GHG EMISSION AND ABATEMENT POTENTIAL ASSESSMENT: THE CASE OF SOLID WASTE MANAGEMENT SYSTEM IN METRO MANILA, PHILIPPINES

Jovelyn Ferrer [a]
[a] Center for Sustainable Human Development, Development Academy of the Philippines
San Miguel Ave., Ortigas Center, Pasig City, Philippines.
[a] Corresponding author: jgferrer2003@yahoo.com

©Ontario International Development Agency ISSN: 1923-6654 (print)
ISSN 1923-6662 (online). Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: Management of solid waste has always been a problem in our society. With economic growth, lifestyle changes and population increase, challenges are expected to aggravate. The negative impacts related to solid waste management (SWM) can be considered as a local problem with global implication considering the resource, energy and greenhouse gas emission associated with it. The goal of this study is to assess the challenges of SWM in Metro Manila, Philippines in terms of greenhouse gas (GHG) emission as well as the abatement potentials.

Solid waste is recognized as an important contributor to global warming due to methane (CH_4) emission from solid waste disposal sites. Through the first-order decay method, emission from the region's solid waste disposal sites was quantified. The resulting amount of CH_4 emission was used to estimate the potential of utilizing landfill gas (LFG) for energy. The estimate shows significant amount of energy that could be provided by LFG-to-energy instead of fossil fuel source.

Over all GHG emission from SWM practice was also assessed through the life cycle inventory (LCI). Among the SWM elements considered are collection, transportation and landfilling. The result affirms that CH_4 from landfilling has the greatest contribution to the SWM GHG emission. Although emission from the fuel consumption when collecting and transporting is very low as compared to landfilling emission, it is still important to be addressed for environmental protection and economic benefits. As the scenarios suggest, emission could be reduced if the amount of waste to be transported will be lessened and if the LFG will be recovered and used for energy.

Keywords: GHG emission, landfill, methane, solid waste management, waste-to-energy, life cycle inventory

INTRODUCTION

Management of solid waste has always been a problem in our society. With economic growth, lifestyle changes and population increase, challenges are expected to aggravate. The negative impacts related to solid waste management (SWM) can be considered as a local problem with global implication considering the resource, energy and greenhouse gas emission associated with it. Developing countries face more challenges from managing their solid waste because of lack of financial resources and low awareness and education.

The goal of this study is to assess the challenges of SWM in Metro Manila, Philippines in terms of GHG emission as well as the abatement potentials specifically by quantifying GHG emission from the active solid waste disposal sites (SWDS) where Metro Manila dumps solid wastes, estimating the GHG abatement potential through CH_4 collection and utilization for energy and assessing various SWM system through the life cycle inventory (LCI). The assessment is aimed to provide options for SWM managers and policy-makers in their decision-making and contribute towards a sustainable SWM in the Philippines.

Metro Manila was chosen as the study area due to the high volume of solid wastes generated in the region. Among the active disposal sites that were assessed are Payatas Controlled Dump Facility (CDF), Navotas New Sanitary Landfill (NSL), Rizal Provincial Sanitary Landfill (PSL) and other smaller dumpsites.

METHODOLOGY

First order decay model and energy potential estimation

The US EPA methodology for estimating CH_4 emissions from SWDS, an approach similar to IPCC (2006) methodology [1], was adapted in this research. It is based on the first order decay (FOD) method which acknowledges that methane is not released instantaneously and that it assumes that the degradable organic component (degradable organic carbon, DOC) in wastes decays slowly. The FOD method provides a time-dependent emission profile that reflects the true pattern of the degradation process over time [2]. This approach has been used extensively in modeling landfill gas generation rate curves for individual landfill. Waste input data (M) for each solid waste disposal sites used in the CH_4 emission calculation were gathered from the Metro Manila Development Authority (MMDA).

