Integrated Solid Waste Management: An Approach for Net Zero Greenhouse Gas Emissions through Resource Recovery

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Introduction

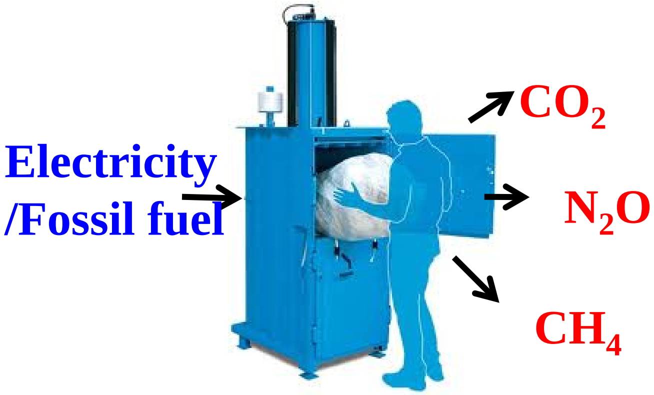
- Municipal solid waste (MSW) management is becoming increasingly pressing matter in many developing countries
- In Asia, MSW generation surpasses 760,000 tonnes/day and, this figure will increase to 1.8 million tonnes /day in 2025
- Many developing Asian countries are practicing open dumping and sanitary landfilling without gas recovery as main disposal methods
- Such poor waste management has caused severe deterioration of environment, economic losses and social burdens
- Application of high-end technologies may not be the immediate solution since such technologies cannot best suit to the local conditions of the developing countries

Current Waste Management and Global Climate Change

- Greenhouse Gas (GHG) emission from waste management activities, and its contribution to climate change is one of the critical environmental concerns

- Each and every step of waste management can cause GHG emissions

Phase I-GHG emission from waste transportation



Phase II-GHG emissions from pre-processing

Phase III -GHG emissions from treatment/final disposal
CH_4emission from open dumping and landfilling - third highest anthropogenic CH_4 emission source

Integrated Solid Waste Management (ISWM): A Practical Solution Towards Zero GHG Emission

- ISWM would be the most promising approach to solve the waste management crisis since it provides multiple benefits from waste

Integrated waste management

Social benefits

Improve the well-being of the local community
- Creation of jobs
- Improving the indirect income generation ways

Environmental benefits

Improve the efficiency waste management and reduce the emissions to air, water, soil

Economic benefits

Creation of ways of revenue generation to all the stakeholders in waste management process chain

