LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

LUT School of Energy Systems

Degree programme in Sustainable Technology and Business

Yilin Zhao

Municipal Solid Waste Management and Waste to Energy Possibilities in the Philippines

Examiner: Professor Mika Horttanainen

D.Sc.Tech Jouni Havukainen

ABSTRACT

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Keywords: Waste to Energy (WtE), municipal solid waste (MSW), Philippines, solid waste management (SWM), Landfill.

Municipal solid waste management are becoming a challenging and vital issue in the Philippines. The typical practice of Philippine MSW management is landfill, however, poor management of dumpsites has arisen health and environmental problems. Philippine government are pursuing innovative solutions for handling waste, in which Waste-to-Energy technologies serve as alternative methods for waste treatment. The aim of this thesis is to identify MSW management problems in the Philippines, and explore Waste-to-Energy possibilities by using scenario analysis in the area of Metro Manila. The three scenarios are Landfill with LFG recovery, Mass Incineration and a

Combined Strategy, in which mechanical-biological treatment (MBT) is applied and MSW is separated as biowaste and Refuse-Derived Fuel (RDF). It is clear that the combined strategy with pretreatment, is the preferable solution rather than Landfill gas recovery and Mass Incineration with superior electricity generation potential. However, financial and political factors should also be taken into account in the future studies.

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Yilin Zhao

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ABBREVIATIONS

AD	Anaerobic Digestion
CDM	Clean Development Mechanism
ISWM	Integrated Sustainable Waste Management
JICA	Japanese International Cooperation Agency
LFG	Landfill Gas
LGUs	Local Government Units in the Philippines
LHV_{ar}	Lower heating value as received
MSW	Municipal Solid Waste
MBT	Mechanical-Biological-Treatment
MRF	Material Recovery Facilities
NCR	National Capital Region (Also Known as Metro Manila)
NSWMC	National Solid Waste Management Commission
RDF	Refused Derived Fuel
WACS	Waste Analysis and Characteristics study
WtE	Waste-to-Energy
SLF	Sanitary Landfill Facilities

1 INTRODUCTION

1.1. Background

An increasing population, rapid urbanization, and fast industrialization are leading to an increase in the amount of municipal solid waste (MSW). Municipal solid waste (MSW) includes all the waste fractions, e.g. organic waste, glass, metal, paper, cardboard, etc., which comes from homes, schools, hospitals, and business.

According to World Bank (Hoornweg, Bhada-Tata 2012) ,in South Asia, the current urban waste generation is approximately 70 million tonnes per year. By 2025, this figure will be tripled to 200 million tonnes per year. Therefore, the municipal solid waste management has become a major challenge for local authorities. However, the developing countries, especially those densely populated Asia countries with lower gross domestic product (GDP), like Philippines, Malaysia, Thailand and Siri Lanka, are experiencing a lack of resources to afford expensive technologies for solid waste management. Besides, technologies successfully used in developed countries may only result in a greater debt instead of a solution. Thus, a waste management with proper technology is needed for those countries.

According to UNEP report (UNEP 2015a) , the organic share of waste in developing countries is larger than developed countries. This means, a tailored waste management should be implemented in the developing area. For example, the large share of organic waste may result in low calorific value, meaning that the waste as fuel for incineration can be inefficient, that the biological treatment is necessary. This may also indicate that waste separation technology is needed, such as mechanical treatment to produce refuse-derived fuel (RDF) or other waste sorting techniques.

In this thesis, the discussion focuses on Philippines. Philippines, like the other developing countries in Asia and Pacific regions, is “under the pressure to modernize its solid waste systems", (Africa 2010) and in need of a shift from simple disposal of landfill, to energy and material recovery. The rapid urbanization and the population growth in Philippines have created severe environmental and health problem due to the insufficient waste management resulting from scarce political, financial, and technological resources. There are several aspects related to municipal solid waste management that need to be considered, such as waste governance (e.g. policy and legislation, financial sustainability, etc.), and the physical elements of wastes (e.g. generation, collection, disposal, etc.). (UNEP 2015) In this thesis, all the aspects are discussed in Chapter 3, and the focus is placed on treatment, especially waste-to-energy (WtE) technology which is discussed in Chapter 4.

1.2. Aim of the study

The overall aim of the study is to identify MSW management situations in Philippines and investigate the possibilities of introducing Waste to Energy technology to Philippines. For this purpose, Metro Manila acts as an object of study.

The report serves as a master dissertation for the Degree programme in Sustainable Science and Solutions at Lappeenranta University of Technology. The report is also part of an ongoing research related to waste management in certain developing countries, where it will be used as a knowledge base for future collaboration work. The optimal outcome of the thesis would be a reference for decision makers from waste-to-energy (WtE) sector.

1.3. Organization of the study

The first part (chapter 2) of this thesis provides the framework of this study and shows the current MSW management pathway and major WtE technologies. The second part (chapter 3) provides current situation of MSW management in Philippines as well as future trends to show the opportunities and challenges they may have during the following decades. The final part (chapter 4 and chapter 5), the most significant one in this thesis, discuss the waste-to-energy possibilities in Philippines by creating four scenarios.

The best way to outline the structure of this study would be through research questions which reflect the ideas throughout the text.

Chapter 1: Introduction
What is the background and aim of this study?

Chapter 2: Literature review
What is the backbone of this study? Municipal solid waste management pathways? Possible Waste-to- Energy technologies?

Chapter3: Municipal Solid Waste Management in the Philippines
The current MSW management and Waste-to-Energy situation in Philippines?

Chapter 4: Waste-to-Energy Possibilities in the Philippines (Case study: Metro Manila)
How we conduct this study? (include the methods and data we use) Scenarios for examine the Waste-to-Energy possibilities in the Philippines?

Chapter 5: Result and discussion
What kind of WtE technologies can be implemented in Philippines? Energy Recovery from different scenarios?

Chapter 6: Conclusion
Conclusion of this study, and the main results and discussion?

2 LITERATURE REVIEW

2.1. Description of Integrated Sustainable Waste Management (ISWM)

This framework of Integrated Sustainable Waste Management (ISWM) is used as the backbone throughout this thesis. The waste management system in the Philippines is discussed under this framework. Waste management does not only involve waste related technologies and infrastructure. It is an integrated system also involving Financial, societal, legal, environmental and other aspects, which are usually overestimated or underestimated. Therefore, to thoroughly examine the Waste-to-energy possibilities in Philippines, a comprehensive overview of all aspects is of utmost importance.

ISWM framework, shown in **Figure 1**, compromises physical and governance triangles. The first triangle is linked to three key elements for solid waste management,

- Public health – linked mostly to waste collection
- Environment – Environment protection during waste chain, especially in disposal stage
- 3Rs – by "closing the loop", returning materials to beneficial use (Wilson, Ing 2013)

The second triangle shows emphasis on governance strategies, the system needs to

- Be inclusive, all stakeholders are involved
- Be financially sustainable, in other words, be affordable and cost-effective
- Rest on sound institutions and proactive policies

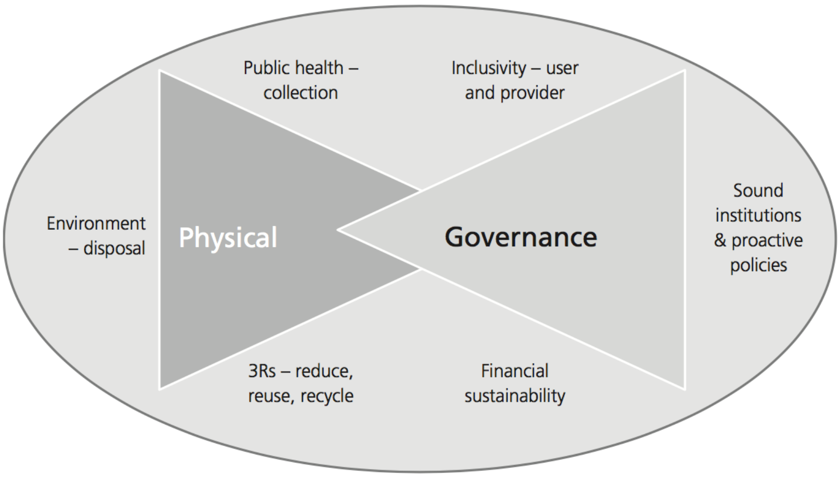

Figure 1 Two Triangles of ISWM ((Wilson, Ing 2013)

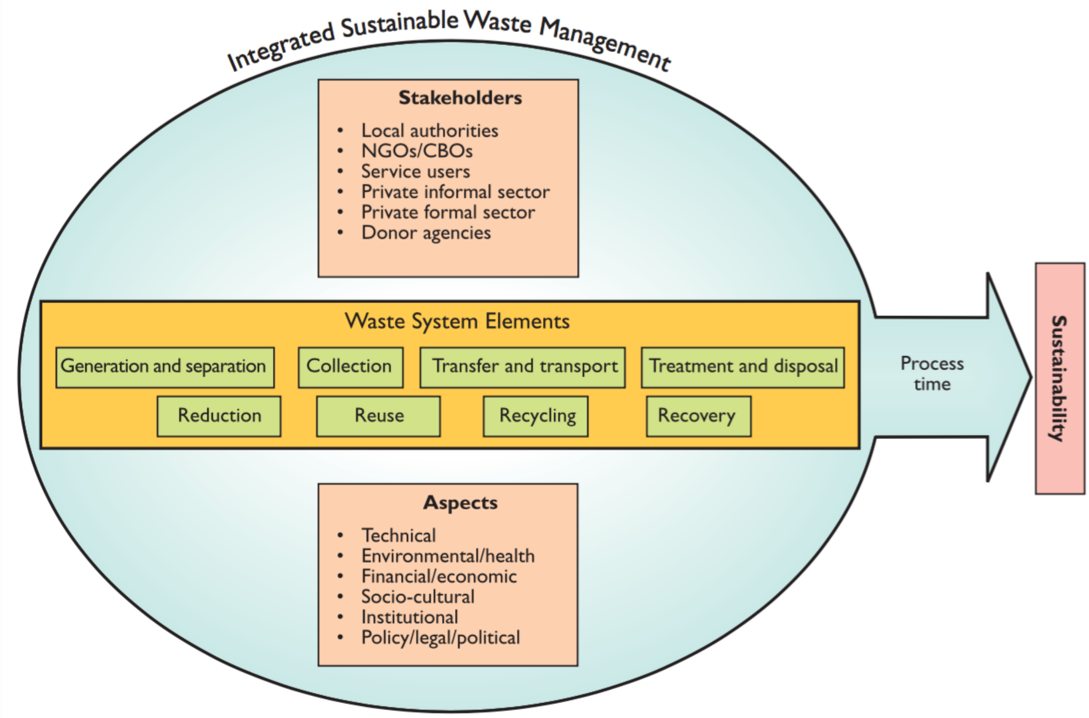

Figure 2 Integrated sustainable waste management framework (Van de Klundert, Anschütz 2001)

There are three dimensions which need to be recognized when dealing with a solid waste management system. The three dimensions, shown in **Figure 2**, are related to three key questions:

1 **The stakeholders** – Those who needs to be involved in solid waste management.

