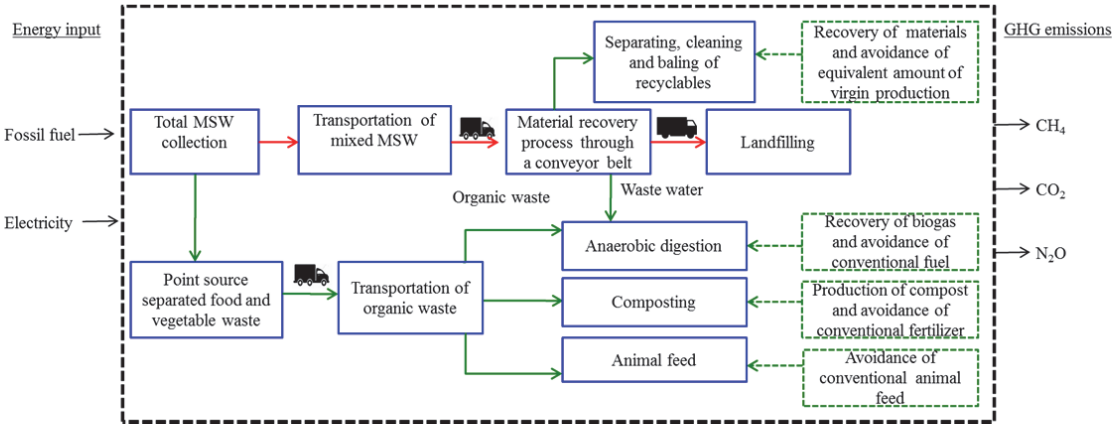


Figure 4.11-3: Life cycle framework for assessing GHG emissions from integrated waste management system

According to Figure 4.11-2, every waste management practice generates GHG, both directly (i.e. emissions from the process itself) and indirectly (i.e. through energy consumption). However, 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. Life cycle inventory analysis needs to be done in order to account for the direct and indirect GHG emissions and GHG avoidance from the entire life cycle of MSW management technologies. Based on inventory analysis results, net GHG emissions can be quantified by subtracting the potential GHG savings from the life cycle GHG emissions that would be useful for making decision on selecting climate-friendly technologies.

Then the net GHG emissions from individual treatment methods can be estimated as follows;

$$GHG_{\text{Net emissions}} = GHG_{\text{Total emissions}} - GHG_{\text{Avoidance}}$$

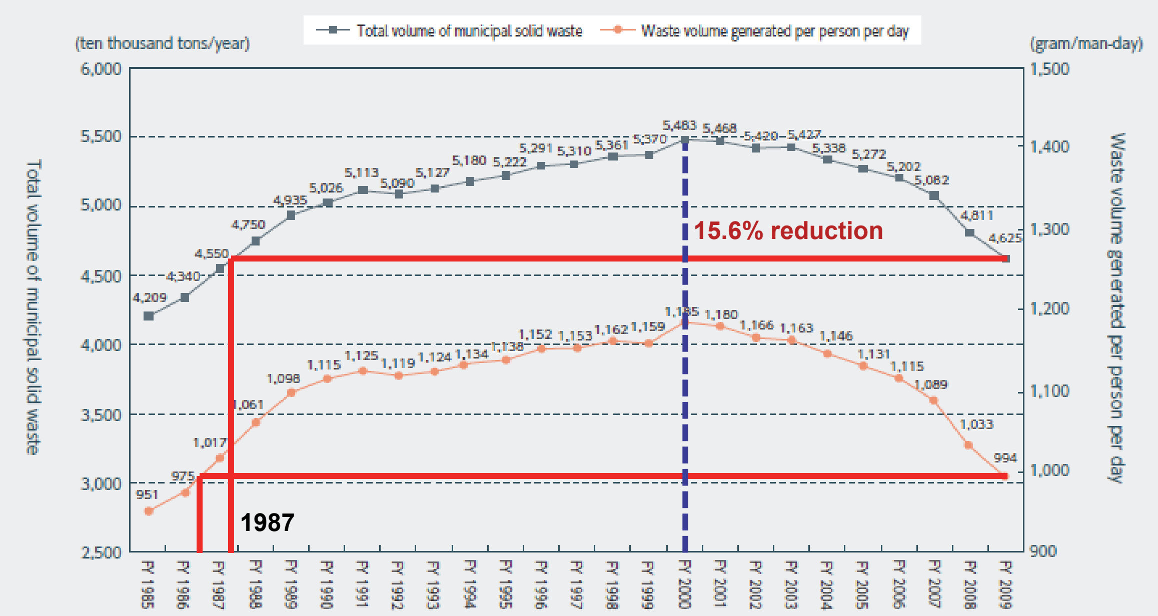
All in all, LCA approach provides a meticulous data collection and calculations procedure to quantify the climate co-benefits from different waste management options and also to perform a quantitative assessment of optimizing climate co-benefits by maximizing resource recovery at local authority level. Thus, 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.

4) Lesson learnt from the implementation of material-sound cycle society in Japan

Japan introduced a material-sound cycle society to improve the resource efficiency and saving landfill space since 2000. At the beginning of preparation for the notification of the sound material cycle society policy and law, in 2000, the total municipal solid waste generation was 54.83 million tonnes and the waste generation rate was 1.185 kg/capita/day. At the beginning of the introduction of this strategy, total waste generation had slightly decreased. A sharp reduction was achieved after the introduction of the national 3R strategies in 2005.