Environmental benefits

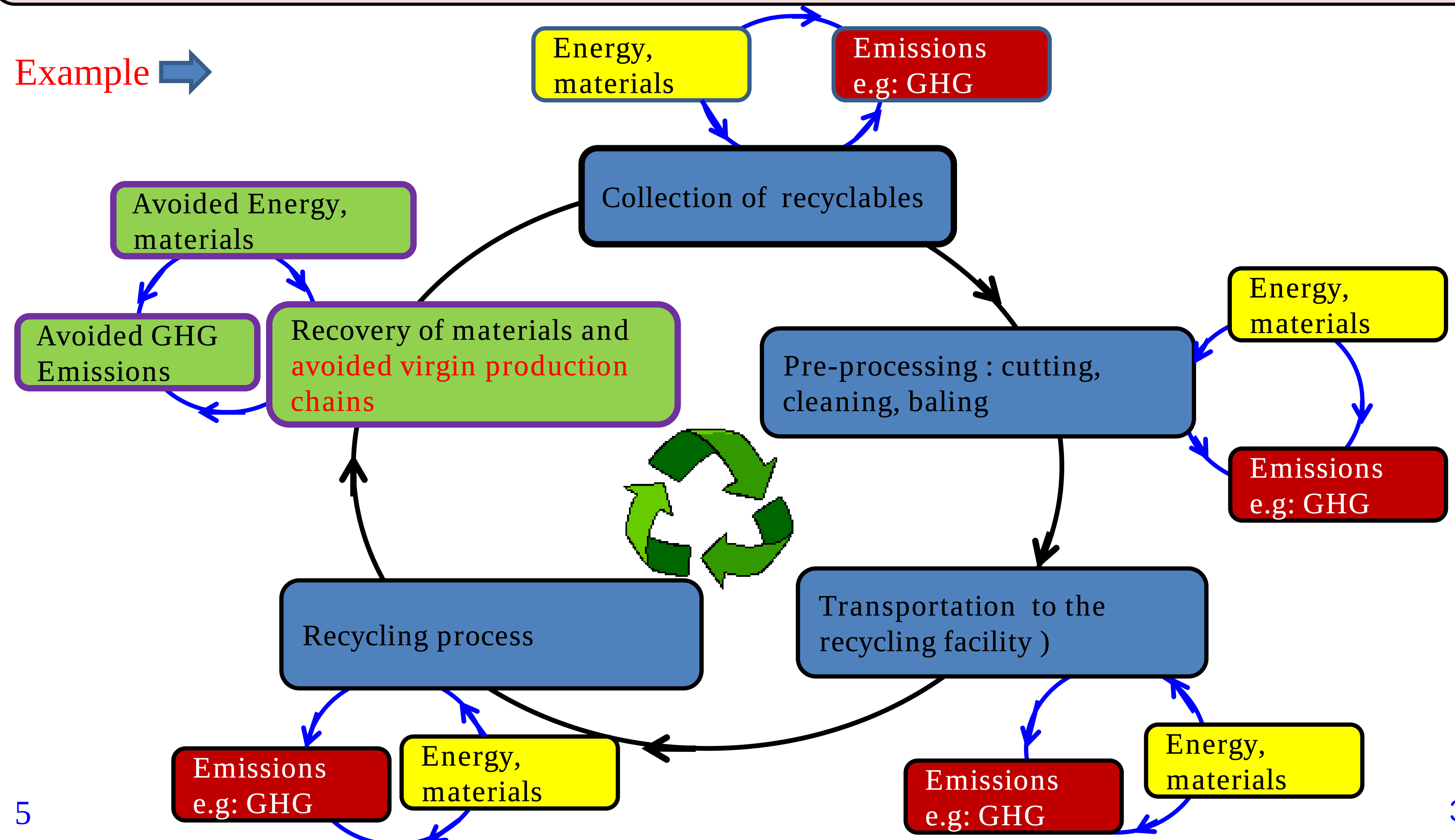
Recovery of materials and energy from waste and replace the conventional production processes

- These benefits from ISWM can be achieved by selecting and adapting the best suited technologies to a particular municipality

How Does ISWM System Contribute for GHG Mitigation?

Materials and energy recovery from waste could contribute to significant GHG reduction that would otherwise occur through the conventional processes

Example



How Does ISWM System Contribute for GHG Mitigation?

Recycling

Plastic recycling

Energy →

← GHG

Waste Plastic- one tonne

→

Recycled Plastic- 900kg

←

Replace virgin plastic

← Energy crude oil (1400 kg)as raw materials

→ GHG

Paper recycling

Energy →

← GHG

Waste Paper

→

Recycled Paper

←

Replace virgin paper

← Energy

→ GHG

How Does ISWM System Contribute for GHG Mitigation?

Anaerobic digestion

Biogas production form organic waste

Organic waste

Energy GHG

Biogas production

Avoid conventional fossil fuel

Energy GHG

Avoid organic waste landfilling

Energy GHG

Composting

Compost production from organic waste

Organic waste

Energy GHG

Marketable compost

Avoid conventional fertilizer

Energy GHG

Avoid organic waste landfilling

Energy GHG

Towards Zero GHG Emissions via Life Cycle Thinking

- Zero GHG emissions via "Zero waste" concept is too ambitious goal for developing Asian countries to achieve with the current trend of waste generation
- The immediate solution would be the promotion of conceptual ideas to achieve "zero GHG emission" via ISWM
- Maximizing resource recovery from waste would minimize the GHG emissions that would other wise occur from rudimentary waste management practices (landfilling) as well as conventional materials and energy production processes