2 **The elements** – Those technical problems which need to be solved.

3 **The aspects** – The solutions to achieve the desired results.

Stakeholders. The main stakeholders include municipalities; governments; some companies working related to SWM; waste generators/service users; service providers; NGOs; etc.

Elements. Physical elements of a waste management system are those technical components, such as waste generation, collection, transfer and transport, treatment and disposal, reduction, reuse recycling, and recovery.

Aspects. An integrated system needs more than technical aspects. It needs to consider political, financial, social, economic, institutional, legal and environment aspects.

'Integrated' refers to integration across all three dimensions, and integrated solid waste management is becoming the norm under discussion in developing countries. This integrated framework is also used in this thesis, however, technical aspects will be focally addressed.

2.2. MSW Management Pathways

Nowadays, several technological options are prevailing to ensure MSW management, such as composting, anaerobic digestion/biomethanation, incineration, gasification and pyrolysis, production of Refuse Derived Fuel (RDF), and sanitary landfilling/landfill gas recovery.(Shekdar 2009) . They can be divided into four groups: thermal treatment options, biological treatment options, Landfill with LFG recovery and material recovery.

Thermal treatment options consist of incineration, gasification, pyrolysis. MSW can be incinerated in dedicated waste-to-energy plant or used in co-combustion in an industrial facility. Incineration with energy recovery has been widely used for MSW for quite a long time. The process produces renewable energy, in the meantime, destroy hazardous wastes (e.g. POPs). However, problems arise regarding this technology, for example, in developing countries, waste is of low calorific value. As for co-combustion, solid recovered fuel (SRF), or RDF can be used in this situation, especially in cement kilns. Gasification is a more efficient method for energy recovery, from which a synthetic gas is generated for combustion. Gasification is applied to biomass fuels and wood wastes. Although the process guarantees more efficiency, high costs and operational challenges are still issues for its widely application. Pyrolysis is process of degradation without oxygen and can produce a liquid fuel. Low moisture content and a high calorific value of waste is preferable for this method.

Waste-to-energy (WtE) option is the process that generating energy from waste in the form of heat, electricity or transport fuels. Study shows that (World Energy Council 2013) if all waste can be used as energy, 10% of global electricity demand can be satisfied, which proves that WtE technologies can be a promising alternative energy solution. Large-scale Waste to Energy technologies has been used in developed countries, such as Denmark, Germany, Sweden, Netherlands, and UK.(Münster, Meibom 2011) . In about 40 countries, more than 800 WtE plants are under operation. (ISWA 2012)

Biological treatment options include composting and anaerobic digestion. Composting is aerobic degradation of organic material and it produces compost, which can be used as natural fertilizer. A wide range of organic wastes can be composted. However, the contamination of compost, especially in developing countries, is an issue, since clean source separated organic waste is optimal feedstock. It is typical that in developing countries, 50% to 70% of total waste by weight is organic materials, therefore, composting is a preferable solution for those countries. Study shows that decentralized composting system works well in low- and middle – income countries.

Anaerobic digestion (AD), also known as biomethanization, is a way to produce biogas as a source of energy. Wet waste, such as sewage sludge and animal waste, is suitable for AD. Nowadays, AD is widely used in developing countries at small and community scale. However, due to high solid content, large particle size and inhomogeneous nature of the waste, it is challenging to applying AD. (UNEP 2015b)

Landfill with LFG recovery produces Landfill gas (LFG), such as methane, which can be used to provide heat and electricity. LFG recovery has widely implemented in developing countries under the Clean Development Mechanism (CDM). (UNEP 2015)

Material recovery facilities (MRFs) accept MSW, and then separate recyclable materials out from other wastes.

As a result, the overview of MSW management pathways is shown in **Figure 3**. Treatment options which are considered as WtE technologies are, landfill with landfill gas (LFG) recovery, MSW incineration, Gasification, pyrolysis and Anaerobic digestion. The most prevailing WtE practice are waste incineration and LFG recovery. (Tan et al. 2014)

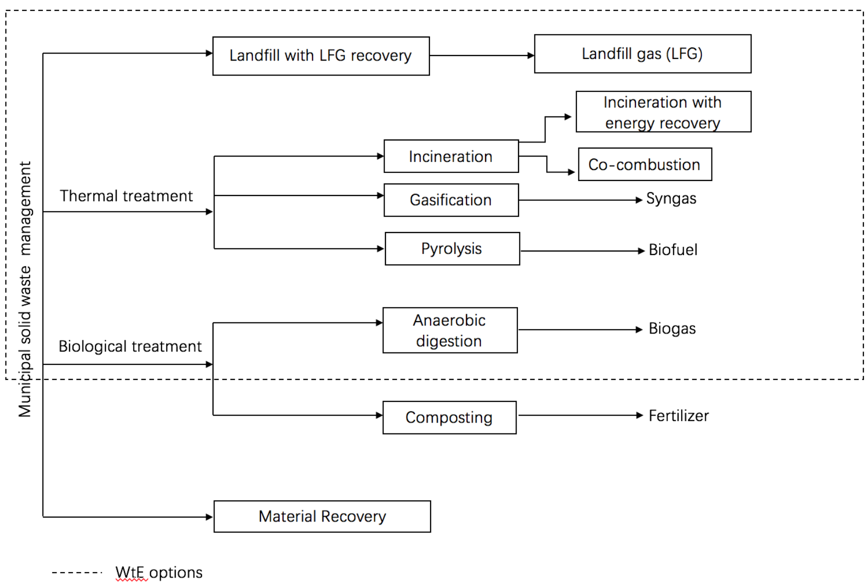

Figure 3 MSW management pathways (Original source: K. M. Nazmul Islam 2016)

3 MSW MANAGEMENT IN THE PHILIPPINES

Industrialization and rapid population growth has increased generation of MSW in Philippines. Like most developing countries, lack of efficient waste collection and disposal are common issues in Philippines. (Kojima and Michida ed 2011) However, this is not the only problem in Philippines. In order to conduct a comprehensive study on municipal solid waste management in Philippines, an integrated solid waste management (ISWM) framework need to be considered, other aspects, such as political, economic, technical and social perspectives of MSW management should also be taken into consideration.

This chapter provides a brief overview of current solid waste management in Philippines based on the integrated solid waste management (ISWM) framework, including information about waste generation and composition, physical elements of waste management system, different aspects related to MSW management and an overview from stakeholders.

3.1. Waste Composition and Generation in the Philippines

3.1.1 Waste Composition

Based on a draft report (NSWMC 2015) from National Solid Waste Management Commission(NSWMC), the typical waste composition of MSW in the Philippines is presented in **Figure 4**.

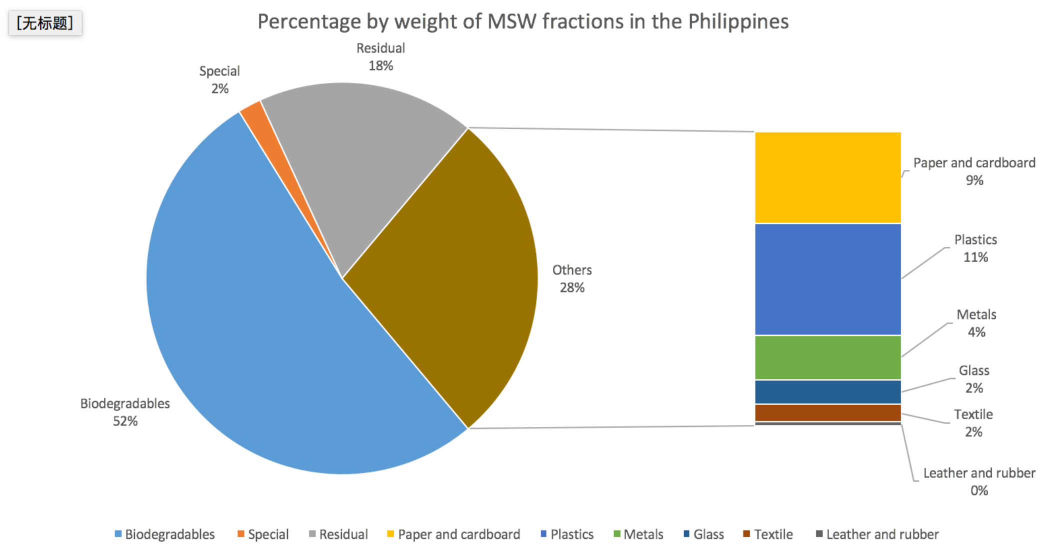

Figure 4 MSW composition in the Philippines, 2008-2013 (Source: NSWMC, 2015)

As shown in **Figure 4**, MSW is dominated by biodegradable wastes with 52.31%, although the figure is not a fixed data, the primary data shows that the number can be from 30% to 78%. Studies show that biodegradable wastes come mostly from food waste and yard waste. It is estimated from the same report that 86.2% of organic waste is from food residue and the rest are leaves and twigs.

Recyclable wastes comprise about 27.78% of MSW in the Philippines, almost a third with a range from 4.1% to 53.3%. Plastic packaging wastes account for 38% of recyclable wastes, followed which paper and cardboard comprise around 31%, the rest 31% includes metals, glass, textile, leather and rubber. Special wastes which contain hazardous materials, consist of merely 1.93%, with a range from negligible to 9.2%. At last, residuals with a share of 17.98%, which are reported by most LGUs (Local government unit) as a mix of disposable wastes and inert materials.

For selected cities in the Philippines, there is some limited data available from the waste analysis and characterization survey (WACS), which is conducted for Metro Manila in year 2013 by Asian Development Bank. The project is aimed for several cities located in Metro Manila, such as Makati, Muntinlupa, Pasig, Valenzuela and Quezon City. The

Table 1 shows the results of waste analysis and characterization survey in these cities. As we can see, although waste composition differs by regions, some characteristics are in common, such as the organic wastes are the leading waste fraction with a range from 43% in Muntinlupa to 53.8% in Quezon city.