The formula for CH_4 emission estimation is given by Eq. 2.1.

$$Q_{CH4} = [k\ L_o M_i\ (e^{-kti})] * (1\text{-}OX) \qquad \text{(Eq. 2.1)}$$

Where:

Q_{CH4} = methane emission rate, m^3/yr

k = methane generation rate constant, $year^{-1}$

L_o = methane generation potential, m^3 of CH_4/MT of refuse

M_i = mass of the waste in the *i*th section (annual increment), MT

T_i = age of the $_i$th increment (or section), in years

OX = oxidation

Methane generation rate constant (k) is based on the environment in which the SWDS is located. The 2006 IPCC Guidelines for GHG inventories [1] provides default k values for various type of waste under different climate zones. Since Philippines is a tropical country with mean annual precipitation of more than 1000 mm, 0.17, as suggested value for k, was used.

Methane generation potential (L_o) depends upon the composition of the waste and varies widely. This is given by Eq. 2.1.1.

Mass of the waste (M_i) is the average annual waste acceptance rate during the SWDS's active life.

Oxidation (OX) reflects the amount of CH_4 from SWDS that is oxidized in the soil or other cover materials of the waste (see Table 1 for the OX factors). This parameter acknowledges that methane can be oxidized by methanothrophic micro-organisms as LFG passes through the landfill cover [1, 3].

The formula for L_o calculation is given by the Eq 2.1.1 below.

$$L_o = MCF * DOCf * FCH_4 * 16/12 * 1/CH_4\ \text{density} * DOC \qquad \text{(Eq. 2.1.1)}$$

Where:

MCF = methane correction factor

MCF reflects the way in which the landfill is managed and accounts for the fact that unmanaged SWDS produces less CH_4 than anaerobic managed SWDS. IPCC methodology default MCF value for managed SWDS is 1 while for unmanaged and uncategorized is 0.6.

DOC_f = fraction of degradable organic carbon (DOC)

This is equal to the portion of DOC that is converted to landfill gas. This value is dependent on many factors such as temperature, moisture, pH, composition of waste etc and may vary from 0.42 for 10^oC to 0.98 for 50^oC. IPCC methodology default value is 0.5, which corresponds to the assumption that the environment is anaerobic and the DOC values include lignin.

F_{CH4} = fraction of CH_4 in landfill gas

The default value 0.50 was used in this calculation.

D_{CH4} = density of the methane (equal to 0.0007168 t/m^3)

DOC = degradable organic carbon

This refers to the organic carbon in waste that is accessible to biochemical decomposition. DOC for bulk waste is estimated based from the composition of waste and can be calculated from a weighted average of the degradable content of the different organic waste type in the waste stream (see Table 2). Eq. 2.1.2 estimates DOC using default carbon content values where DOC values where adapted from the IPCC methodology [1].

$$DOC = DOC_i * W_i \qquad \text{(Eq. 2.1.2)}$$

Where:

DOC_i = DOC value for waste type i

W_i = percentage of waste type i by waste category

Table 1: Oxidation (OX) factors for SWDS

Type of site	OX default
Manage [1], unmanaged and uncategorized SWDS	0
Managed [2], covered with CH_4 oxidizing material	0.1
[1]Managed but not covered with aerated material [2]Examples: soil, compost	

Source: IPCC Guidelines for National GHG Inventories

Table 2: DOC values for different waste type and MM percentage of waste type

Organics	DOC values	Percentage of waste type in MM
Paper	0.4	12.5
Garden and Park Waste	0.2	0
Food Waste	0.15	32.7
Wood and straw waste	0.43	0
*other organics	0.24	17.4
DOC		0.14
*average of IPCC default DOC values for textiles, garden and park waste, and nappies		

Source: IPCC Guidelines for National GHG Inventories

Table 3: Parameters for L_o calculation

Type of SWDS	MCF	DOC_f	FCH_4	Molecular weight ratio CO_2/CH_4	$1/CH_4$ density (MT/m^3)	DOC	L_o (m^3/MT)
Managed	1.00	0.50	0.5	1.33	1395.09	0.14	65
Unmanaged	0.60	0.50	0.5	1.33	1395.09	0.14	39
Managed	1.00	0.70	0.5	1.33	1395.09	0.14	91
Unmanaged	0.60	0.70	0.5	1.33	1395.09	0.14	55