Through these initiatives, Japan achieved 15.6% reduction of total municipal solid waste generation and 16.1% of waste generation per capita per day by 2009. The total municipal solid waste in 2009 was 46.25 million tonnes, with a generation rate of 0.99 kg/capita/day. The level of waste generation in 2009 was similar to the level in 1987 (Figure 4.11-4).

Several efforts were made by both consumers and producers to achieve waste reduction. For example, consumption patterns were changed through awareness raising campaigns and announcements by waste collection trucks, promoting the use of refill products, introducing reusable cup in offices, and so on. In addition, there are also initiatives on product design to minimise use of resources and reduce waste.



Note: "Total volume of municipal solid waste" = "designed collection volume + volume of waste directly brought in + group-based recyclable resource collection"
Source: Ministry of the Environment

Figure 4.11-4 Changes in MSW generations after introducing the sound material cycle society and 3R policies
Source: Sang-Arun, 2012 (modified from MOEJ, 2012)

Waste separation at source is mandatory to facilitate efficient recycling and waste treatment, and recycling is mandatory for some types of materials. Each municipality publishes a detailed manual in Japanese and other foreign languages for separation at source.

In general, recyclables is separated for recycling by designated recycling facility. Burnable waste including food waste, and some cities also included plastic and paper is incinerated. Only inert waste and ashes is landfill. Therefore, the lifetime of landfill in Japan has extended from the remaining of 12.8 years in 2000 to 18.7 years in 2009 (Figure 4.11-5).

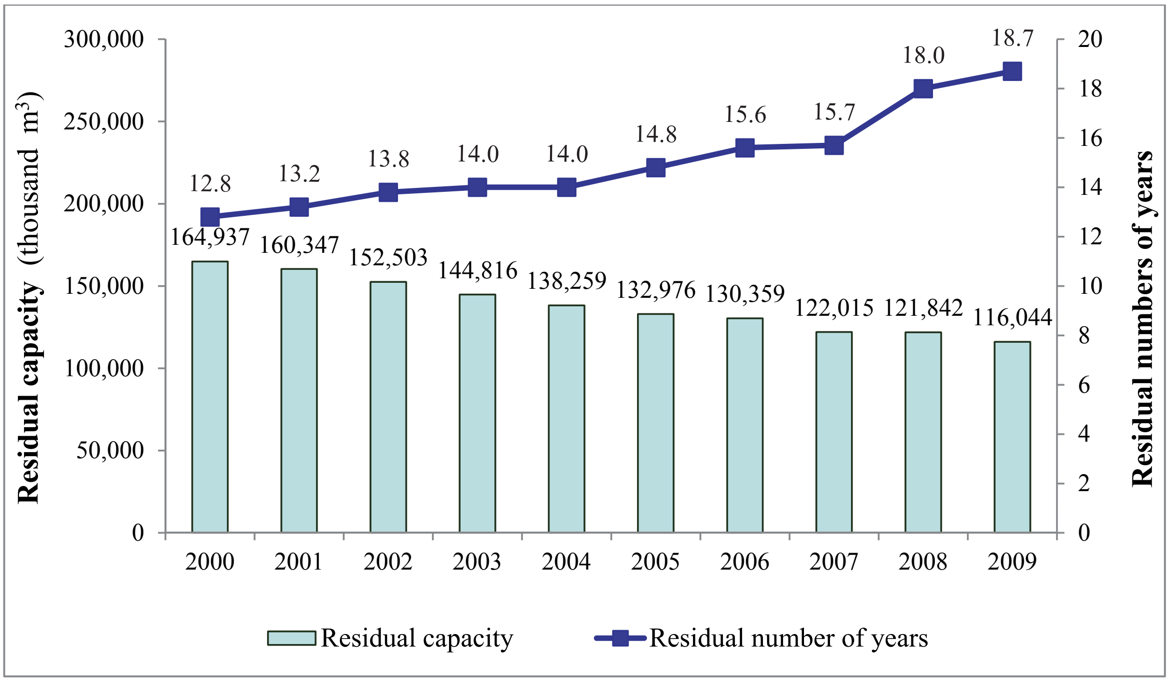


Figure 4.11-5 Changes in residual lifetime of landfill in Japan
Source: Sang-Arun, 2012 (modified from MOEJ, 2012)

In our study, GHG emissions from incineration and plastic recycling were estimated based on a lifecycle approach. In order to estimate the GHG emission from incineration of mixed waste contained plastic waste and packaging plastic recycling activities in Japan, Yokohama city has been chosen as a case. The City of Yokohama formulated "Yokohama G30 Plan" to promote separation of garbage and recyclables for recycling and at the same time to reduce garbage to be incinerated. As a result of Yokohama G30 plan implementation, 30% of the garbage has been reduced in the year 2010 as compared to the waste generation in 2001.

a) GHG emissions from incineration in Japan

For the estimation of the GHG emission from incineration in Yokohama, Kanazawa incineration plant was selected to obtain the plant specific data. The life cycle phases of the incineration process include MSW collection and transportation, then incineration and ends in electricity production and heat recovery. This plant was initiated in 2001 and it is operated by the Yokohama local government. The designed capacity of Kanazawa incineration plant is 1,200 tonnes/day and it consists three incineration units.

Based on the analysis results, it was revealed that GHG emission from waste transportation and fossil based waste combustion is amounted to 343 kg CO_2-eq/tonne of waste. Furthermore, mitigation of GHG emission from incineration due to the recovery of electricity and heat energy (use as alternative to replace for conventional electricity and heat production) amounted to 309 kg CO_2-eq/tonne of waste. Therefore, net impact of incineration on GHG emission amounted to 34 kg CO_2-eq/tonne of waste, see Figure 4.11-6.