Table 1 The Results of Waste Characterization Studies (Source: WACS)

COMPONENT	MAKATI	MUNTINLUPA	PASIG	QUEZON CITY	VALENZUELA
QUANTITY					
TONNES/YEAR	87,200	80,400	102,067	532,100	60,200
POPULATION	421,308	366,674	528,179	2,1301,261	519,227
AVERAGE KG/CAP-DAY	0.57	0.60	0.53	0.63	0.32
BULK DENSITY	92	172	139	218	159
COMPOSITION (%WET WT.)					
PAPER	14.7	10.2	12.4	14.1	11.3
GLASS	2.4	3.1	5.0	3.4	1.4
METALS	2.7	3.9	11.6	3.6	3.1
PLASTIC	25.0	28.1	20.9	21.4	28.3
KITCHEN/ FOOD WASTE	32.6	29.1	23.1	39.9	38.0
OTHER ORGANIC	18.9	20.4	18.9	14.8	14.2
OTHER INORGANIC	3.5	5.0	6.7	2.4	2.2
HAZARDOUS/SPECIAL	0.2	0.2	1.4	0.4	0.6
MOISTURE CONTENT	41	29	33	67	38

3.1.2 Waste Generation

Waste generation rates are estimated by National Solid Waste Management Commission, based on waste analysis and characterization studies from Environmental Management Bureau (EMB) regional reports. Year 2010 is used as base year, **Table 2** shows waste generation rates in the Philippines (Nationwide), Metro Manila, highly urbanized cities (HUCs), municipalities, provincial capitals, and other cities.

Table 2 Waste generation rates in the Philippines for the base year 2010

(Source: NSWMC, 2015)

	Scope / Coverage	**Sample size (as % of demographics)**	**kg/capita/day**
		Range	Weighted Average
Metro Manila (NCR)	100 %	0.55 – 0.79	0.69
Metro Manila and some highly urbanized cities (HUCs)	N/A	0.53 – 0.79	0.69
Other cities and provincial capitals (excluding NCR/HUCs)	N/A	0.29 – 0.64	0.50
PHILIPPINES (Nationwide)	79 %	0.10 – 0.79	0.40
All LGUs in the country, excluding Metro Manila	76 %	0.10 – 0.71	0.34
Municipalities (cities and some capital towns excluded)	N/A	0.10 – 0.64	0.31

As shown in **Table 2**, waste generation rates vary in different regions in the Philippines. The heart region of Philippines, Metro Manila, has the highest generation rate up to 0.79 kg/capita/day, when the other regions excluding Metro Manila can be as low as 0.10 kg/capita/day. The results depend on income level, economic activity, waste policies, etc. It is clear that the generation rates are closely connected with GDP. The average generation rate in the Philippines is 0.40 kg/capita/day.

3.2. Aspects of MSW management

3.2.1 Policies in the Philippines

It is difficult to address waste problems from a political, economic and social perspective due to the complexity of this issue. In this section, the role of government is discussed and evaluated.

In the past decades, a set of policies have been implemented regarding solid waste management. From a summary of laws and regulations in the Philippines regarding to solid waste management, a few policies should be highlighted for the purpose of this thesis. The first one is Republic Act 8749, also known as The Clean Air Act, which is a wide-ranging air pollution control policy. It needs to be noticed that its Section 20 bans incineration of "municipal, bio-medical, and hazardous waste", except traditional small-scale community burning. (Kojima and Michida ed 2011) The second, and the most important Act is Republic Act 9003, which will be discussed thoroughly in the next section, which is a systematic solid waste management program.

Although the government has set many regulations on collection, disposal and penalties, the poverty issue in the Philippines still remain a challenge to a proper MSW management. (Guzman, Reyes 2003) However, most of these policies were announced to have failed. The failure of previous policies could be caused by several factors. First, the "command and control" policies lacks the support from various stakeholders. Second, the lack of sufficient infrastructure in inner provinces makes it inefficient and ineffective for waste management. In addition, bureaucracy could do harm to the implementation of those regulations. (Kojima and Michida ed 2011)

3.2.2 Philippines Republic Act 9003

To have a better understanding of policies/Legal framework in the Philippines, the ecological solid waste management Act, also known as Republic Act 9003 (RA 9003), needs to be emphasized. It highlights that waste can be recovered as a resource. This Act acts as a turning point or milestone of MSW management in the Philippines. In the first three years of the implementation of the Act, 25% waste was diverted from landfill and the number has been increased thereafter. (Magalang 2014)

This policy is based on the following hierarchy:

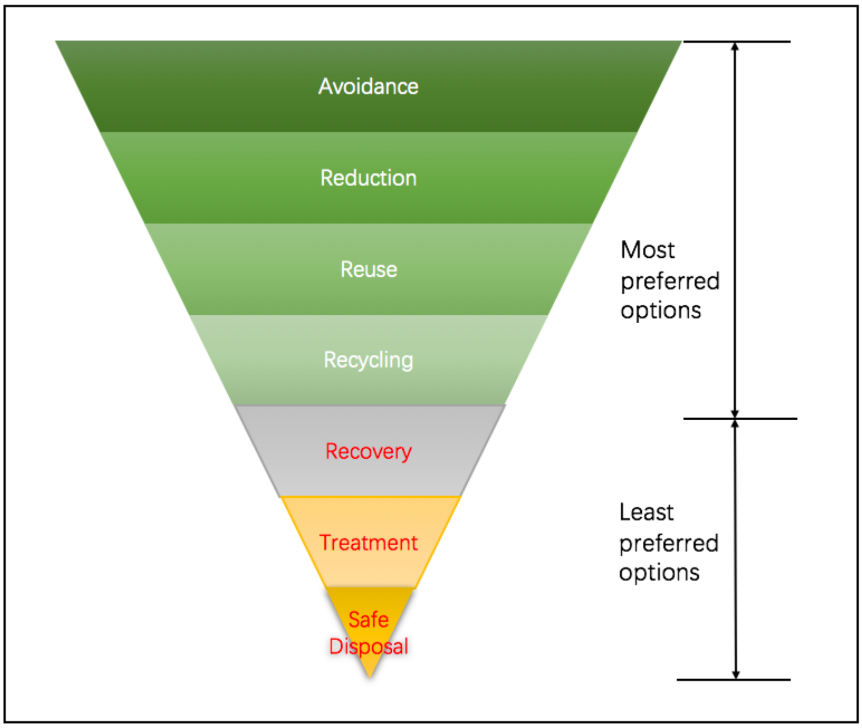

Figure 5 Policy of RA 9003 based on waste management hierarchy (Source: NSWMC, 2015)

As shown in **Figure 5**, the Act puts emphasis on waste avoidance, waste reduction, waste reuse and recycling. The least preferred options are recovery, treatment and safe disposal.

Features of RA 9003 are quite noticeable.

- **Closure of dumpsites.** RA 9003 bans the all open dumpsites and states that open dumpsites should be transformed into controlled dumpsites within three years. In addition, controlled dumpsites should be closed within five years. Sanitary landfill (SLF) is accepted as final disposal option instead.

- **Stakeholders' participation.** It requires not only the Local Government Units (LGUs) 's participation, it also inspires private sector, communities, NGOs, citizens, and other industries to be involved in MSW management.
- **Incentives and Penalties.** Incentives are set to encourage the implementation of this Act, while penalties are provided for those who violate the regulation. (Kojima and Michida ed 2011)

However, although the RA 9003 was a giant step forward, the implementation of RA 9003 is not that good based on the reports of NSWMC. There still exist numerous dump sites. (NSWMC 2015)

To solve this problem, National Solid Waste Management Commission (NSWMC) has prepared a 3-strike Policy in 2008, including a review of those municipalities that failed to comply with RA 9003, reminder letters for related LGUs to implement the Act and warnings for approximately 200 LGUs that did not respond. (Dr.-Ing. Johannes Paul, AHT GROUP AG 2012)

However, at the end of year 2010, only 331 out of 1,610 municipalities have offered their 10-Year Solid Waste Management Plan, and by the year of 2014, over 900 open dumpsites are still under operation in 790 municipalities even though dump sites have been prohibited since 2006. In the meantime, sanitary Landfill (SLF) has more or less made some progress. By the year of 2014, 86 SLF is in operation and 51 SLF are under construction. (NSWMC 2015)

3.2.3 Institutional Framework

The institutional framework of solid waste management under Republic Act 9003 is shown in **Figure 6**. As mandated by the regulation, National Solid Waste Management Commission (NSWMC) was founded in order to ensure the implementation of the Act and to prepare National SWM Framework and strategy. Under NSWMC, Naitonal

Ecology Center was established to provide technical support and Secretariat of the NSWMC is responsible for day-to-day management. Provincial Solid Waste Management Boards, City Solid Waste Management Boards serve as the executives and supervision of solid waste management. Barangays are the smallest administrative division that are responsible for waste collection and establish material recovery facility.

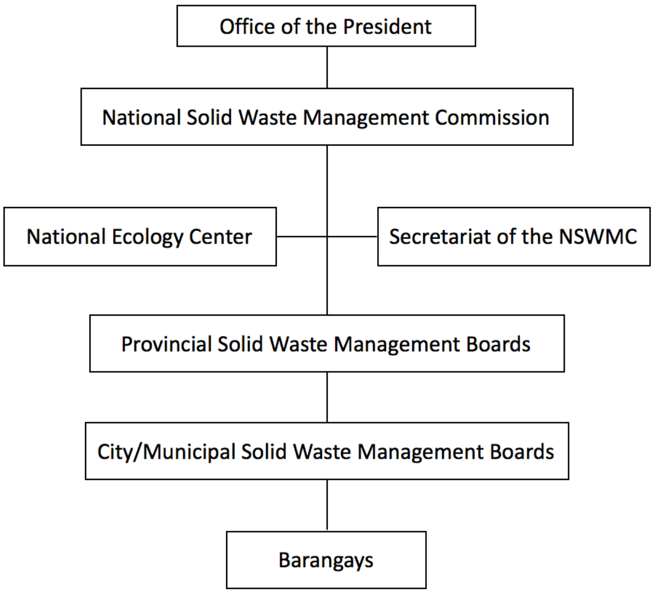

Figure 6 Institutional Framework of SWM (Source: World Bank, 2001)

3.3. Waste system elements in the Philippines

Waste system elements includes separation and collection, transfer and transport, treatment and disposal, reduction, reuse, recycling, and recovery (3R). (Van de Klundert, Anschütz 2001) In this section, basic elements are discussed under the circumstance of the Philippines.

