SUCCESS FACTORS FOR SOLID WASTE-TO ENERGY PRODUCTION: A CASE STUDY OF THAILAND

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ด้วยปริมาณขยะชุมชนที่เพิ่มขึ้นจนกลายเป็นวิกฤตการณ์ระดับโลก การจัดการขยะมูลฝอยจึงเป็นเรื่องที่สำคัญที่สุดเรื่องหนึ่งในศตวรรษนี้ ในประเทศที่พัฒนาแล้วบางประเทศ ขยะถือว่าเป็นสินค้าโภคภัณฑ์ และมีระบบการจัดการขยะมูลฝอยและการผลิตพลังงานจากขยะที่ทันสมัย ซึ่งได้มีการนำไปใช้แล้วได้ผลจริง ประเทศกำลังพัฒนาทั่วโลกเล็งเห็นถึงศักยภาพของขยะ ที่จะนำไปใช้เป็นทรัพยากร โดยมีการลงทุนสร้างระบบการนำขยะกลับมาใช้ให้เป็นประโยชน์ อย่างไรก็ตาม แม้ว่าจะมีการสนับสนุนให้เกิดการผลิตพลังงานจากขยะมากขึ้นเรื่อยๆ แต่ในประเทศกำลังพัฒนา ยังคงมีอุปสรรคต่างๆที่ขัดขวางความก้าวหน้าในด้านนี้ วิทยานิพนธ์ฉบับนี้เป็นกรณีศึกษาสถานการณ์ในประเทศไทย โดยเจาะจงโรงงานผลิตพลังงานจากขยะภายในประเทศ จากการวิเคราะห์ข้อมูลทุติยภูมิ และการสัมภาษณ์ผู้มีส่วนได้เสียหลัก พบว่ามีอุปสรรค 2 ประเภทใหญ่ๆ คือ การขาดความโปร่งใส และ การมีส่วนร่วมของคนในชุมชน จากข้อมูลนี้อาจกล่าวได้ว่า การให้ความสนใจกับการพัฒนา ดำเนินการ และ บังคับใช้กฎข้อบังคับอย่างโปร่งใส เป็นขั้นตอนสำคัญในการส่งเสริมการผลิตพลังงานจากขยะ รวมทั้งการสร้างจิตสาธารณะและการส่งเสริมให้มีการคัดแยกขยะในบ้านเรือน ผลจากกรณีศึกษานี้สามารถนำไปใช้ในการวิเคราะห์และเปรียบเทียบปัจจัยแห่งความสำเร็จของโครงการผลิตพลังงานจากขยะ และอุปสรรคที่พบในบริบทของประเทศที่พัฒนาแล้วเมื่อเทียบกับประเทศที่กำลังพัฒนา

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Municipal solid waste (MSW) represents a major threat to the environment and health, particularly around waste management (WM) sites. In developing countries, environmental and social problems are worsened by ineffective waste management (WM) schemes as well as a lack of awareness. This is in sharp contrast with developed countries, where waste is treated as a commodity, a paradigm that helps advance solid waste management (SWM) systems as well as waste to energy (WTE). Developing countries around the world recognize the potential of WTE and are investing in different waste recovery systems. Despite the growing support for WTE, current barriers in developing countries are preventing its further development. Focusing on the case study of Thailand, this thesis analyses the barriers to and the success factors to waste-to-energy development. Through analysis of secondary data and in-depth interviews with key stakeholders, this thesis identifies two major types of barriers: lack of transparency and public participation. The findings suggest that further attention must be placed on the improvement of municipal capabilities in order to advance, apply, and enforce comprehensive guidelines for encouraging WTE promotion.

Field of Study:	Environment Development and Sustainability	Student's Signature	....
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CONTENTS

Page

List of Tables

List of Figures

Acronyms

WTE= Waste-to-Energy
MSW= Municipal Solid Waste
WM= Waste Management
ISWM= Integrated Solid Waste Management
RDF= Refuse Diffused Fuel
GHG= Green House Gases
SW= Solid Waste
MW=Mega Watts
TWh= Terawatt hour(s)
EU= European Union
ADB= Asian development Bank
WEF= The World Economic Forum
MONRE=Ministry Of Natural Resources
MOIN= Ministry Of Industry
MOI= Ministry Of Interior
ONEP=Office of Natural Resources and Environment
BMA= Bangkok Metropolitan Administration
MOE= Ministry Of Industry
MSWM= Municipal Solid Waste Management
EEC= Earth Engineering Center
UNEP= United Nations Environmental Program
3R = Reduce, Reuse and Recycle
ADB= Asian Development Bank
AIT= Asian Institute of Technology