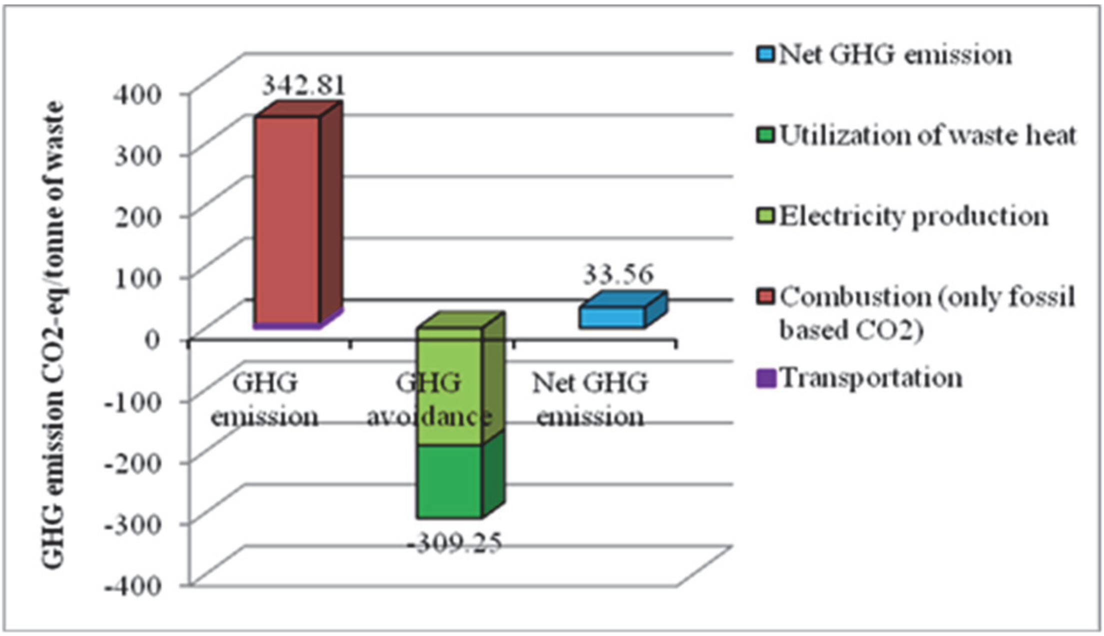


Figure 4.11-6: GHG emission, avoidance and net emission from mixed waste incineration in Kanazawakojo incineration plant

b) Packaging plastic recycling in Japan

In this study, an assessment was done on the collection and recycling of packaging plastics such as plastic bags, kitchen wrap, plastic tray, plastic bottle (except PET in this study due to the different collection and treatment system), plastic cup and pack, plastic cushioning, etc. Average collected packaging plastic waste from Yokohama city is 133 tonnes/day and approximately 14%-15% is transported to the recycling facility which is situated in Shizuoka prefecture. The rest of plastic waste is being treated in other plastic recycling facilities. Life cycle GHG emissions from the plastic recycling were calculated considering all the phases of the life cycle such as collection, transportation and the recycling process.

Life cycle GHG emissions from the overall recycling process have been calculated considering all the phases of the life cycle such as collection, transportation, baling and recycling process. Based on the analysis results, it was revealed that recycling process also consumes a significant amount of energy, and it has resulted in emissions of 478 kgCO_2-eq/tonne of mixed plastic waste. Furthermore, the emissions in the recycling were compared with the same amount of the material production process through the virgin production process chain, see Figure 4.11-7. GHG emission potential from an equivalent amount of virgin resin production process is much higher than that of recycling. Therefore, the resulting net impact from recycling amounted -853 kg CO_2-eq/tonne of plastic waste. The resulted net negative magnitude value revealed that, as a reward for the recycling of packaging plastics, there is a possibility for avoidance of 853 kg CO_2-eq of GHG emission per tonne of plastic waste.

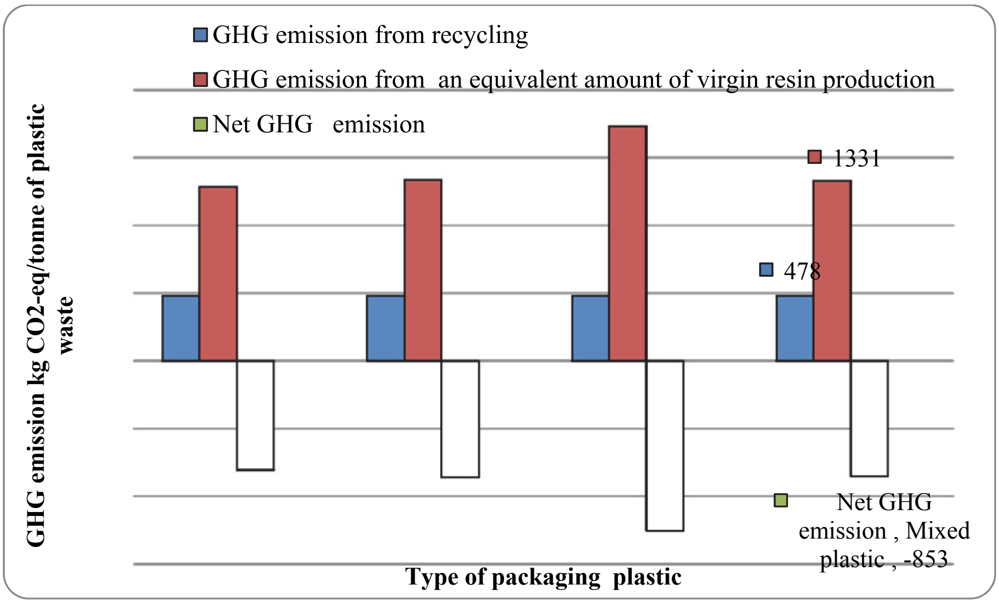


Figure 4.11-7: GHG emission from recycling, virgin resin production and net emission. (Note: mixed plastic represents 56% PE, 38 %PP, 6 % PS)