3.3.1 Waste separation and collection

Separation at source is required by Philippine government. The wastes should be primarily separated as biodegradable wastes and non-biodegradable wastes. Separation is defined as a solid waste management practice in order to follow the hierarchy of RA

9003, which promotes reuse recycling and the avoidance of waste. Solid waste shall be labelled as: 'compostable'', ''non- recyclable'', ''recyclable'', or ''special waste''. A nationwide campaign is conducted with a slogan of "no separation, no collection", whereas compliance of LGUs to separation at source vary from 53% to 100% based on validations conducted by NSWMC Secretariat. (Magalang 2014)

However, the reality is, segregation at source is not always working, most wastes remain "mixed wastes" in the end. To solve this problem, waste containers with color codes are implemented by some LGUs. In 2013, a regulation, Resolution No.60 is approved as recommendatory guideline for segregation at source. (NSWMC 2015)

Surprisingly, collection is the most important aspect of solid waste management due to the following two reasons. It not only requires the most expenditure, but also has the greatest impact on public health and environment. (Coffey, Coad 2010)

In the Philippines, segregated collection is required by RA 9003. Biodegradable and recyclable wastes are separated and collected at the barangay (the smallest administrative division in the Philippines) level. City or municipality is responsible for the collection and disposal of non-recyclable and special wastes. (NSWMC 2015) Some LGUs outsource waste collection to private contractors, and some LGUs still practice mixed waste collection. Similar to waste separation, compliance to segregated collection vary from 43% to 100%. (in the Selected 128 sites) The waste collection coverage in the Philippines may vary from 30% to around 99%. More urbanized, higher coverages and frequencies of waste collection. (NSWMC 2015)

3.3.2 MRFs and Recycling

Material Recovery Facility (MRF) is mandated by RA 9003 to establish at barangay level. Compostable and recyclable material shall be processed in the MRF and the residue needs to be sent to proper disposal. Localized MRFs are being established in schools, commercial locations, even the junkshops serve as MRFs in some areas.

Number of MRFs reported to NSWMC is presented in **Figure 7**, by the year of 2014, the total number of MRFs is almost tripled since 2008, from 2438 to 8656.

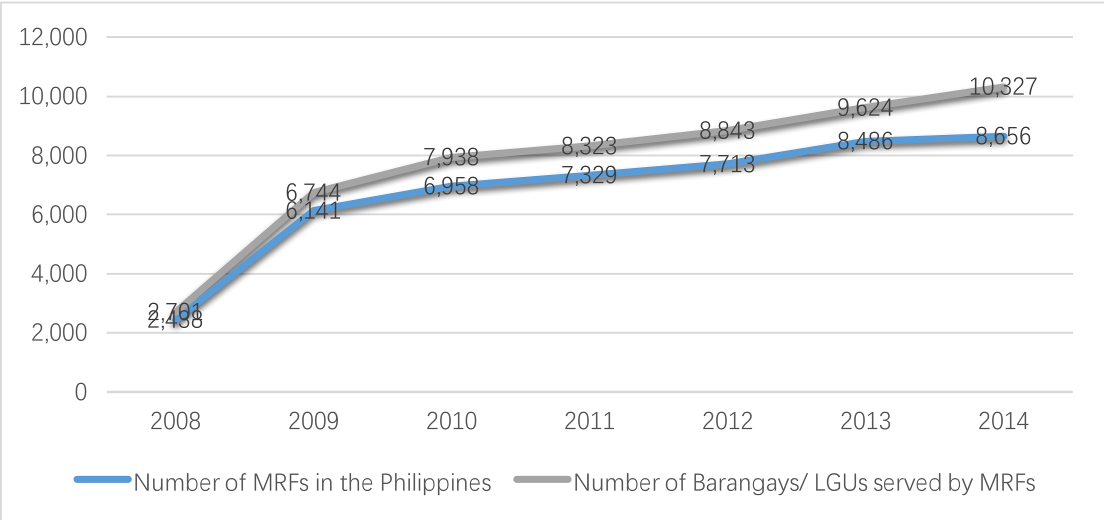

Figure 7 Number of MRFs in the Philippines (NSWMC 2015)

Recycling is also recognized under RA 9003 and it is of great importance in this law. Guidelines are offered by RA9003, it recommends to establish buy-back centers and MRFs, in addition, it lists an inventory of markets and promotes Product Coding/Eco-labeling Program (ELP).

As mentioned before, junkshops serve official MRFs in the Philippines. Recyclables with high commercial value are sold to junk dealers. In many cases, collectors, recyclers or generators themselves bring their recyclable waste to junkshops. Mostly recovered materials will be sold outside the Philippines for utility by industries. However, recycled products (e.g. recycled aluminum) are also produced locally by recyclers.(NSWMC 2015)

A 2008 study shows that huge volumes of recyclables could be diverted by primary waste collector as shown in **Table 3**. Primary waste collectors include street collectors, collection workers and disposal site scavengers. As we can see, Metro Manila has the highest collection rates in Paper, Aluminum, Plastic and other Metals, which makes sense due to the economic performance of Metro Manila. Take Paper as an example (**Figure 8**), primary collectors, especially disposal site scavengers, could collect paper of 22.01kg/capita/day, followed collection workers with 21.83 kg/capita/day, and street collectors with 3.18 kg/capita/day. However, the lack of collector numbers makes it impossible to estimate the total collection amount by this data. In 2001, Work bank has conducted a study, and in Metro Manila, the recycling rate is 13%, while Japan International Cooperation Agency (JICA) gives a number of 6%.

Table 3 Collection of Recyclable Materials by Primary Collectors (unit: kg/capita/day) (NSWMC 2015)

Recyclable Material	Primary Collector	Metro Manila	Metro Cebu	Southern Mindanao
Paper	Street Collectors	3.18	3.59	2.45
	Collection Workers	21.83	1.81	0.62
	Disposal Site Scavengers	22.01	8.21	12.86
Aluminum	Street Collectors	0.76	0.35	0.4
	Collection Workers	0.78	0.13	0.02
	Disposal Site Scavengers	2.5	0.05	1.79
Other Metals	Street Collectors	1.39	5.04	14.76

	Collection Workers	12.35	0.94	0.64
	Disposal Site Scavengers	16.75	6.34	13.75
	Street Collectors	1.63	3.94	3.5
	Collection Workers	9.79	0.5	0.63
Plastic	Disposal Site Scavengers	20.32	4.48	25
	Street Collectors	0.85	0.58	6.65
	Collection Workers	6.58	0.26	0.94
Glass	Disposal Site Scavengers	9.96	0.32	49.64

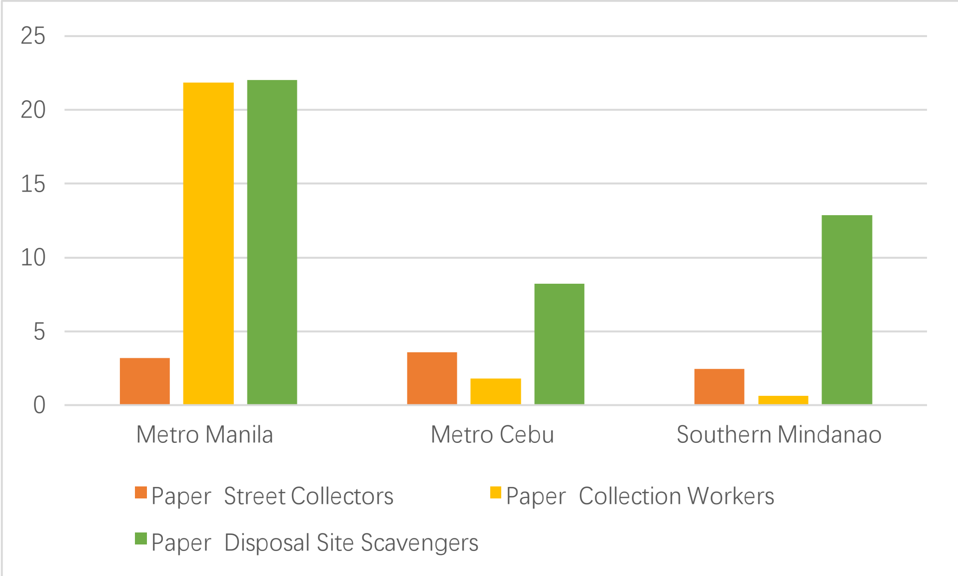

Figure 8 Collection of Paper by Primary Collectors (unit: kg/capita/day)

Due to the essential contribution of informal sectors, such as primary collectors, some LGUs have explored partnership with them in adding recycling rate. There is also alternative way to pursue this purpose, by diverting recyclable materials into innovative products, such as slippers, bags and accessories, etc.

3.3.3 MSW treatments regarding Waste to Energy

Because of the shortage of energy, Philippines starts to seek the Waste-to-Energy opportunities. City Government of Tagum and Global Green International Energy Philippines, Inc. signed a Memorandum of Agreement in September 2013, which is marked of the first Waste-to-Energy facility in the Philippines. (City Government of Tagum 2016) It states that this project will generate fuel and electricity from solid waste.

Since this historic agreement, there appears several ongoing projects and potential projects concerning Waste-to-Energy facilities in the Philippines.

Incineration

All kinds of Incineration technologies are banned in Philippines. The following Act defines the "waste to energy" technology in Philippines, which means, Waste to Energy technology can only be biodegradable treatment instead of incineration. Especially, In the Clean Air Act of 1999, incineration of municipal waste is prohibited.

The definition of Waste to Energy technology is provided in Section 30 of RA 9513 which subjects to RA 9003 and Clean Air Act. Specifically, waste to energy technology refers to *"systems which convert biodegradable material such as but not limited to animal manure or agricultural waste, into useful energy processes such as: anaerobic digestion, fermentation, and gasification, among others, subject to the provisions of the Clean Air Act of 1999 and the Ecological Solid Waste Management Act of 2000"*.(NSWMC 2016)

This law influenced attitudes towards Waste-to-energy. They equalize waste-to-energy to incineration, which make it difficult for utilizing waste-to-energy technology in general. Some environmentalists state that even pyrolysis-based incineration and anaerobic digestion should be banned as well for the technology legitimizing creation of waste, threatening the livelihoods of waste collectors and reducing the production of compost.

Co-processing

Since incineration is banned by legislation in the Philippines, co-combustion, or co-processing, becomes an alternative method for Waste-to-Energy. Guidelines are issued on "the use of Alternative Fuels and Raw Materials in the Cement Kilns", In the Guidance Manual, combustible waste replace portion of traditional fuels and non-combustible waste replace part of the raw materials. (NSWMC 2016)

Currently, there are 14 cement plants of six companies in operation in the Philippines. The increasing prices for oil and raw material serve as incentives for enterprises to search for alternative fuels and raw materials (AFRs) Co-combustion is identified as an environmentally friendly technology concerning energy utilization due to the replacement of fossil fuels and raw materials. (NSWMC 2016)

Refuse-derived Fuel (RDF), selected waste with recoverable calorific value can be used as fuel in cement industry, power industry and paper industry. (WRc 2003) . In 2015, the largest RDF plant comes online in Pasia, Manila. The plants transfer selected waste into fuel pellets as alternative fuel for cement kilns. 25%-35% of processed waste is converted to RDF. (Global Cement Staff, 2015)

Anaerobic Digestion

In most developing countries, the municipal solid waste stream is "dominated by organics." This means that the use of incineration is difficult, that the use of biological treatment is necessary.