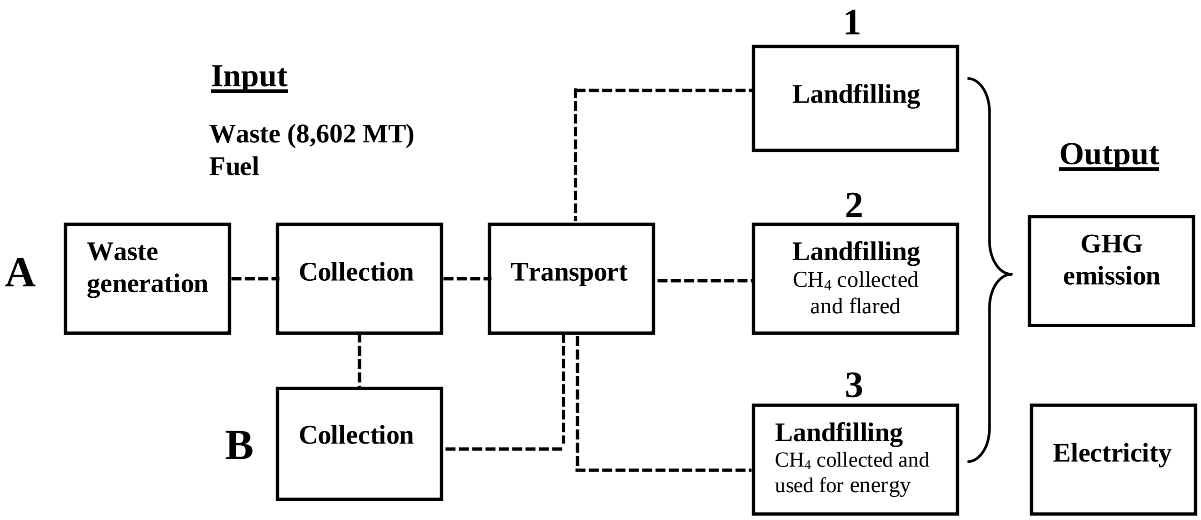

Figure 1: System boundaries

Table 4: Formula and calculated emission coefficient value for each element

Emission Coefficient	Formula	Value	Source
EC_c	$\sum$[Fuel used/trip * GHG$_{i\ inventory}$/diesel thermal value * (GHG$_{i\ mol.\ mass}$/CO$_{2\ mol.\ mass}$) * GWP$_{GHGi}$]	24.28 kg CO_2e/MT	calculated
EC_t	Same as above	27.40 kg CO_2e/MT	calculated
EC_l	CH4 emission/MT * CO_2 density *GWP$_{CH4}$	4,052.85 kg CO_2e/MT	calculated
EC_f	*CO_2 emissions from LFG combustion are of biogenic origin and should not be included in the national total	*0	IPCC (2006) [1]
EC_e		-0.6138 kg CO_2e/KWh	Montalban PDD [9]

.