This analysis could not solely illustrate the different between incineration and recycling of plastic waste because the incineration in Yokohama city is applied for mixed municipal solid waste. However, this analysis clearly demonstrated that packaging plastic recycling generate less GHG emissions than incineration of mixed waste, even though the transportation distance of plastic waste for recycling is further than that of mixed waste for incineration. In practice, electricity generation potential from incineration is depend on the amount of plastic in the mixed waste. In one hand, combustion of high fraction of plastic could emit significant amount of fossil CO_2. On the other hand, if the amount of plastic waste is low in the mixed waste, electricity production capacity would drop significantly due to the low heating values of the combustibles.

Based on a LCA, the experiences of 3Rs implementation in Japan clearly illustrates that the 3Rs can significantly reduce GHG emission from not only the waste sector but also the other sectors. Nowadays, the major source of GHG emissions from the waste sector in Japan is carbon dioxide emissions from incineration. However, this emission can be minimized once the recycling of plastic waste increased.

5) Lesson learnt from case studies on municipal solid waste management in Thailand

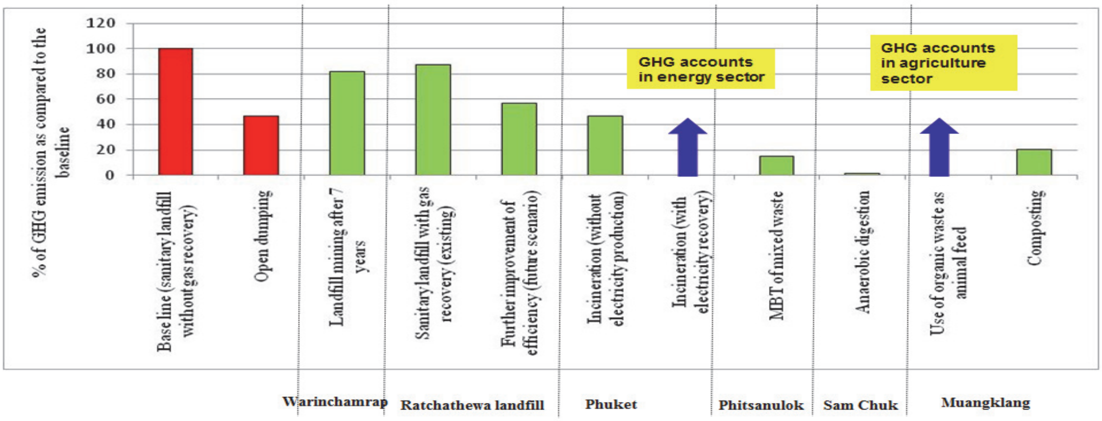
Thailand is selected for this study as it has various types of municipal solid waste treatment system including mechanical biological treatment (MBT) in Phitsanulok Municipality, anaerobic digestion in Sam Chuk and Muangklang Municipalities, landfill mining to waste plastic pyrolysis in Warin Chamrap Municipality, use of organic waste for composting and animal feed in Muangklang Municipality, sanitary landfill with gas recovery in Bangkok Metropolitan Administration, incineration with electricity generation in Phuket Island, and recyclable waste separation which is being practiced by both local authority and residents in many of municipalities in Thailand.

The GHG emissions from a life cycle of the above mentioned treatments were estimated by using the secondary data that provided by local authorities and the operators. Quantity of GHG emissions of each technology was varied depending on waste composition particularly on organic waste, except for incineration that depending on plastic waste. In addition, type of technology, machineries, transportation distances and management practices are other influencing factors on the GHG emissions especially when a life cycle approach is used for the estimation. The efficiency of GHG emissions reductions from these treatments were then compared with two baselines: deep sanitary landfill without gas recovery (>5 m depth) and shallow open dumping (<5 m depth).

As shown in Figure 4.11-8, GHG emissions from the deep sanitary landfill without gas recovery is higher than other treatments, while as the GHG emissions from open dumping is approximately 50% of the sanitary landfill. However, open dumping is no longer acceptable due to its negative impacts on health and environment. Therefore, many countries try to upgrade their final disposal sites from open dumping to sanitary landfill or incineration. As shown in the figure, to some extent, landfill mining and sanitary landfill gas recovery can reduce GHG emissions from the sanitary landfill: less than 10% reduction for landfill mining and less than 50% reduction for landfill gas recovery. The majority of GHG emissions are released to the atmosphere. The level of GHG emissions from incineration with no electricity generation are that of similar to open dumping, even though the source of emissions is different. However, investment and operation cost of incineration is very high. Furthermore, sanitary landfill and incineration do not associate efficient use of resources since many of valuable wastes are being buried or incinerated.

It is worth noting that GHG emissions from the incineration that equipped with electricity generation are accounted under the energy sector. GHG emissions from use of organic waste as animal feed are accounted under the agriculture sector.