Anaerobic digestion (AD) is one of the oldest technology used by human. It is common and only used in the wastewater plants. (Palmisano, Barlaz 1996) Anaerobic digestion can lead to more efficient energy recovery by producing biogas rather than composting and landfilling. In addition, due to its closed and controlled process, it is more preferable than above technologies. (Levis et al. 2010) However, even high efficiency has been proved, technical difficulties are faced by the requirement of "clean" feedstock. Furthermore, High investment and operation cost can be another significant barrier. (Kelleher 2007) Anaerobic digestion facilities in the Philippines face the same awkward situation. There is lack of documented studies regarding Anaerobic digestion in the Philippines, however, it is reported that the first anaerobic digestion project planned in Philippines in 2014. This will be a $47 million project and the first ever biomethane plant which produce biomethane from waste in the Philippines. (Gazasia Ltd 2014)

Landfill with Landfill Gas Recovery (LFG)

Before the passage of RA 9003, Almost all wastes go raw, open-space dumpsites, that lack control systems and management. The regulation mandates the transition from raw dumpsites to controlled ones and finally end up to sanitary landfills (SLFs). SLFs are facilities with impermeable liners and gas control system, a regular soil cover and other protection measures. Number of dumpsites has decreased from 2001, and till 2014, still existing dumpsites in the Philippines is 900 in total. Before 2004, only four SLFs existed in the Philippines, and now, operating SLFs is 86 and another 51 under construction. (NSWMC 2015)

There are four Clean Development Mechanism (CDM) registered projects related to landfill gas recovery,

- Payatas Landfill Gas Capture and Electricity Genration
- Metro Clark Landfill Gas Capture and Flare System
- Montalban (Rodriguez) Gas Capture and Electricity Generation
- Cebu City Landfill Gas and Waste to Energy Project

Payatas landfill project is the first CDM project in solid waste management in the Philippines and even in Southeast Asia. The project registered in February 2008. Metro Clark project (2009) is designed as a landfill gas (LFG) collection, flaring and electricity generation project. Montalban project has been in operation from 2002, and Cebu City Landfill project started even earlier in 1998, and its captured CH_4 is expected to produce up to 10 MW of electricity. (NSWMC 2016)

4 WASTE-TO-ENERGY POSSIBILITIES IN THE PHILIPPINES (CASE STUDY: METRO MANILA)

Most of studies about MSW management in Philippines is concentrated in Metro Manila, due to the lack of data outside this area and the fact that wastes generated in Metro Manila account for 25% of total waste, we take Metro Manila as the example to explore waste-to-energy possibilities in the Philippines.

4.1. Description of study area – Metro Manila

Metropolitan Manila, also known as Metro Manila, is the capital and heart region of Philippines. The National Capital Region (NCR) consists of Manila, Quezon city, and the cities of Caloocan, Las Piñas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasay, Pasig, San Juan, Taguig, and Valenzuela, including the only remaining municipality of Pateros.

Metro Manila with an area of 636 km^2 and a population of 12,877,253, This region is the cultural, economic, educational, and governmental center of the Philippines. NCR accounts for 37.2% of gross domestic product of this country. (Census of Population 2016)

Figure 9 Map of Metro Manila source: (Ragragio 2003)

Existing SWM Practice in Metro Manila

Asian Development Bank (ADB) has conducted a comprehensive study on solid waste management in Metro Manila, although the study is in 2003, later reports still use the data from this report due to the insufficiency of studies in the Philippines. Based on Asian Development Bank (ADB 2003) report, there is a clear deficiency of the provision for proper waste treatment in Metro Manila. Some problems are found by their study: waste collection rates are quite low for household; Financial support is not sufficient; Waste collection is missed from businesses and commercial establishments; LGUs are unclear about their responsibilities.

4.2. Methodology of this study

4.2.1 Data collection

Data of this study is mainly from extensive literature review. The chosen area is Metro Manila, the purpose is to identify and quantify Waste-to-Energy options that can be utilized in Metro Manila. Four scenarios are created to find the optimum solution. The methodological framework is shown in **Figure 10**. In this study, electricity production is used to compare energy recovery from different scenarios.

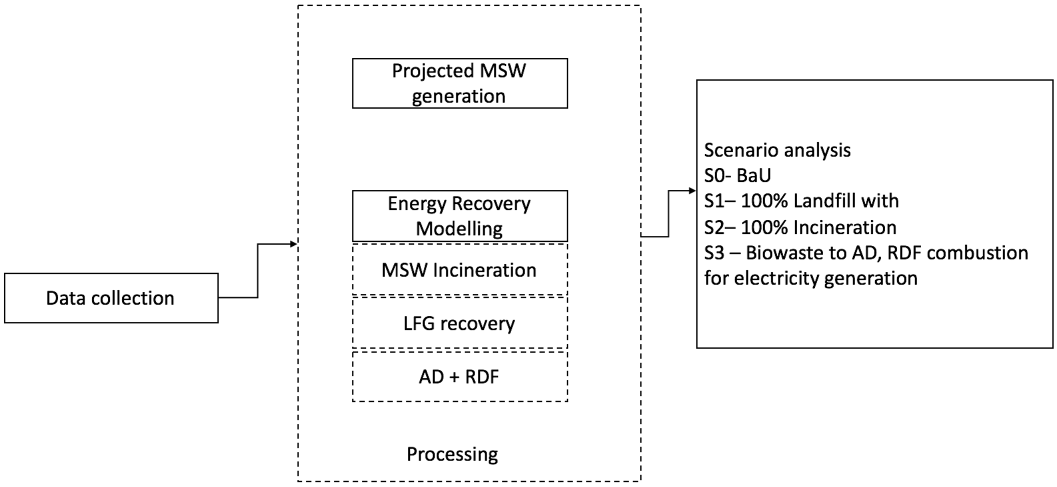

Figure 10 Methodological framework of this study

4.2.2 Projected MSW Generation

The projected MSW generation in Metro Manila indicates the increase of population and economic development. The average waste generation rate in Metro Manila is 0.69 kg/capita, the estimated generation range is from 2012 to 2035.

4.2.3 MSW Properties

Waste composition on wet basis, dry weight fraction, moisture content, chemical properties, and other figures to estimate energy recovery is needed. Characteristics of MSW in Metro Manila is determined by waste analysis and characterization studies (WADS) conducted by Asian Development Bank (ADB) in 2003 and Japan International Cooperation Agency (JICA) studies in 1999.

4.2.4 Energy from MSW Incineration

Waste incineration is to transfer energy content of MSW into heat, electricity or both.

Mass incineration implies that unsegregated waste feedstock is combusted in a furnace under high temperature with excess oxygen. Lower heating value as received (LHV_{ar}) is the way to express energy content of MSW in this study. Lower heating value as received indicates that lower heating value with all moisture- and ash- forming mineral present. LHV_{ar} of MSW in Metro Manila is 7.65 MJ/kg from literature, which is shown in **Table 4**. The efficiency of electricity production is taken as 20% since the average rate of efficiency is 15% to 27% from literature. (Defra 2014)

Table 4 Waste fraction and assumed LHV_{ar} in Metro Manila from Literature (Source: Rand, T 2000)

Mass Basis Fraction	% of Waste	LHV_{ar} (kJ/kg)	LHV_{ar}(MJ/kg)
Food and organic waste	45.0%	1912	1.91
Plastics	23.1%	20144	20.14
Textiles	3.5%	11789	11.79
Paper & cardboard	12.0%	6440	6.44
Leather & rubber	1.4%	14265	14.27
Wood	8.0%	9310	9.31
Metal	4.1%	-147	-0.15
Glass	1.3%	-73	-0.07
Inert (slag, ash, soil, tec.)	1.0%	-245	-0.25
Fines	0.6%	2584	2.58
Weighted Average	100%	7649.667	7.65

4.2.5 Energy from Refuse-derived Fuel (RDF)

In this study, MSW is assumed to be separated by a typical mechanical-biological treatment (MBT) which is shown in **Figure 11**. Metals, glass and inerts are separated out and organic waste are partitioned and cleaned for AD. The rest fraction is processed as refuse-derived fuel (RDF).

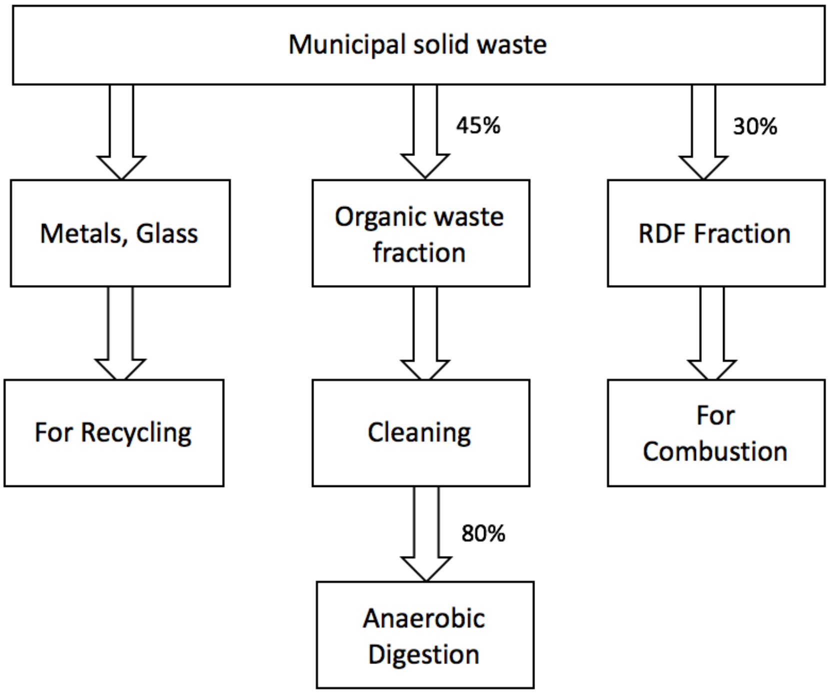

Figure 11 A typical MBT process

Values of energy content of waste fraction are used from literature due to the lack of data, which are shown in **Table 4**. Glass, Metal, Inert, Fines are excluded from RDF by mechanical separation. The calculated lower heating value is 14.1 MJ/kg. Based on a European report, conversion rate of RDF from mixed waste is from 23-50% (WRc 2003) and a Philippine RDF plant indicates that the conversion rate is 25-35% (Global Cement Staff, 2015), therefore, 30% is taken in this study for calculation. For a better comparison with other scenarios, RDF is assumed to be combusted in a power plant to generate electricity. The power generation efficiency of RDF is taken as 25% from literature. (Defra 2014)

4.2.6 Energy from Anaerobic Digestion (AD)

A Finnish study (Motiva 2013) shows an average gas yield from typical food waste is 150-250 m^3/tonne with 65% methane content. 200 m^3/tonne (including carbon dioxide) is used to calculate gas generation in this study, in which methane comprises about 60%.