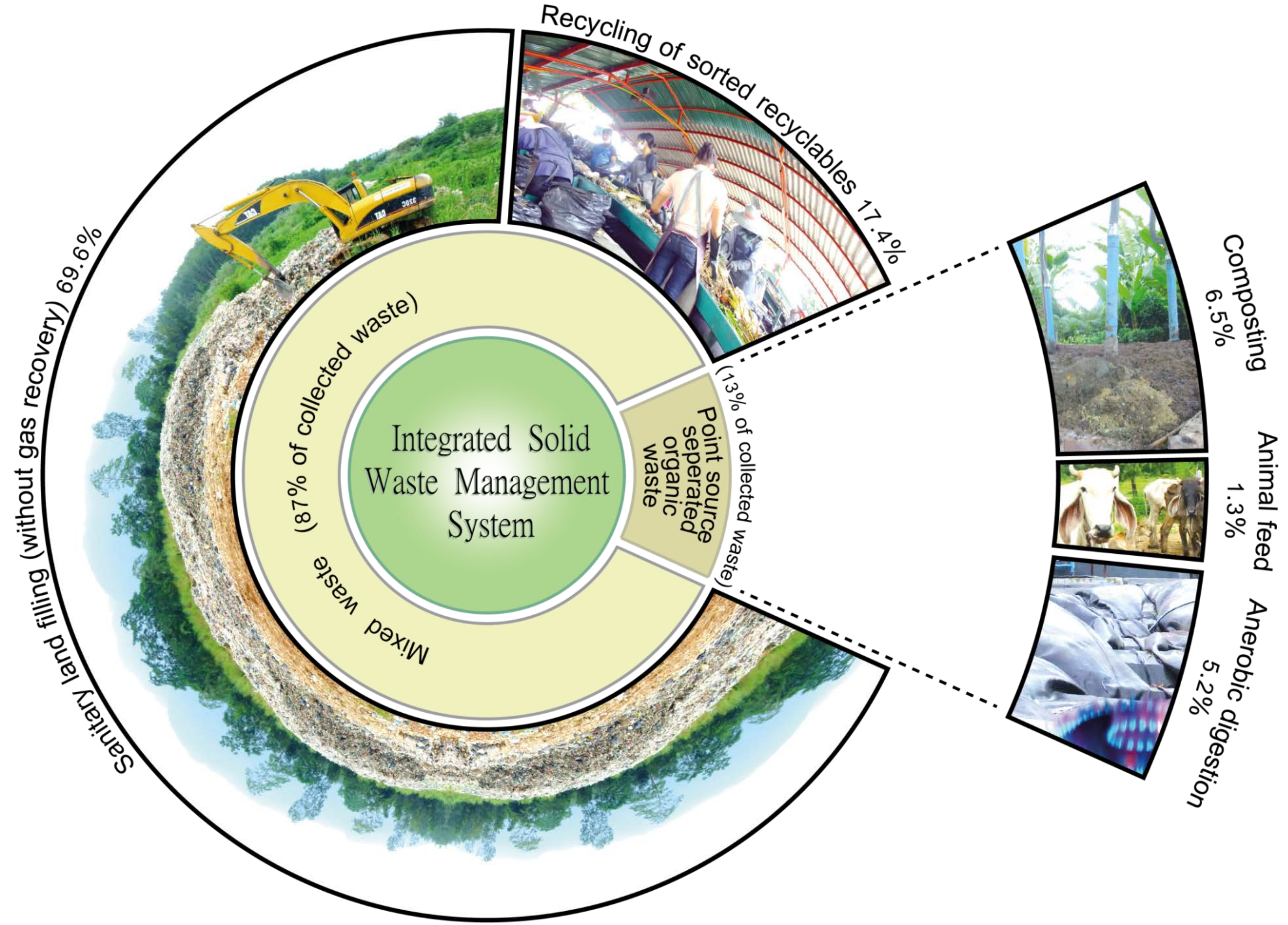
GHG emission from the integrated system - GHG saving/avoidance via resource recovery ≤ 0