Chapter 1

Introduction

1.1 Introduction

Population growth, urbanization, and changing consumer habits are driving energy demand and waste generation to grow at an excessive rate. The global production of municipal solid waste (MSW) is 1.8 billion tons, this represents the largest volume of waste produced worldwide (UNEP, 2013). Ineffective collection and unregulated disposal of solid waste (SW) causes adverse effects for the environment and public health (Zurbrügg, 2012). Low and middle-income countries[1] experience the most difficulties when it comes to these inefficiencies. This is the main reason why waste management (WM) is currently at the top of international priorities. The United Nations in Agenda 21 states that sustainable waste management (SWM) "presents a unique opportunity to reconcile development with environmental protection" (UNEP, 1992). Developing countries must improve organizational structures in order to promote WTE, e.g., through progressive policy, good governance, and public acceptance (Sutabutr, et al., 2010; Sajjakulnukit, et al., 2002). Consequently most countries are now heavily promoting integrated solid waste management legislation (ISWM).

Waste-to-Energy (WTE) mechanisms are now considered essential to ISWM policies of and should always be included. The World Economic Forum recognizes WTE as one of the eight technologies expected to create a significant influence for sustainable energy development (DEFRA, 2011). WTE can convert MSW to energy in various forms, including electricity, heat, or fuels. This is how WTE can address energy needs of a growing population while promoting efficient and sustainable use of a potential resource. Careful analysis of the composition and amount of waste is needed to diagnose and implement an integrated approach of technologies. Although low- to middle-income countries realize the need for change in the approach of WM, municipalities in these countries often lack appropriate infrastructure and resources to minimize the WM problem (Yoshida, 2006, UNEP, 2009).

Considering the many benefits of converting MSW in to energy, the traditional practices of waste disposal that are prevalent in developing countries should be seen as a loss of potential resources. The fundamental building blocks to fully utilize MSW as a viable energy source are large investment (public and private), political commitment, and a higher level of social awareness. For these reasons, an organized effort is necessary for the promotion of successful WTE: incorporating outlines in procedure and permits, institutional arrangements, financial provisions, technology, operations management, human resource development, public participation and awareness (Shekdar, 2009).

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[1] Low-income countries are defined by the World Bank as having a Gross National Income per capita of $1,045 or less in 2013; Middle-income countries have GNI per capita of more than $1,045 but less than $12,746 (World Bank, 2015)

Thailand currently produces 53,240 tons of MSW per day (Thailand State of Pollution Report, 2011) and is expected to grow with population and consumption trends. The country's energy demand is 153,332.16 billion kWh (Energy Statistics of Thailand, 2012) and the net generation is projected to increase to 346,767 GWh by 2030 (DEDE, 2012). In a country where 60% of the total energy supply is imported (Sutabutr, 2012), investigating underused alternative fuel resources like MSW is fundamental for environmentally friendly energy supplies. Barriers towards WTE projects in Thailand have been identified including the lack of comprehensive governance, insufficient budget for investment, inadequate maintenance, lack of access to technology, ineffective feedstock and public resistance (Vanapruk, 2010; Kaosol, 2009).

The Thai Government has set national energy policies and strategic plans for energy efficiency and alternative energy development to combat the MSW problem. The Thai Alternative Energy Development Plan (AEDP) proclaims that, the government has set a target for 2021 of 400 MW to be derived from WTE plants. As of mid-2013, the total installed capacity from MSW is 47.48 MW, but growth of WTE plants is slow and inefficient. Jacob et al. (2012) states that almost 50 projects were submitted for approval under the very small power producer (VSPP) regulation (sale capacity≤ 10 MW). Of the approved projects most have had substantial problems in the development stages and are not implemented (Jacob et al, 2012).

This thesis reviewed studies on the development of WTE plants in Thailand and found limited information regarding success factors for the development WTE plants. Based on an initial survey, it has been found that some provinces and municipalities have attempted to mount and manage different MSW anaerobic digestion and incineration plants with the intended goal of energy production but according to Cherdsatirkul (2012) nearly half have failed. An updated survey of the status of 18 WTE facilities listed in the Provincial Electricity Authority (PEA)'s database (see Table 1); seven plants have gone out of operation or are suspended. The objective of this thesis is to analyze characteristics form WTE projects that have been successful, and assess the viability to implement them in countries in low to middle income (here known after as Developing) using Thailand as a case study.

Table 1: Waste-to-Energy Plants in Thailand.