It is not possible to find the detailed percentage of biowaste residue as feedstock for AD since AD requires a certain of purity, so in this study, we assume that 80% of biowaste is separated from food waste fraction. The lower heating value of methane is about 40 MJ/m^3n. (Li Y, et al. 2011)

In most cases, biogas can be used as fuel for electricity generation. Two typical technologies are used here, a gas electric generator set or natural gas boiler system. (Energypedia 2016). In this study, it is assumed that a Spark ignition engine is used for power generation, and the efficiency of power generation is 22-28% for biogas from waste. (Li Y, et al. 2011)

4.2.7 Energy from Landfill Gas Recovery

Landfill Gas production

Methane emission is estimated by **Philippines Landfill Gas Model** developed in 2009. (EPA 2014). This landfill gas model is based on USEPA LandGEM model and following IPCC guidelines. The default parameters are determined by this model. The estimation is calculated by equation (1).

$$\boldsymbol{Q_{CH_4}} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} \boldsymbol{kL_0} \left(\frac{\boldsymbol{M_i}}{\boldsymbol{10}}\right) \boldsymbol{e^{-kt_{ij}}} \quad (1)$$

Where

- Q_{CH4} = the quantity of methane emission
- K = Methane Generation Rate
- L_0 = Ultimate Methane Generation Potential
- M_i = Annual Waste Intake
- User inputs site-specific data for landfill:
- opening and closure years
- landfill characteristics (collection efficiency)
- history of landfill fires

In this equation (1), the default average methane generation rate (k) value for

Philippines is 0.18, expected methane content of LFG is 50%, and the recommended L_o value is 60 m^3/Mg. (Hala, et al, 2013) Collection efficiency is determined by the following criteria (**table 5**). They suggest "a 3% discount for "No" to Question 1, a 5% discount for "No" to Question 2, a 10% discount for "Yes" to Question 3, a 10% discount each for "No" to Questions 4 and 5, and a 5% discount each for "No" to Questions 6 and 7 for the seven questions." (EPA 2009) a recommended value for collection efficiency is shown in **Table 6** from a research on Landfill Gas potential in the Philippines, the estimated collection efficiency for Philippines is 67%. (Hala, et al. 2013)

Table 5 Criteria for collection efficiency of LFG emission (Source: Hala, et al. 2013)

No	Question	Response	Collection Efficiency Discount for Response
1	Is the waste placed in the Dump properly compacted on an ongoing basis?	Yes	0%
2	Does the Dump have a focused tipping area?	Yes	0%
3	Are there leachate seeps appearing along the Dump side slopes? Or is there ponding of water/leachate on the Dump surface?	Yes	10%
4	Is the average depth of waste 10 meters or greater?	Yes	0%
5	Is any daily or weekly cover material applied to newly deposited waste?	Yes	0%
6	Is any intermediate/final cover applied to newly deposited waste?	Yes	0%

7	Does the Dump have a geosynthetic or clay liner?In which bracket (I to V) does LFG System Area Coverage Percentage fall?	No	5%
8	In which bracket (I to V) does LFG System Area Coverage Percentage fall?	I (80-100%)	0%

As for question 8, The LFG System Area Coverage Percentage indicates that the percentage of the landfilled area which is equipped with an operating LFG collection system. It is divided into 5 categories and is shown in **Table 6.** The collection efficiency would decrease in accordance with Area Coverage Factor.

Table 6 LFG system Area coverage factor

LFG System Area Coverage Percentage	Bracket	Area Coverage Factor (ACF)
80-100%	I	95%
60-80%	II	75%
40-60%	III	55%
20-40%	IV	35%
<20%	V	15%

As for power generation from LFG, it is assumed that the LFG is combusted in an engine with 30% efficiency to produce electricity.

Sensitivity Analysis

Since the collection efficiency is indeterminate, a sensitivity analysis is applied to check the influence of this value. It is assumed that the collection efficiency is 30%, 50%, 67% as recommended, and 90%. And in different scenarios of collection efficiency, the generated LFG is compared.

4.2.8 Waste-to-Energy Scenarios

Waste-to-Energy scenarios are presented in this section. The scenarios are created based on the current situation in the Philippines. They are pursuing several alternative energy possibilities within the legal framework, as discussed above, landfill with landfill gas recovery, co-processing and anaerobic digestion (AD).

Table 7 Waste-to-Energy scenarios in this study

Scenario	Description
S0	Business as usual scenario, Recycling and landfill.
S1	Landfill with LFG recovery.
S2	Mass Incineration
S3	Bio-waste to AD, RDF combustion for electricity generation

Table 7 shows the four scenarios (one baseline scenario and three WtE scenarios) considered in this study. The scenarios are of different strategy. **Scenario 0** is Business as Usual scenario, the current situation. **Scenario 1** is landfill gas (LFG) recovery strategy, with the other factors remain the same. **Scenario 2** is total incineration strategy, although incineration is forbidden in the Philippines, there is still possibilities to utilize this technology in the future, therefore, incineration is taken as a potential alternative in this study. **Scenario 3** is combined strategy, by using mechanical biological treatment, MSW is divided into two flows, biowaste is processed by anaerobic digestion (AD) in order to produce biogas, refuse-derived fuel (RDF) is sent to power plant to produce electricity.

Detailed information of scenarios is shown below.

Scenario 0 - Business as usual

National Solid Waste Management Commission has published a waste flow in Metro Manila as shown in **Figure 12**.

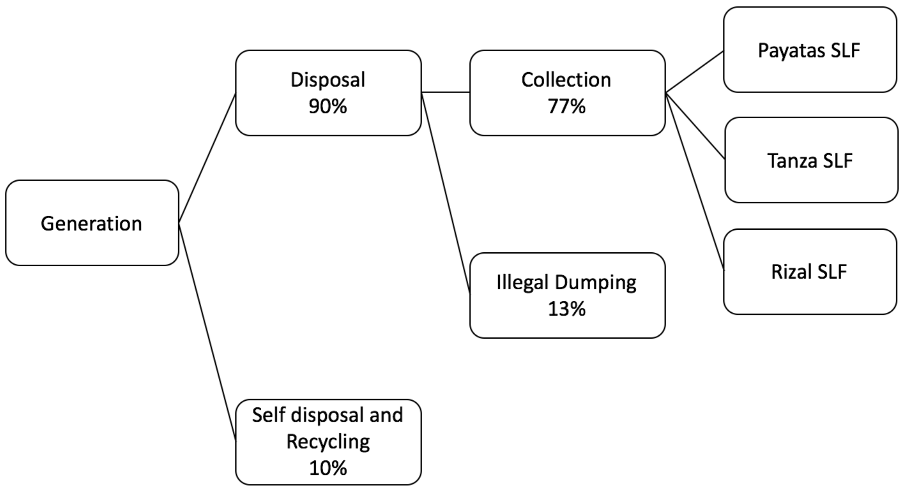

Figure 12 Waste Flow in Metro Manila (Source: NSWMC)

The diagram is used as the current scenario in Metro Manila, self-disposal is that waste is recycled or composted by household themselves, while illegal dumping is that uncollected waste is illegally burned, buried or dumped into vacant lots, rivers. There is no open dumpsite or controlled dumpsite in Metro Manila but three sanitary landfill (SLF) sites, which are Payatas SLF located in Quezon city, Tanza SLF locataed in Navotas city, and Rizal provincial SLF. Rizal provincial SLF is a clustered landfill regarding several LGUs. (NSWMC 2015) As shown in **Figure 12**, Self-disposal and recycling rate is taken as 10%, the rest 90% of waste ends in disposal, in which proper collected waste takes 77% and illegal dumping is 13%. (JICA 1999)

Scenario 1 – LFG recovery

In this scenario, all waste excluding recyclables go to landfill, and the amount waste sent to landfill is determined by the current situation in scenario 0. It is assumed that Landfill Gas (LFG) recovery is applied to all waste sent to landfill.

Scenario 2 – Mass incineration

In this scenario, all waste excluding recyclables go to mass incineration. The amount of waste is determined by waste collection rate.

Scenario 3 – Combined strategy (RDF + AD)

This scenario is a combined strategy, in which non-biowaste with higher LHV_{ar}, such as paper, plastics, is taken as refuse-derived fuel (RDF), which comprises 30% of total MSW, and 80% of biowaste fraction is sent to anaerobic digestion (AD).

5 RESULTS AND DISCUSSION

5.1. Projected Waste Generation

Waste generation rate in Metro Manila has been estimated from a waste analysis and characterization studies (WACS). (NSWMC 2015) The studies use 2012 as base year. It shows that the average generation rate of Metro Manila is 0.69 kg/capita/day. Based on the generation rate and projected population of this area, the projected waste from 2012 to 2035 can be seen in **Figure 13**. The Figure shows that the estimated MSW keeps increasing and is expected to rise from 3.14 million tonnes in 2012 to 4.4 million tonnes in 2035. It can be seen that collected waste is 77% of total waste and the rest are recycled and illegally dumped.