Methodology

Selection of the study location

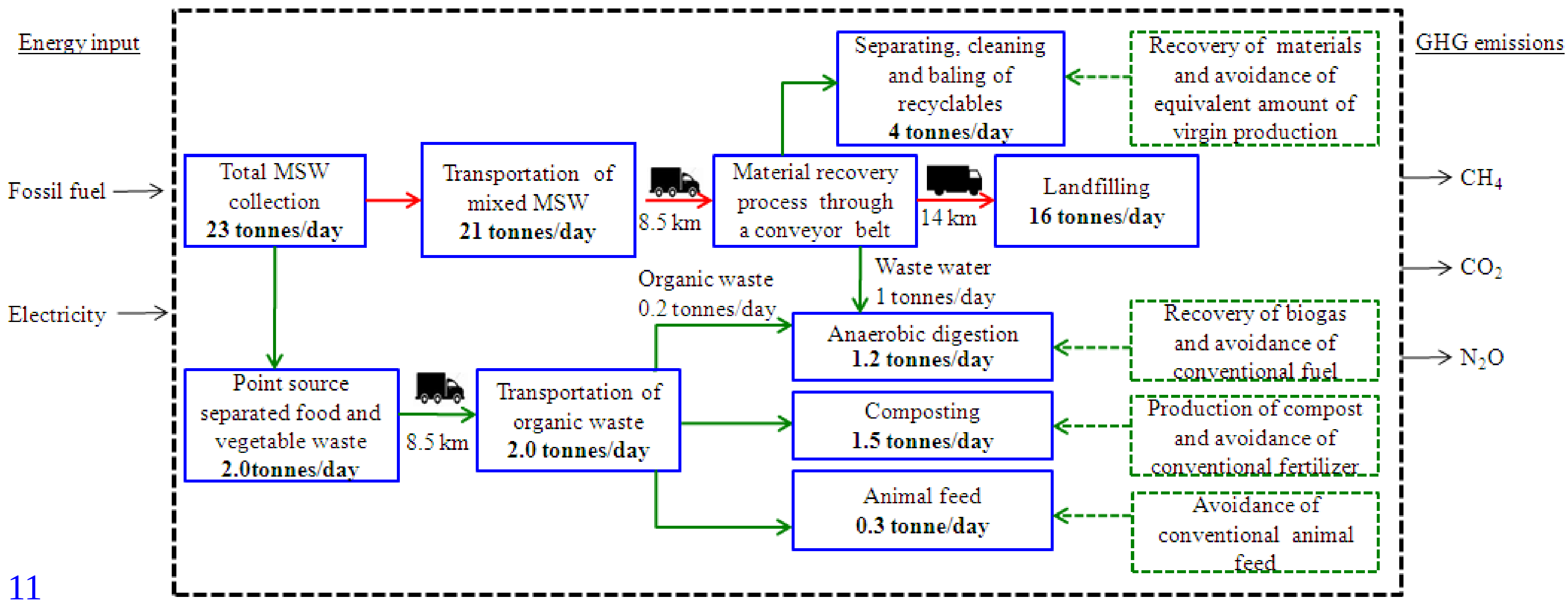
- GHG mitigation potential via ISWM was evaluated by using an example in practice
- The Muangklang Municipality is located in Rayong Province (190 km from East Bangkok)
- It has a total of 13 communities and covers 14.5 km^2
- The registered population within the Municipality -17,200 (Dec 2010)
- This municipality has initiated an ISWM system as a sustainable solution by incorporating effective waste collection and transportation service, waste sorting facility for recovery of recyclables, anaerobic digestion facility, composting facility, raising some farm animals to feed organic waste and so on

Existing ISWM in Mungklang Municipality, Thailand



Development of LCA Framework for Estimating GHG Emissions from ISWM System

- Life Cycle Assessment (LCA) is a useful methodology for estimating the possible mitigation options of environment impacts
- LCA framework designed considering all the phases of integrated system
- Inventory analysis was performed to account fossil fuel and electricity consumption, recovery of materials/energy from waste treatment methods and potential avoidance of materials/energy production from virgin processes



Quantification of Life Cycle GHG Emissions from ISWM System

Mathematical formulas were derived to quantify GHG emission from different phases