Based on a lifecycle approach, contribution of incineration for electricity generation in Phuket is not significantly different from incineration without electricity generation because the majority (59%) of generated electricity is used for the plant operation (Figure 4.11-9).



Baseline for mixed waste management is sanitary landfilling of mixed waste without gas recovery.
The baseline of organic waste utilisation is sanitary landfilling of organic waste without gas recovery

Figure 4.11-8 GHG emissions from waste treatment facilities employed in Thailand – non-LCA (Sang-Arun and Menikpura, 2012)

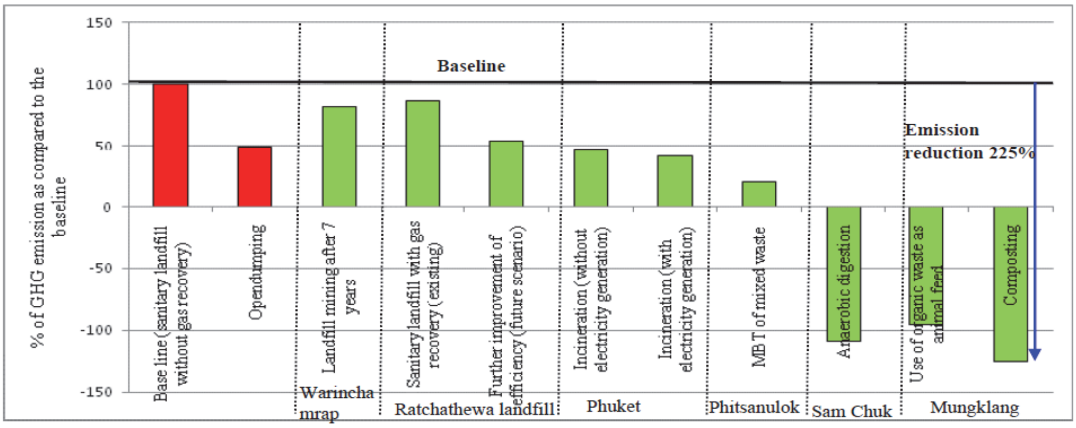


Figure 4.11-9 GHG emissions from various waste treatments employed in Thailand – LCA (Sang-Arun and Menikpura, 2012)

Amongst the waste treatments in Thailand, MBT, anaerobic digestion, animal feed and composting are a promising waste treatment technology for climate change mitigation due to several reasons: i) smaller amount of GHG emissions and less environmental impacts compare with open dumping, ii) provide co-benefits, depends on type of technologies, for instance, extending lifetime of landfill, providing soil amendment materials that can increase crop productivity, and generating alternative energy source, and providing alternative source for animal feed.

Use of good quality food waste for animal feed is being practice informally by farmers. It can significantly reduce cost of instant animal feed. Furthermore, it can reduce burden of local governments. Therefore, this kind of private initiatives should be promoted.

Anaerobic digestion releases less GHG emissions than composting and MBT. In addition, it can contribute both energy and soil amendment materials; however the investment and operation cost is relatively higher than composting and MBT. It is noteworthy to mention that, emissions from these technologies can be varied depending on the advancement of technology and management practices.

The benefits of organic waste utilisation technologies are more obvious when a lifecycle approach is taken into consideration. As shown in ***Figure 4.11-9***, anaerobic digestion, use of organic waste for animal feed and composting showed negative value because these treatments generate outputs that can replace or minimise GHG emissions in other sectors. For instance, anaerobic digestion generates biogas that can be used for replacement of fossil fuel use for electricity generation or firewood requirement for cooking. Anaerobic digestion and composting produce liquid fertiliser or compost that can minimise use of chemical fertiliser which can avoid GHG emissions from production of chemical fertiliser and on-farm emissions due to use of nitrogen fertiliser. In addition, all these biological treatments can avoid methane emissions from landfill. It is noted that climate benefits of use of discharge from anaerobic digestion and manure as organic fertiliser is not included in this estimation due to lack of data.

The comparative analysis of waste treatment in Thailand clearly illustrated that aerobic treatment (e.g. MBT) and utilization of organic waste as a resource (e.g. animal feed, compost, biogas) can significantly contribute to climate change mitigation better than landfill gas recovery or incineration.

6) Lesson learnt from pilot project in Cambodia

Cambodia is a least developed country that has relied on open dumping of municipal solid waste. IGES has implemented a pilot project to promote organic waste separation at source for composting. Waste separation at source is very new to Cambodia. Therefore, capacity building for all stakeholders including local governments, community, waste collection company, waste cleaning company, market operator and civil society is required.

After training, all stakeholders agree to implement a pilot project on organic waste separation at source for composting for climate change mitigation. At the implementation, there are several challenges occurred. However, all stakeholders discuss and find solution together. Therefore, the project can achieve increase of waste quantity to composting center and minimizing waste to disposal site. Additionally, the activity will be continued after the project end as all stakeholders have ownership on their activities.

7) Proposal to promoting the 3Rs and organic waste utilization for the Nationally Appropriately National Actions for climate change mitigation on municipal solid waste management in developing countries

7.1) Promoting the 3Rs for NAMAs

The benefits of organic waste utilisation are more obvious when its co-benefits on food and energy production are included in the estimation of GHG emission reduction. Therefore, it is recommended that reduce, reuse, utilisation of organic waste, and pre-treatment of organic waste prior to final disposal should be promoted and be included in the NAMAs as it could contribute to achieve sustainable solid waste management and climate change mitigation.