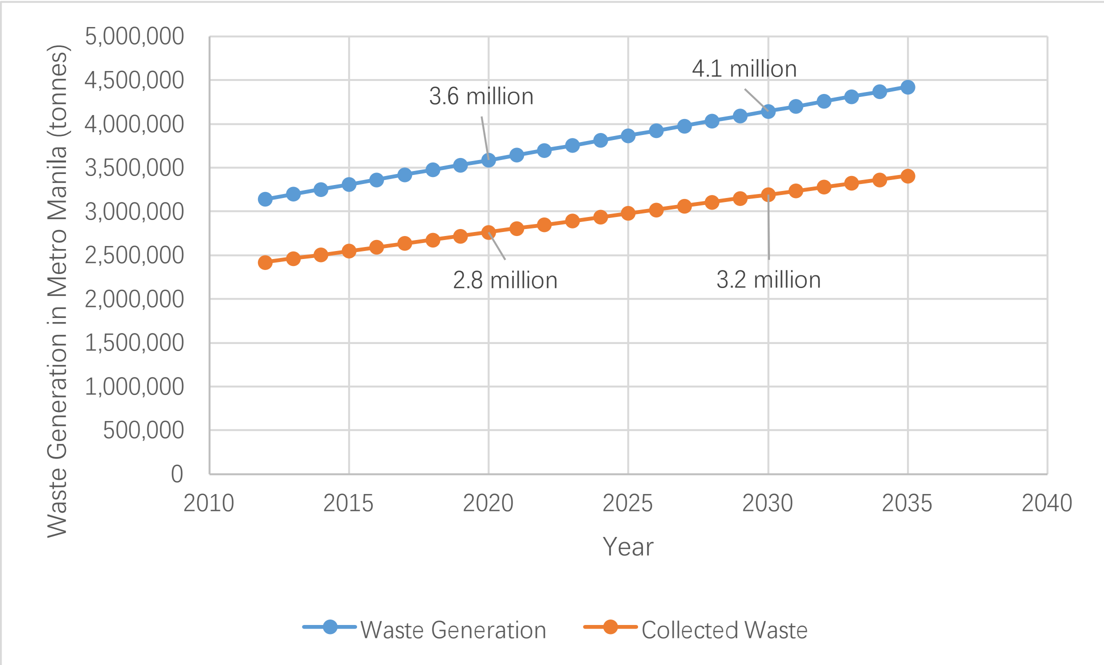

Figure 13 Projected waste generation in Metro Manila 2012 -2035 (tonnes per year)

5.2. WtE Scenario Analysis

5.2.1 Scenario 1 – LFG Recovery

The result of total LFG generation in landfill can be seen in **Figure 14** for the period of 2012-2035. It is assumed that the opening year of landfill is 2012 and the closure year is 2035. After the closure of landfill, the gas is collected continued until LFG is completely collected. The maximum landfill gas production will be in 2036 with 43,000 m^3 per hour. The estimated energy recovery from LFG recovery is shown in **Figure 14.** In this study, it is assumed that the gas is combusted in an engine with 30% efficiency to produce electricity. In the whole time period, from 2012 till 2098, a total amount of Energy from LFG recovery is 9,059 GWh. As shown in **Figure 15**, Energy recovered from landfill gas keep increasing till 2036 with 409 GWh, and decrease from 2036 with the decrease of LFG generation.

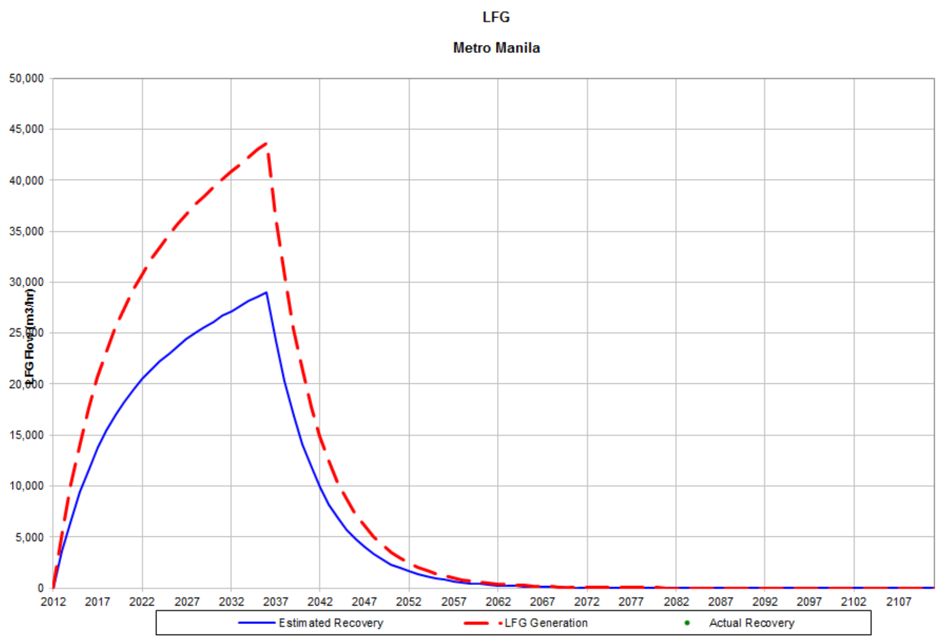

Figure 14 Landfill gas generation in Metro Manila

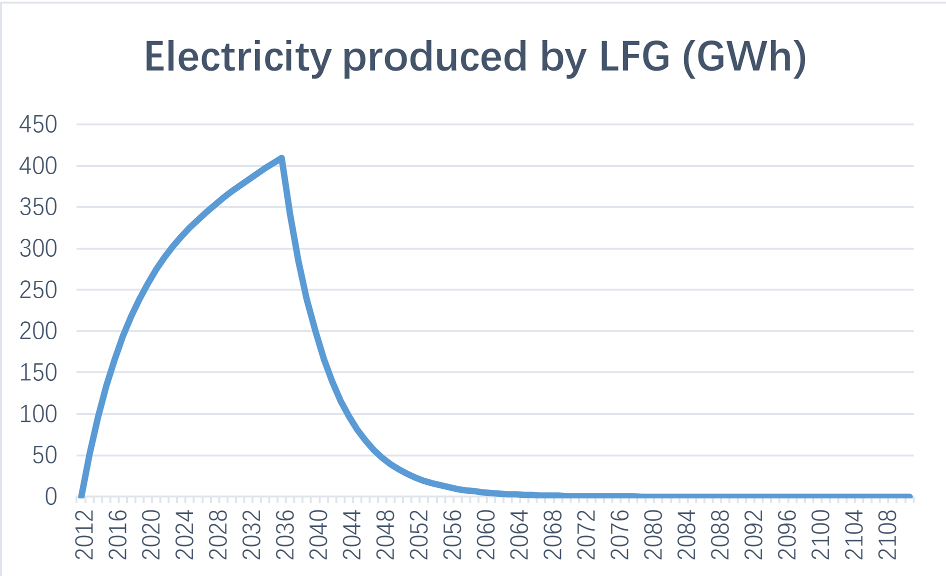

Figure 15 Electricity generated by LFG

Result of Sensitivity Analysis

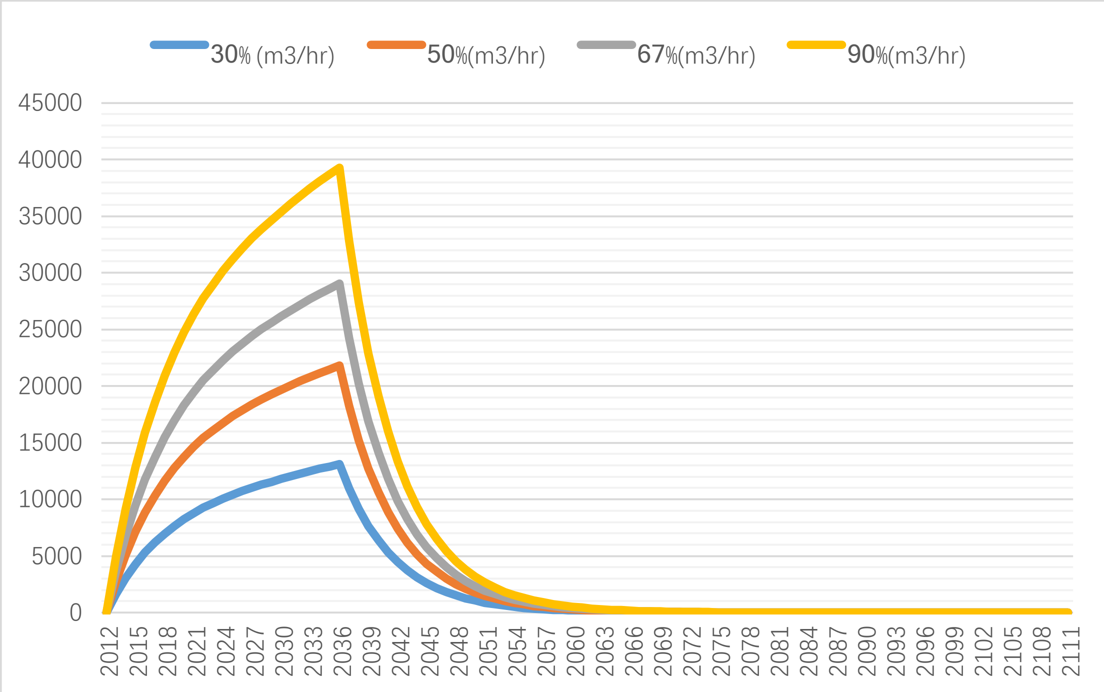

Figure 16 LGF Recovery under different collection efficiency

As shown in **Figure 16**, under different collection efficiency with 30%, 50%, 67% and 90%, the LFG recovered is of significant different. The energy output from electricity generation project is shown in **Table 8**. Collection efficiency has immense impact on the result of power generation potential from LFG recovery. Thus, detailed information is required in the future studies.

Table 8 Energy output from electricity generation project under different collection efficiency

Collection efficiency	Energy output from electricity generation project in 2020 (MW)	Energy output from electricity generation project in 2030 (MW)
30%	14.1	18.9
50%	22.1	31.7
67%	29.4	42.1
90%	39.8	57.0

5.2.2 Scenario 2 - Mass Incineration

As shown in **Figure 17**, Power generation (electricity) from Mass Incineration is significantly higher than Landfill gas recovery. With the increasing amount of waste in

Metro Manila, Energy from Mass incineration is increasing from 1028 GWh in 2012 to 1448 GWh in 2035. The total electricity generation from mass incineration is quite impressive, which is 29,700 GWh during 2012 to 2035.

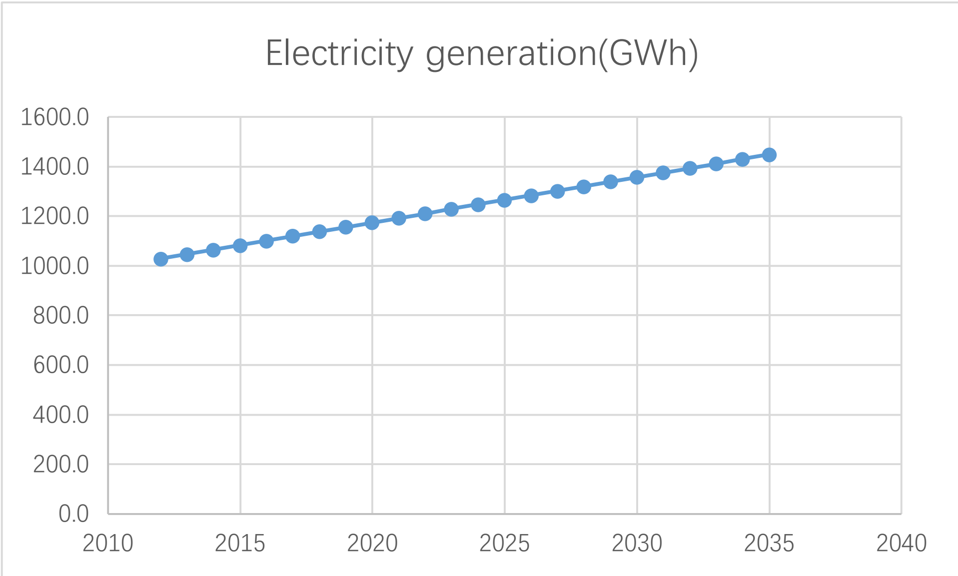

Figure 17 potential electricity generation from Mass Incineration

5.2.3 Scenario 3 – RDF + Anaerobic Digestion (AD)

In this combined strategy, Waste is separated into RDF and biowaste. In Metro Manila, biowaste accounts for 45% of total MSW. Energy recovered from RDF and AD is calculated separately. The results can be seen in **Figure 18.** It shows that electricity generation from RDF is rather high. During the time period, from 2012 to 2035, the total amount of electricity generated is around 34,000 GWh, in which RDF as fuel and biogas from AD generates about 20,000 GWh and 14,000 GWh respectively.