Activity/life cycle phase	**Mathematical formula to quantify GHG emissions**
I - GHG emissions from waste transportation	
Emission of CO_2, CH_4, N_2O owing to fossil fuel combustion[a]	$E_{Transportation} = \sum_j (Fuel \times EF_j \times GWP_j)$ $E_{Transportation}$ –GHG Emissions from transportation (kg CO_2 -eq/tonne of collected waste) Fuel – Amount of fuel used (MJ/tonne of collected waste) EF_j – Emission Factor of type j GHG (kg/TJ) GWP_j – Global Warming Potential of type j GHG (kg CO_2 -eq/kg of j^{th} emission)
II - GHG emissions from operational and maintenance activities	
Emission of CO_2, CH_4, N_2O owing to fossil fuel combustion for operating machines. Emission of GHG owing to grid electricity production with respect to the electricity consumption for machine operations [a]	$E_{Operation} = \sum_i (EC_i \times EF_{el}) + \sum_{i.j} (FC_i \times NCV_{FF} \times EF_{i.j} \times GWP_j)$ $E_{Operation}$ –Emissions from operational activities (kg CO_2/tonne of treated waste) i - i^{th} operational activity (loading of waste to the conveyor, delivery of waste through conveyor belt) ECi - Electricity consumption apportioned to the activity type i (MWh/tonne of treated waste) EF_{el} - Emission factor for grid electricity generation (kg CO_{2-}eq/MWh) FC_i - Fuel consumption apportioned to the activity type i (mass or volume/tonne of treated waste) NCV_{FF} - Net calorific value of the fossil fuel consumed (TJ/unit mass or volume) $EF_{j.i-}$ Emission factor of a j^{th} GHG by activity type i (kg of GHG/TJ) GWP_j – Global Warming Potential of type j GHG (kg CO_2 -eq/kg of j^{th} emission)

Quantification of Life Cycle GHG Emissions from ISWM System

Activity/life cycle phase	Mathematical formula to quantify GHG emissions
III - GHG emissions from biological treatment: Anaerobic digestion and composting	
Emission of CH_4 and N_2O from the biological degradation of organic waste[b]	$E_{Treatment} = (E_{CH4} \times GWP_{CH4} + E_{N2O} \times GWP_{N2O})$ $E_{Treatment}$ – Emissions from treatment of organic waste (kg CO_2/tonne of organic waste) E_{CH4}- Emission of CH_4 during waste degradation (kg of CH_4/tonne of organic waste) GWP_{CH4}- Global warming potential of CH_4 (25 kg CO_2/kg of CH_4) E_{N2O}- Emission of N_2O during waste degradation (kg of N_2O/tonne of organic waste) GWP_{N2O}- Global warming potential of N_2O (310 kg CO_2/kg of N_2O)
IV - GHG emissions from use of organic waste as animal feed	
CH_4 emissions from animal manure management. CH_4 emission from enteric fermentation is assumed to be negligible from the type of animals raised at Muangklang[b]	$E_{Treatment} = \sum_i (E_i \times a_i) \times \frac{1}{x} \times GWP_{CH4}$ $E_{Treatment}$ = Emissions from treatment by utilizing organic waste as an animal feed (kg CO_2/tonne of organic waste) E_i- Emission factor from manure management for i[th] livestock category (kg CH_4 head^{-1}year^{-1} a_i _ No of animals belongs to i[th] category x – Total amount of organic waste used as animal feed materials (tonnes/year) GWP_{CH4}- Global Warming Potential of CH_4 (kg CO_2 -eq/kg of CH_4)
V - GHG emissions from final disposal at the sanitary landfill	
CH4 emissions during the waste degradation in the landfill[b]	IPCC 2006 waste model was used to quantify the CH_4 emission from waste degradation

$$GHG_{\text{Direct emissions}} = E_{\text{Transportations}} + E_{\text{Operations}} + E_{\text{Treatment}}$$