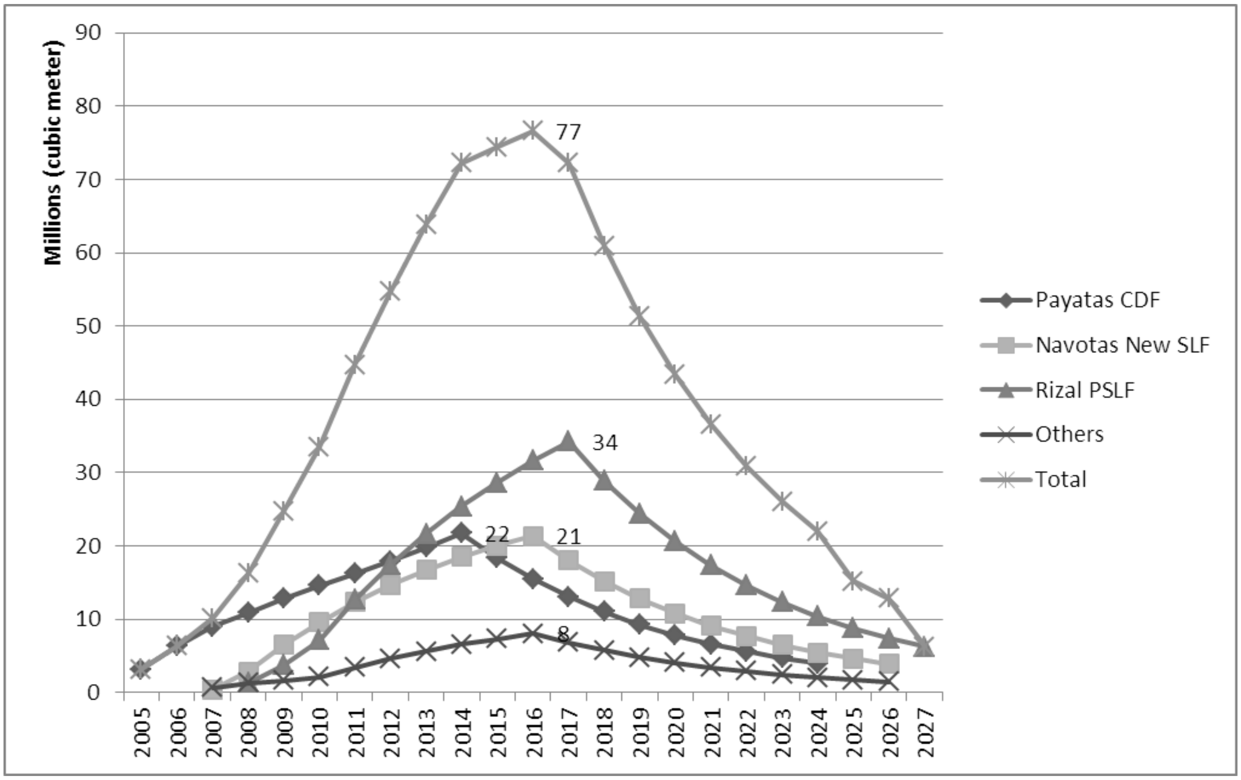

Figure 2: Methane emission of active SWDSs in 20 years within a 10-year operation

By multiplying the percentage of waste type by the default DOC values for each type, 0.14 DOC value was obtained. Table 3 shows the L_o using different values for the parameters used.

The resulting methane emission in each landfill was used to estimate the gross power generation potential based from US EPA methodology as used by Thuy P.C [4]. Consequently, the result was used for calculating the electricity outputs. Eq. 2.2.3 was used for this estimation.

kWh = methane gas flow * energy content * 1/heat rate * 1d/24 hr * OP (Eq. 2.2.3)

Where:

methane gas flow= net quantity of methane gas captured per day (m^3/d)

energy content = for methane gas 37,630 Btu/m^3 or 39700 kJ/m^3

heat rate = an assumption of 11,000 Btu/kWh was used

OP = operating hours (6,935hrs/yr)

Collection and transportation distance

Collection and transportation distances as well as fuel consumption, which are needed for the collection and transportation emission calculation, were acquired from each LGU. In cases where LGUs do not have the data, collection distance was estimated. For Marikina, Las Piñas and Valenzuela, actual collection distances were obtained through the Garmin Foretrex 101 GPS loggers which were attached to the collecting trucks. The data from the loggers were retrieved through the Map Source software. Collection distances per trip were determined by identifying the coordinates of each trip's starting point and last point which is the transfer station or SWDSs. The software displays the distance between the identified points.

The transportation distances were estimated since there is no actual data available. Coordinates of the center point for each LGU were identified and the coordinates of SWDSs, then direct distances were calculated through ArcGIS. To reflect a better estimate, a regression analysis was done using the available data from some LGUs.