At present, many countries are developing national action plans on climate change which cover both mitigation and adaptation strategies. Some countries have already completed their action plans – e.g. China, India, Indonesia, Thailand and Bangladesh. The Philippines, Viet Nam, Malaysia, Laos and Cambodia are still developing theirs.

A summary of our findings is presented in Table 4.11-6. From the ten studied countries, six countries mentioned GHG emissions reduction in the waste sector: China, India, Indonesia, Thailand, the Philippines and Bangladesh. Amongst these, China, India, Indonesia, and Thailand have stated explicitly that they intend to promote the 3Rs for climate change mitigation. It is noteworthy that the three with the largest GHG emissions from the waste sector (China, India and Indonesia) have emphasized the 3Rs in their national action plans for climate change.

For the Philippines, a specific climate change act was notified in 2009 and a national framework strategy on climate change was finalised in 2010. The national framework emphasized the Ecological Solid Waste Management Act (RA9003) as the measure for climate change mitigation from the waste sector (CCC, 2010). The RA9003 act indicated the 3Rs practices for waste minimization and utilization (Congress of the Philippines, 2000), thus it could avoid GHG emissions from disposal and treatment of municipal solid waste.

Table 4.11-6 National climate change policy for the waste sector and 3Rs approach in selected developing Asian countries

Country	Mentioning of the waste sector (municipal solid waste)	Mentioning of the 3Rs approach (or similar) to climate change	Sources
China	Yes	Reduce, Recovery, Utilization	NCCCC, 2007
India	Yes	Reduction, Recycling	PMCCC, 2008
Indonesia	Yes	5Rs for industry & 3Rs for domestic waste	MENLH, 2007
Thailand	Yes	3Rs	ONEP, 2008
Philippines	Yes	3Rs	CCC, 2010
Bangladesh	Yes	No	MoEF, 2009
Viet Nam	No	No	MONRE, 2010
Malaysia	No	No	MOSTE, 2000
Cambodia	No	No	MOE, 2002
Laos	No	No	STEA, 2000

Note: Updated as of February 2011

Source: Sang-Arun et al, 2011

In all studied countries, governments placed priority on the energy sector. Generally, governments give lower attention to the waste sector as the share of GHG emissions from this sector is lower. However, we observed that most countries that announced their action plans in 2007 or later have accommodated the 3Rs into their national action plans for climate change mitigation strategies. Some countries that have not yet included the 3Rs in their national action plans actually practice the 3Rs to some extent. Further, some have integrated the 3Rs into their national waste management plan. Therefore, it is likely that the 3Rs will be included in the new national action plans on climate change.

Our observation was that overall the studied countries are interested in waste-to-energy (e.g. biogas and landfill gas recovery), recycling of non-organic waste, composting, and promoting use of compost for reduction of agrochemical use (Table 4.11-7). India, Philippines and Thailand mentioned waste separation at source, which this practice is very important for successful implementation of reuse and recycle. Further, the carbon market seems to be attractive to the studied countries as they are expecting to sell carbon credit to developed countries.

Table 4.11-7 Summary of strategies for national climate change mitigation in the waste and related sectors.

Countries	General 3Rs statement			Specific 3Rs strategy						Other policies that associate 3Rs implementation		
	Reduce	Reuse	Recycle	Waste separation at source	Composting	Anaerobic digestion	Landfill gas recovery	Incineration for energy recovery	Other waste to energy technology (e.g. fuel briquette, bio-ethanol)	Promoting use of compost	Reducing use of chemical fertilizer	Promoting use of biodegradable products
China	O	O	O		O	O	O	O	O	O		
India			O	O	O	O			O	O		
Indonesia	O	O	O			O			O	O		
Philippines	O	O	O	O	O				O	O		
Thailand	O	O	O	O	O				O		O	O
Bangladesh					O		O		O			

Source: Sang-Arun et al, 2011

7.2) Application of LCA for Nationally Appropriate Mitigation Actions (NAMAs)

LCA can clearly illustrate the effectiveness of GHG emission reduction of each technology better than the conventional approach that focuses on direct emission reduction. Therefore, the LCA should be applied for MRV especially in developing countries where end-of-pipe solutions are often selected for improvement of municipal solid waste management.

LCA studies can provide useful analyses of the potential climate impacts and benefits of various waste management options. Furthermore, the concept of life cycle thinking would help local authorities to realise the indirect paths that could possibly decrease the GHG emissions and other environmental impacts from waste management.

The ultimate goal of application of LCA would be used for identifying inefficiencies of waste management, improving efficiency of the waste management system, enhancing development of the mitigation actions and offset protocols, and promoting implementation of appropriate technologies that benefits to not only the waste sector but also others. Therefore, LCA approach would be a useful tool for development of NAMAs and promoting GHG accounting and carbon crediting under a new market mechanism.

Example of accounting 3R implementation for climate change mitigation at local level based on a LCA approach: Muangklang municipality

The Muangklang municipality is located in Rayong Province (190 km east of Bangkok). This municipality has initiated an integrated municipal solid waste management (IMSWM) system based on a 3R approach 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 4.11-10. Due to all these ongoing initiatives, Muangklang waste management has been identified by national governmental organizations like Thailand Environment Institute (TEI), as one of the best integrated waste management systems in Thailand.