$$GHG_{\text{Avoidance}} = \sum_i (PA_i \times EF_i)$$

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

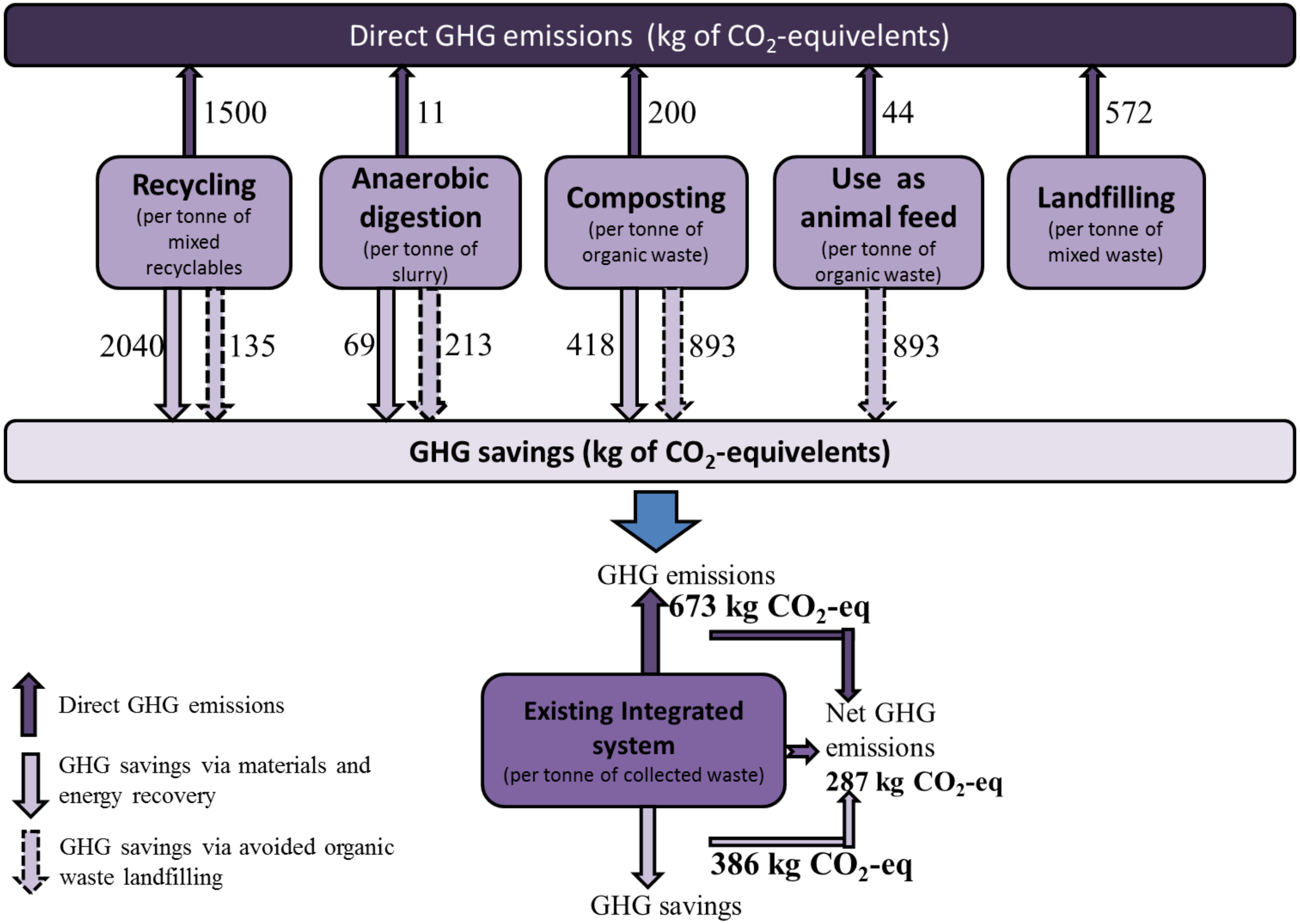
Results and Discussions

Inventory Analysis

•Quantification of input energy, recovered and avoided energy and materials (through the conventional processes) from different treatment methods are the key information to estimate GHG emission