Table 5: Power potential and energy outputs from LFG

Year	Total CH_4 generated (m^3/yr)	CH_4 Gas Flow (m^3/d)	**100%** CH_4 CE (kW)	energy output (kWh/yr)	**80%** CH_4 CE (kW)	energy output (kWh/yr)	5**0%** CH_4 CE (kW)	energy output (kWh/yr)
2005	3,216,296	8,812	1,256	8,710,436	1,005	6,968,349	628	4,355,218
2006	6,345,226	17,384	2,478	17,184,267	1,982	13,747,414	1,239	8,592,133
2007	10,146,439	27,798	3,981	27,611,640	3,185	22,089,312	1,991	13,805,820
2008	16,268,716	44,572	6,477	44,916,989	5,181	35,933,591	3,238	22,458,495
2009	24,714,058	67,710	9,935	68,898,676	7,948	55,118,941	4,967	34,449,338
2010	33,544,269	91,902	13,517	93,741,813	10,814	74,993,450	6,759	46,870,907
2011	44,743,307	122,584	18,010	124,897,524	14,408	99,918,019	9,005	62,448,762
2012	54,779,607	150,081	22,031	152,787,828	17,625	122,230,262	11,016	76,393,914
2013	63,873,283	174,995	25,671	178,027,216	20,537	142,421,773	12,835	89,013,608
2014	72,213,215	197,844	29,004	201,142,718	23,203	160,914,174	14,502	100,571,359
2015	74,431,576	203,922	29,937	207,610,160	23,949	166,088,128	14,968	103,805,080
2016	76,555,922	209,742	30,824	213,764,529	24,659	171,011,623	15,412	106,882,265
2017	72,192,744	197,788	28,975	200,942,208	23,180	160,753,767	14,488	100,471,104
2018	60,906,789	166,868	24,445	169,528,739	19,556	135,622,991	12,223	84,764,369
2019	51,385,178	140,781	20,624	143,026,164	16,499	114,420,931	10,312	71,513,082
2020	43,352,089	118,773	17,400	120,666,760	13,920	96,533,408	8,700	60,333,380
2021	36,574,819	100,205	14,680	101,802,821	11,744	81,442,257	7,340	50,901,411
2022	30,857,046	84,540	12,385	85,887,898	9,908	68,710,318	6,192	42,943,949
2023	26,033,137	71,324	10,449	72,460,968	8,359	57,968,775	5,224	36,230,484
2024	21,963,354	60,174	8,815	61,133,083	7,052	48,906,466	4,408	30,566,541
2025	18,529,804	50,767	7,437	51,576,095	5,950	41,260,876	3,719	25,788,047
2026	15,633,024	42,830	6,274	43,513,159	5,020	34,810,527	3,137	21,756,580
2027	13,189,100	36,135	5,294	36,710,709	4,235	29,368,568	2,647	18,355,355

Table 6: Emissions from 6 scenarios

Sce	SWM elements					Total emission kg CO_2e		
	Collection	Transport	LF 1 (100% CE)	LF 2 (80% CE)	LF 3 (50% CE)	C+T+L1	C+T+L2	C+T+L3
A1	195,745	220,899	33,090,721	–	–	33,507,365	–	–
A2	195,745	220,899	416,644	6,313,917	15,159,825	833,288	6,730,561	15,576,469
A3	195,745	220,899	-835,711	5,312,032	14,533,648	-419,067	5,728,677	14,950,292
B1	195,745	154,629	23,222,228	–	–	23,572,603	–	–
B2	195,745	154,629	350,375	4,478,465	10,670,601	700,749	4,828,840	11,020,976
B3	195,745	154,629	-526,274	3,777,146	10,232,277	-175,900	4,127,521	10,582,651