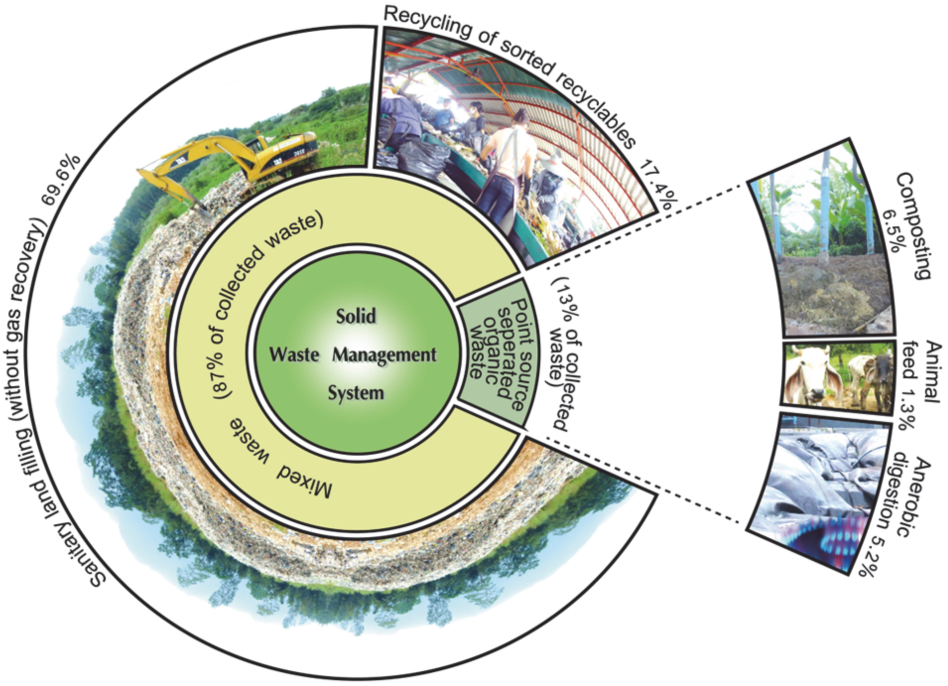


Figure 4.11-10 The existing IMSWM system in Mungklang municipality (percentages are calculated based on wet weight)

The current rate of solid waste collection is 23 tonnes/day. The people in the community have taken the initiative to separate a part of the organic fractions 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 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.

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 **Figure *4.11-11.*** In this case, the greenhouse gas savings from anaerobic digestion are 25 times higher than the direct greenhouse gas emissions and more than 75% of the savings are due to avoided landfill disposal.

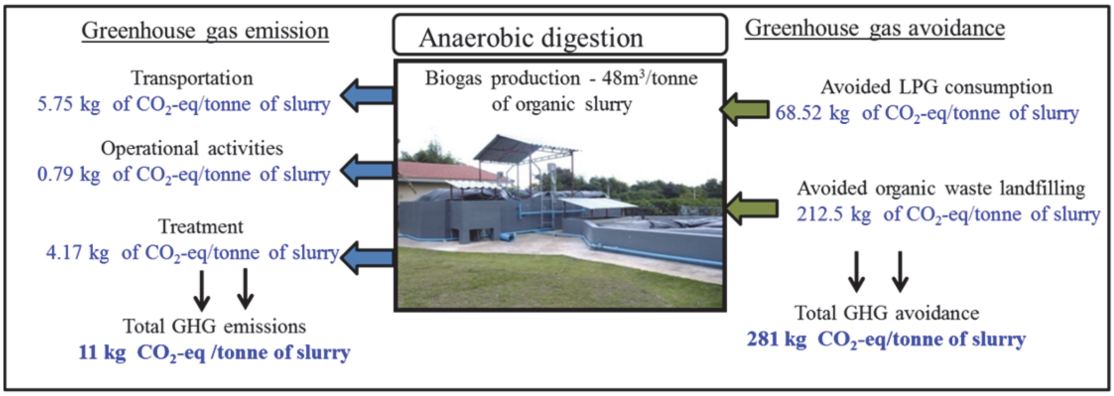


Figure ***4.11-11*** Greenhouse gas emissions and avoidance potential from anaerobic digestion in Muangklang (Note: Dry matter content of the organic slurry is maintained at 8.5%)

The direct greenhouse gas emissions from each of the treatment methods used in the integrated system are shown as the upwards arrows in Figure 4.11-12. Greenhouse gas saving potential is shown as downwards arrows in the figure. The results show that the greenhouse gas savings potential is higher than the direct emissions for most of the technologies based on resource recovery: materials recycling, composting and anaerobic digestion. Despite the greenhouse gas savings from resource recovery and reduced landfill disposal there are still emissions from the integrated system. This is mainly because the fraction of waste landfilling is still rather high (69.6%). Net greenhouse gas emission from the current integrated system amounts to 287 kg CO_2-eq/tonne of waste collected, see the lower part of the figure.