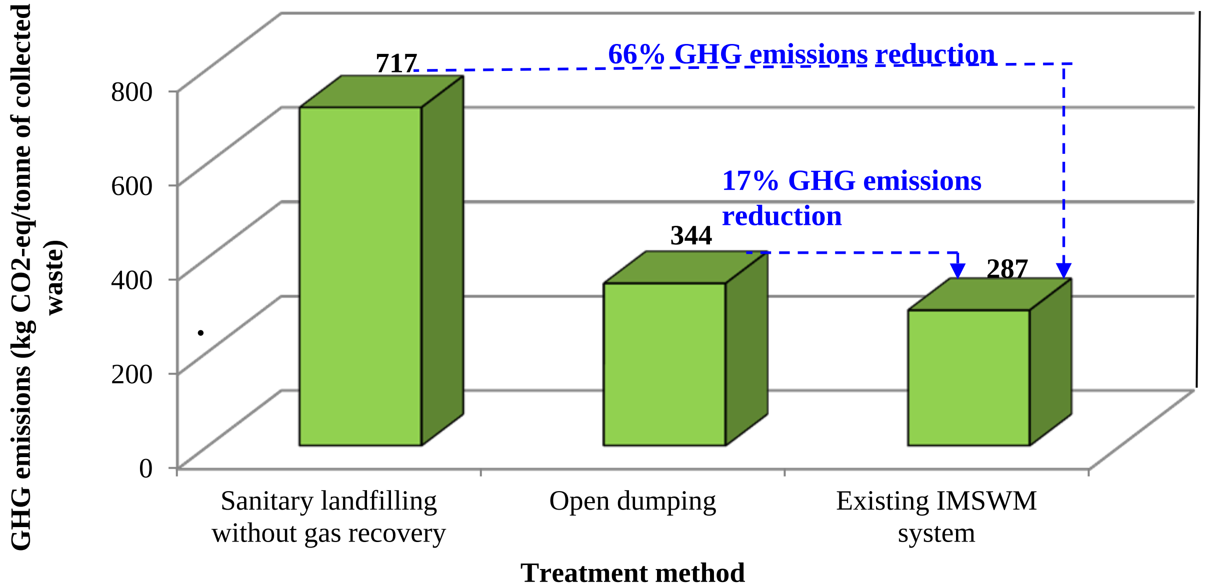
Life cycle phase/Treatment method	Unit	Amount of input energy/ materials	Amount of recovered energy/materials	Avoided energy/materials consumption for conventional production processes
Transportation	Per tonne of waste	Diesel fuel – 2.13 L	0.00	0.00
Recycling	Sorting of per tonne of mixed recyclables	Electricity – 1.54 kWh	Recovered mixed recyclables – 1000 kg	0.00
	Recycling of per tonne of mixed recyclables	Electricity – 193 kWh Hard coal – 146 kg Soft coal – 350 kg Heavy fuel oil – 29 kg Natural Gas – 304 m^3	Recycled paper –357.2 kg Plastic granules – 360 kg Aluminium ingot –38 kg Recycled steel – 45 kg Recycled glass – 95 kg	Electricity – 1043 kWh Hard coal – 261 kg Soft coal – 240 kg Heavy fuel oil – 376 kg Natural Gas – 364 m^3
Anaerobic digestion	Per tonne of organic slurry	Diesel fuel – 0.29 L	Biogas – 49.33 m^3	LPG – 40.8 L
Composting	Per tonne of organic waste	Diesel fuel – 1.76 L	Compost – 194 kg	[c] N –1.38 kg P – 0.79 kg K – 1.05 kg
Landfilling	Per tonne of mixed waste	Diesel Fuel – 4.52 L	0.00	0.00

GHG emissions and savings potential from individual technologies and ISWM system



• Net GHG emission from the ISWM system is still positive due to high fraction of waste landfilling (69.6%)

GHG emission reduction from existing ISWM system as compared to the "business-as-usual" practice



- GHG emission reduction via the existing ISWM system in Mungklang municipality is significant as compared to the "business-as-usual" practices
- There is a possibility that Mungklang municipality can reach to "net zero GHG emission" level even by upgrading the capacity of recycling and biological treatments

Conclusions

- This assessment revealed that replacement of conventional disposal methods with appropriate ISWM, which designed for maximum resource recovery would be the key driving force towards "zero GHG emissions" or beyond
- GHG emissions from exiting ISWM system amounts to 287 kg CO_2-eq/tonne of MSW collected, which is only 34% emissions from sanitary landfilling
- The ISWM system could soon become a net carbon sink if the municipality make further efforts to expand the existing technologies
- ISWM system implemented by Muangklang municipality, useful as a practical model for demonstrating and promoting ISWM elsewhere
- Initiation of ISWM methods by targeting "net zero GHG emissions" would shift the entire waste management from "being part of the key problem" to "being part of the solution" in sustainable development

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THANK YOU VERY MUCH FOR YOUR ATTENTION

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