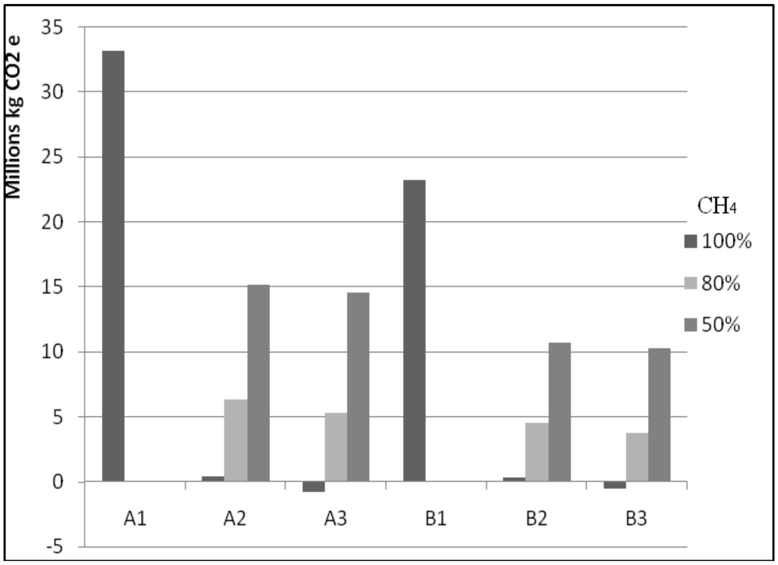

Figure 3: Total emission from each scenario

Life cycle inventory

Life cycle inventory is part of life cycle analysis that involves data collection and calculation in quantifying inputs and outputs of materials and energy associated with a product or process under study. LCI is being used extensively in the environmental assessment of solid waste management systems such as the studies of Chen and Lin, Cherubini, *et. al*., and Liamsanguan & Gheewala, [5,6,7]. Main inputs considered in this study are wastes and fuel consumption and the outputs considered are GHG emission and energy from solid waste management practices.

Based from the FOD method, methane emission for every MT of waste was calculated. An amount of 82 m^3/MT was obtained. This served as the CH_4 emission coefficient used for calculating emissions in 3 landfilling practices: landfilling, landfilling with CH_4 collection and flaring, landfilling with CH_4 collection and electricity generation.

For the collection and transportation emission, fuel consumption per tonne.km of collected and transported waste was calculated considering scenarios with and without transfer station or materials recovery facility.

Goal definition

Life cycle inventory was used to assess the GHG contribution from the solid waste management of Metro Manila.

Functional unit

In an LCI of waste, functional unit is defined in terms of the system's input. Per MT of waste disposed daily is used as functional unit in this study.

System boundary

The "cradle" is the point of collection while the grave is the final disposal. In the Philippines where curbside is the dominant collection system, the points of collection are the households while the final disposal is the landfill. The system boundary considered in this study as well as the routes of each scenario are illustrated in the Figure 1.

Scenarios

A1- wastes are collected then transported to the landfill without gas collection system

A2- wastes are collected then transported to the landfill with gas collection system and LFG flaring (without energy generation)

A3-wastes are collected then transported to the landfill with gas collection system and LFG flaring (with energy generation)

B1- wastes are collected, brought to MRF, then transported to the landfill without gas collection system

B2- wastes are collected, brought to MRF, then transported to the landfill with gas collection system and LFG flaring (without energy generation)

B3-wastes are collected, brought to MRF, then transported to the landfill with gas collection system and LFG flaring (with energy generation)

GHG emission from SWDSs considered in this calculation only includes CH_4. Although LFG consists primarily of CH_4 and CO_2, the latter which is a product of organic waste decomposition is not contributing to the net CO_2 in the atmosphere since they are from biomass sources [3]. CO_2 produced from the combustion of CH_4 is also excluded. Gases considered from the fuel consumption include CO_2,

CH_4 and N_2O. It was assumed that the fuel used for collection and transportation is from fossil fuel. Global warming potential (GWP) for each greenhouse gas is based from the IPCC Fourth Assessment Report [8] and 100-year time horizon was used.

The GHG emission in terms of CO_2 equivalents of each route was determined using the following equations.

$ET = C + T + L_i$ (Eq. 2.2)

Where:

ET = total GHG emission in each route (kg CO_2e)

C = emission due to waste collection (kg CO_2e/ MT)

L_i = emission due to landfilling (kg CO2e/ MT)

$C = W_c * F_c * EC_c$ (Eq. 2.2.1)

Where:

W_c = Waste collected (MT)

F_c = amount of fuel consumption due to collection (l/MT)

EC_c = emission coefficient of collecting waste (kg CO_2e/ MT)

T = Emission due to waste transportation (kg CO_2e/ MT)

$T = (W_c-W_r) * F_t * EC_t$ (Eq. 2.2.2)

Where:

W_c = Waste collected (MT)

W_r = Waste recovered at MRF (MT)

F_t = Fuel consumption due to transportation (l/MT)

EC_t = Emission coefficient of transporting waste (kg CO_2e/ MT)

L_i = emission due to landfilling (kg CO_2e/ MT)

$L_i =(W_t * EC_{li})$ (Eq.2.2.3)

Where:

W_t = waste collected – waste recovered (MT)

EC_{li} = emission coefficient of landfilling (kg CO_2e/ MT)

Since 3 landfilling scenarios were analyzed, additional 2 equations were used.