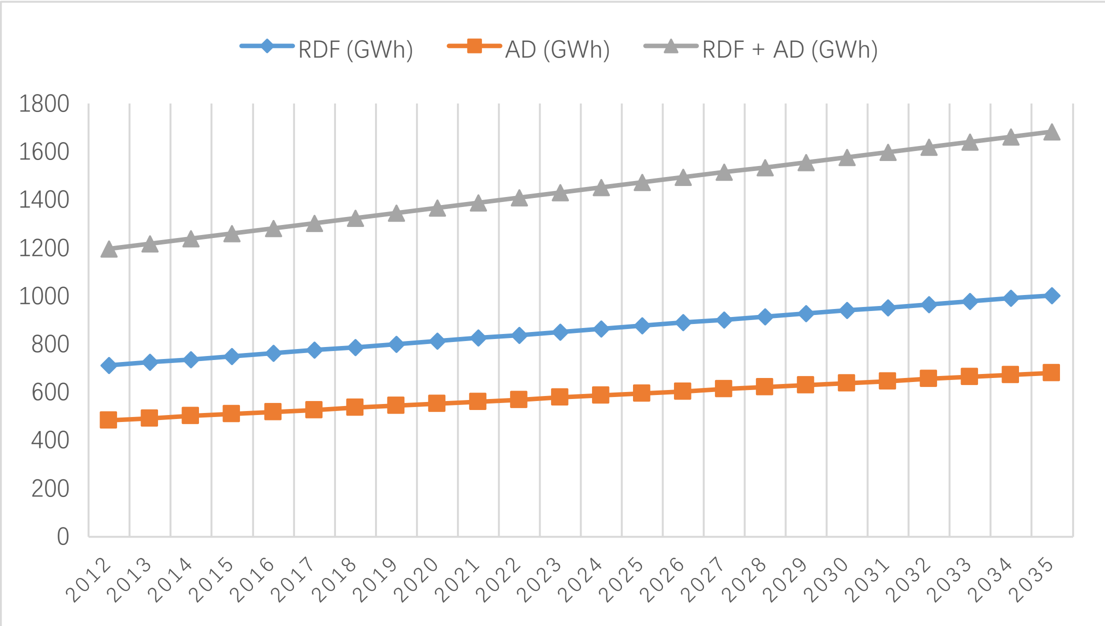

Figure 18 Electricity Generation from RDF + AD

5.2.4 WtE Scenario Analysis - Summary

To compare three WtE scenarios, electricity generated from different scenarios is shown in **Figure 19**. It is obvious that power generation (electricity) from combined strategy is the highest and way much higher than the other two scenarios. Although after the closure of landfill, LFG is still produced at site, the accumulated energy is not as high as other two scenarios. In **Figure 20**, it shows that during the whole time period, the total electricity generated by three scenarios. It can be seen that, S3, the combined scenario, is slightly higher than incineration scenario and significantly higher than LFG recovery scenario.

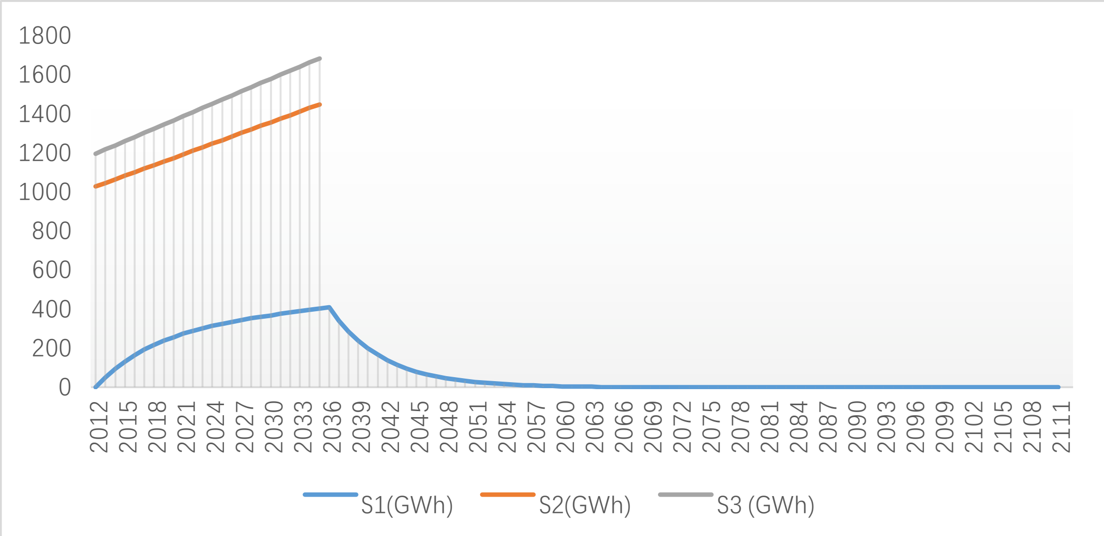

Figure 19 Electricity Generation from three scenarios by year

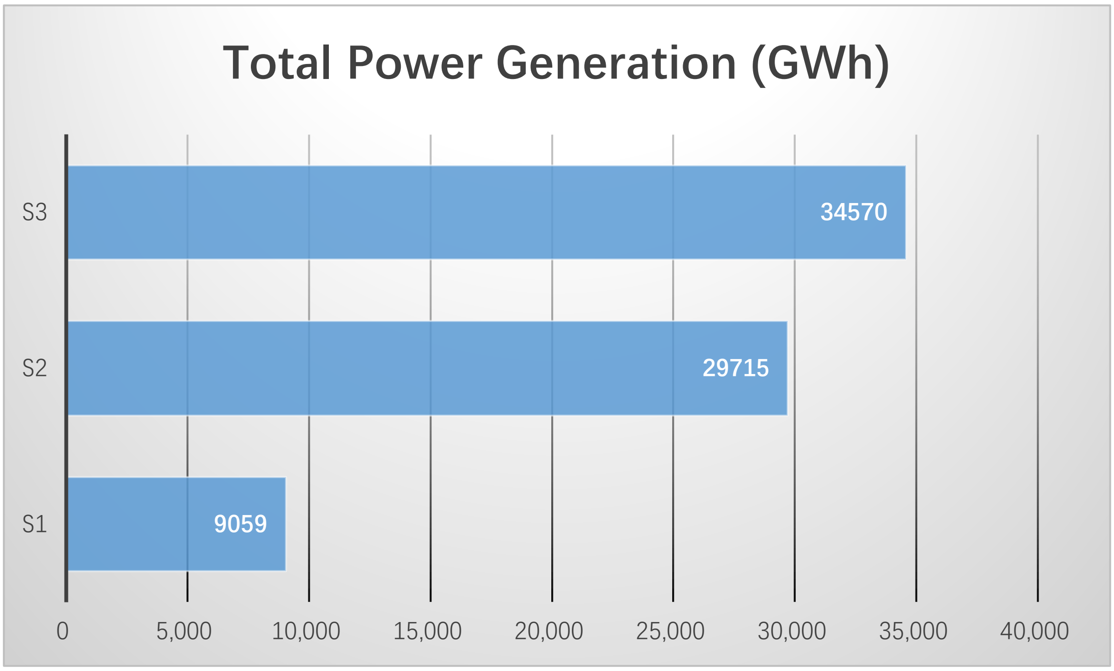

Figure 20 Total Electricity Generation from three scenarios

6 CONCLUSION

In this thesis, MSW management in the Philippines is discussed under the framework of Integrated Sustainable Waste Management (ISWM) with the focus on Waste-to-Energy technologies. Scenario analysis is conducted to identify preferable options for the Philippines.

It is typical in developing countries that increasing population has generated numerous issues, one of those issues is the great pressure to “modernize its solid waste systems”. Waste characteristics in the Philippines is similar to other developing countries with higher organic fraction compared to developed countries. There are two important issues considered in this thesis, which is political, technological aspects of MSW management.

The political aspect in the Philippines met its milestone in 2001. RA 9003, an ecological solid waste management act, has significantly improved MSW management and has given birth to National Solid Waste Management Commission (NSWMC), which is a Government institute responsible for National Solid Waste Management Framework for the whole nation. Under RA 9003, a series of practices has been conducted following the hierarchy of waste management. Open dumpsites are mandated to close within three years after the issuing of the Act; More participation from stakeholders is encouraged; Incentives and Penalties are set to ensure the implementation of RA 9003. However, the results of implementation of RA 9003 is not as good as expected.

As for technical aspect in the Philippines, waste separation and collection has been improved during past decade. Campaigns and regulations has been promoted to implement “no separation, no collection”. MRF has been increased and to triple in numbers.

MSW treatment options regarding waste to energy meet different situations when applied in the Philippines. Incineration is entirely banned due to the Clean Air Act of 1999, while co-processing is becoming a new attempt by Philippine government. Anaerobic digestion is also an alternative way of waste treatments, however, the high investment cost becomes the barrier to apply the technology in the Philippines. Landfill with LFG seems to be the easiest and fastest method applied in the Philippines since it is supported by CDM program.

The last and most important section of this thesis is the case study of Metro Manila. Metro Manila, also known as NCR, is the political, economic, educational and governmental center of the Philippines. The aim of this study is to identify desirable WtE option for Metro Manila. Three WtE scenarios and one baseline scenario are created and compared by electricity generation potential. These scenarios are:

S0 - Business as Usual (Landfill)

S1 - Landfill with LFG recovery

S2 – Mass Incineration

S3 – Biowaste to AD, RDF combustion for electricity generation

The results of this study shows that, S3 has highest power generation potential (electricity). In order to implement this combined strategy, mechanical-biological-treatment is required and there needs to be a RDF plant. The Philippine government is seeking opportunities to implement these new technologies and in the year 2014 and 2015, AD project and RDF plant has come online in the Philippines.

Since Philippines is a low- middle- income developing countries, lack of capital can be a barrier to apply WtE technologies. In the future, financial possibilities of these technologies should be examined considering Philippine economic development.

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