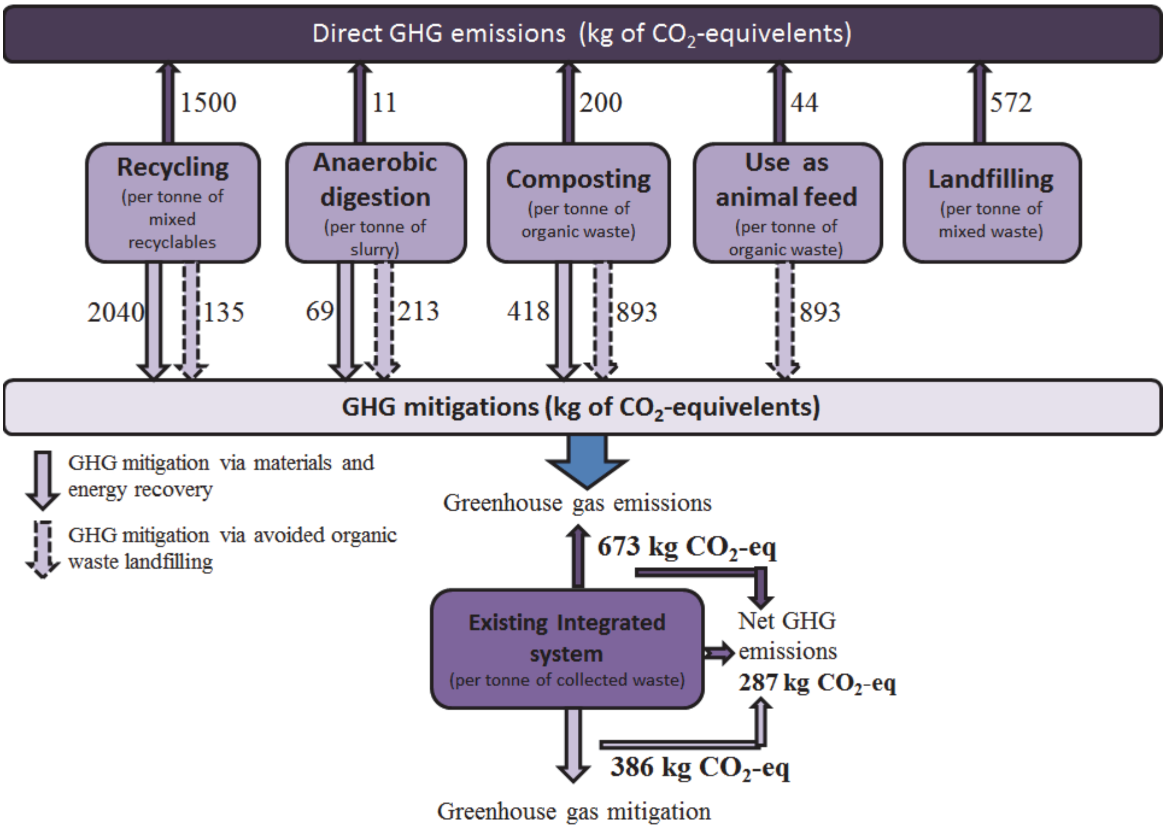


Figure 4.11-12: Greenhouse gas emissions and greenhouse gas avoidance potential of individual technologies and of the whole integrated system in Muagnklang Municipality

If Muagnklang had been like most of other municipalities in Thailand, it's 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). As shown in Figure 4.11-13, the current integrated system has achieved a substantial reduction in greenhouse gas emissions compared to the two most common treatment methods currently used in Thailand: sanitary landfilling without gas recovery (60% reduction) and open dumping (17% reduction). 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 achieve additional reductions. With such further improvement it may even be feasible to achieve zero net greenhouse gas emissions.

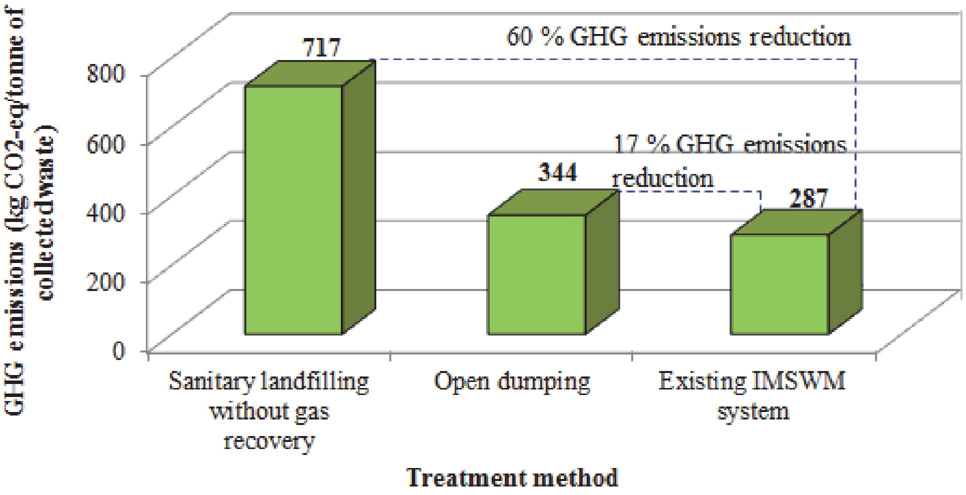


Figure 4.11-13: Comparison of greenhouse emissions of two business as usual scenarios and the existing IMSWM system in Mungklang municipality

For instance, by improving the resource recovery rate from the current 30.4% (recycling 17.4% + organic waste utilisation 13.0%) to 47.9% (recycling 30.0% + organic waste utilisation 17.9%), the integrated system would result in zero net greenhouse gas emissions and thereby be carbon neutral. This is possible since at this level of resource recovery, the avoidance of greenhouse gas emission via energy and material recovery would fully compensate the greenhouse gas emissions from the system itself. The required level of resource recovery to achieve zero net greenhouse gas emissions from an integrated system would vary from one location to another based on the composition of waste and would also depend on other factors, such as energy efficiency of recycling and types of energy used.

This case study demonstrates that it is possible for municipalities in developing Asia to achieve climate-friendly waste management by adapting appropriate the 3Rs in an integrated waste management system.

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