$L_{flaring} = W_t * [(CH_4 * CE * EC_f) + [CH_4 * (100\% - CE) * EC_l]]$ (Eq. 2.2.4)

Where:

CH_4 = volume of CH_4 emitted per MT of waste (m^3/MT)

CE = collection efficiency

EC_f = emission coefficient due to flaring LFG gas (kg CO_2e/ MT)

$L_{electricity} = (W_t) * [(CH_4 * CE * KWh * EC_e) + [CH_4 * (100\% - CE) * EC_l]]$ (Eq.2.2.5)

Where:

CH_4 = volume of CH_4 emitted per MT of waste (m^3/MT)

CE = collection efficiency

EC_f = emission coefficient due to flaring LFG gas (kg CO_2e/ MT)

KWh = electricity output (kWh/m^3)

EC_e = emission coefficient/avoided emission due to LFG utilization for energy (kg CO_2e/ MT). The emission coefficients are listed in Table 4.

RESULTS AND DISCUSSION

First order decay method and energy potential calculation

Methane emission from SWDSs was computed using Eq. 2.1 which is based from first order decay method. Individual SWDS CH_4 emission peaks on the 10th year of operation – the assumed last year of waste acceptance. Total CH_4 emission reached its highest value, amounting to 77 million cm^3 in 2016. Figure 2 shows the CH_4 emission annually per active landfill and total CH_4 emission.

Based from the computed methane emission, the energy that can be generated was estimated (see Table 5).

The huge amount of methane emitted strongly suggests a good potential for LFG utilization for energy. Based from the calculation, 1 m^3 of CH_4 can produce approximately 1.35 kWh. Given an average of 948 kWh [10] annual energy consumption per household in Metro Manila, more than 100 thousand houses can be powered up if the LFG is utilized during the time of peak season.

Collection and transportation distance

Based from the logged collection distance, fuel consumption, and truck load per trip, an average of 0.41l/MT.km (diesel) fuel consumption was obtained. Considering an average collection distance of 18 km per round trip gives an emission of 24.28 kg CO_2e/MT of waste collected.

Based from the average transportation distance obtained through projection which is equal to 49 km/roundtrip, a fuel consumption of 0.17 liter/MT.km of a 3MT truck load, an emission of 27.40 kgCO_2e/MT of waste transported was calculated.

A total of 51.68 kg CO_2e is emitted for every MT of waste collected and transported in the SWDS which is equal to the amount of carbon sequestered by a tree seedling grown for 10 years.

Life cycle inventory

Emission from six scenarios, with a waste input of 8,062 MT per day, is calculated using the formula and emission factors discussed in the previous section. Comparing the three elements considered in the system boundary, landfilling has the greatest emission even when there is gas collection, flaring and utilization of LFG for electricity generation except for the scenario with 100% collection efficiency and utilization. Contribution of landfilling could be as much as 99% of the total emission while collection and transportation is only 1%. This, however, could be reduced as illustrated in the modeled scenarios.

Avoidance of venting LFG has a great impact in emission reduction. As shown in Table 6, total GHG emission was reduced by 99% for 100% CE, 81 percent for 80% CE, and 54 for 50% CE from A1 to A2. It is further reduced when LFG is use for generating electricity (A3). A negative emission of 835,711 CO_2e (credits) is gained from producing electricity from the 100% collection of methane, a reduction of 84% and 56% for 80% and 50% CE respectively.

The A scenarios refer to SWM without materials recovery facility where wastes are collected and directly transported to the SWDS. The B scenarios, on the other hand refer to SWM with materials recovery facility where wastes are collected, brought to the MRF where recyclables are recovered then transported to the SWDS. The difference of having MRF from nothing is the reduction of waste volume that will be transported as a result of recovering materials from the collected waste. The emission due to transportation from A to B scenarios was reduced by 66,270 CO_2e when transported wastes' weight is reduced by 30%. Although this inventory does not include cost estimate, lesser wastes to be transported would mean a cut in fuel consumption thus reducing expenditure.

The total emission reduction of B2 scenario is 99%, 86% and 68% as compared to A1 for CE of 100%, 80% and 50% respectively. For the B3 scenario, by having 100% CE and using it for electricity, a total of 525,274 were earned as credits due to avoided emission of the displaced electricity which could have been produced from fossil fuel. For 80% and 50% CE, the reduction would be 89% and 69% respectively.

The difference in total emission between A2 & B2 and A3 & B3 comes from the reduced weight of waste transported as the same landfilling practice was employed. Figure 3 shows the emission from each scenario.

CONCLUSION

This paper has discussed and assessed the challenges of SWM in Metro Manila, Philippines. It has quantified environmental impacts in terms GHG emission. The estimation of CH_4 emission using FOD method reaffirms findings from previous studies that SWDSs contributes considerably to the global warming. Alongside with this finding is the indication of a huge potential of energy production from LFG. This could even contribute to the country's goal of increasing its non-fossil fuel energy source.

The LCI result quantifies the GHG contribution of SWM in Metro Manila. Among the elements considered in the system boundary, simply landfilling has the greatest GHG contribution. A large amount, however, could be reduced if CH_4 will be collected and even further lowered if utilized for energy. Although an LFG-to-energy facility requires a considerable amount of capital, the opportunities provided by the Kyoto Protocol through the Clean Development Mechanism (CDM) makes it possible for such undertaking to take place even in the developing countries.

ACKNOWLEDGEMENT

I would like to thank my supervisors, Prof. Sohei Shimada, PhD and Professor Motoharu Onuki, PhD, for their support and guidance in the conduct of this study and the Japan's Ministry of Education, Culture, Sports, Science and Technology for funding my graduate studies at the University of Tokyo.

REFERENCES

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste. Retrieved from http://www.ipcc-nggip.iges.or.jp /public/ 2006gl/vol5.html

[2] Kumar, S., Gaikwad S.A. , Kshirsagar, P.S., Singh, R.N., & Shekdar, A.V. (2004). Estimation method for national methane emission from solid waste landfills. *Atmospheric Environment, 38*, 3481–3487.

[3] US-EPA (2004). Direct Emissions from Municipal Solid Waste. Climate Leaders Greenhouse Gas Inventory Protocol Core module guidance. Environmental Protection Agency. Retrieved from http://epa.gov/climateleaders/documents/resources/protocol-solid_waste_landfill.pdf

[4] Thuy, P.C. (2004). Environmental and Economic Aspects of Power Generation System Using Landfill Gas in Nam Son Landfill. Master Thesis. Institute of Environmental Study, Graduate School of Frontier Sciences, The University of Tokyo, Japan.

[5] Chen TC., & Lin CF., (2008). Greenhouse gases emissions from waste management practices using life cycle inventory model. Journal of hazardous materials, 155, 23-31.

[6] Cherubini, A., Bargiglib, S., & Ulgiatic, S. (2009). Life cycle assessment (LCA) of waste management strategies: Landfilling, sorting plant and incineration. *Energy*, *34*, 2116-2123. doi:10.1016/j.energy.2008.08.023

[7] Liamsanguan C. & Gheewala S.H. (2008). LCA: a decision support tool for environmental assessment of MSW management systems. *Journal of Environmental Management. 87, 132-138.*

[8] IPCC (2007a) Climate Change: The Physical Science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Cambridge University Press.

[9] Montalban Landfill Methane Recovery and Power Generation Project Design Document. Version 03. http://cdm.unfccc.int/Projects/DB/SGS-UKL1211828991.5

[10] Energy Efficiency/CO_2 Indicators (Philippines). Retrieved from http://www.worldenergy.org /documents/phl.pdf

ABOUT THE AUTHOR

Name: Jovelyn G. Ferrer
Project Officer
Center for Sustainable Human Development
Mailing address: DAP Building, San Miguel Avenue, Ortigas Center, Pasig City, Philippines
Tel: +63 917 857-5887; +63 2 631-2131
Fax +63 2 631-2131
e-mail : jgferrer2003@yahoo.com