	Name	Technology	Location	Energy Produced MW	Date of Commission	Status
1	Phuket Municipality	Incinerator	Muang District, Phuket	2.500	1 July 2009	Closed
2	Rayong City Municipality	Anaerobic Digestion	Central district, Rayong	1 (DEDE) 0.6(PCD)	1 January 2007	Closed

3	Jaroensompong Co.,Ltd,	(LFG)	Rachathewa District, Samutprakarn	1.040	30 August 2007	Operational
4	Active Synergy, Co., Ltd.	(LFG)	Kampaeng Saen district, Nakhon Pathom	2.080 (DEDE) 1 (PCD)	4 April 2009	Operational
5	Clean City Co. Ltd.	Incinerator	Sriracha district, Chonburi	1.5 (DEDE) //5.12	5 June 2009	Closed
6	Landfill Gas to Energy (Royal Initiated Project)	(LFG)	Kampaengsaen District, Nakhon Pathom	0.230	9 January 2009	Closed
7	Zenith Green Energy	(LFG)	Kampaeng Saen ditrict, Nakhon Pathom	8.515	1 May 2010	Operational
8	Bangkok Greenpower Co., Ltd.	(LFG)	Kamphangsean District, Nakornprathum	8.150	Increased production by 2 MW 9 March 2012	Operational
9	Jaroensompong Co.,Ltd	(LFG)	Phanomsarakam district, Chacheongsao	2.400	6 May 2010	Operational
10	Rak Baan Rao Co. Ltd.	(LFG)	Khlong Luang, Pathumthani	1.000	15 December 2009	Closed
11	Tha Chiang Tong	LFG	Chiang Mai	1.051	4 May 2010	Operational
12	Thungsong WTE Plant	Anaerobic digestion	Thungsong district, Nakhon Sri Thammarat	0.320	9 March 2010	Suspended
13	PJT Technology, Co., Ltd. (Incinerator 1)	Incinerator	Muang District Phuket	7.00	11 June 2012	Operational
14	PJT Technology, Co., Ltd. (Incinerator 2)	Incinerator	Muang District Phuket	7.00	19 June 2012	Operational
15	Baan Tarn Power Plant	(LFG)	Hot district, Chiang Mai	1.051	10 August 2012	Operational
16	Koh Kaew Green Energy Management	Gasification	Sak Lek district, Pijit	0.24	1 August 2012	Operational
17	Bangpu Environmental Complex	Incinerator (industrial waste)	Tumbol Bang Pu Mai Amphoe Mueang Samut Prakan 10280	1.600	1 December 2013	Operational

18	Nakhon Ratchatisima Waste Management Center	Anaerobic digestion	Nakhon Ratchatisima	0.800	15 July 2013	Suspended
Total				**47.477**		

Source: VSPP (2012); CDM projects (2013); Energy Policy and Planning Office (2013); DEDE (2013), PCD (2013)

Therefore, this thesis analyzes what political and social factors could and should be implemented in Thailand and extends the recommendations to other low- to middle-income countries.

Thailand is selected because:

1. Serious environmental burdens from waste generation and its potential for WTE
2. Currently the only option for waste management is regulated and un regulated landfills
3. WTE projects are of high importance to the current Thai government
4. Previously applied WTE practices have had serious obstacles in their operational stage
5. Lessons learnt could potentially apply to other countries of similar characteristics.

1.2 Research Questions

1. Why have more than half the WTE plants in Thailand failed?
2. What are barriers for successful WTE projects?
3. What are key factors or models that promote successful WTE project design and implementation?
4. Are current policy measures in Thailand enough for successful WTE development in the public and private sector?

1.3 Research Objectives

1. Identify the social, economic, and environmental benefits for developing WTE plant in Thailand**.**
2. Determine the barriers and success factors for of WTE from MSW development in low and middle income countries using Thailand as a case study.
3. Provide policy recommendations for successful WTE development that could be applicable to medium-income countries.

1.4 Scope of Study

1. Review WTE policy and technology in developed and developing countries.
2. Review Thai policy and regulatory framework that promotes WTE, of which only municipal solid waste is considered.
3. Consult with key stakeholders to understand WTE management, with particular focus on barriers and Success factors.
4. Evaluate different success factors for WTE that are common in developing countries.

1.5 Expected Outcomes

1. Identify a comprehensive and functional set of success factors that will help the implementation of WTE plants in developing countries.
2. Provide academic data about the current state of WTE in Thailand, thus filling the information gap as to why most WTE plants have failed.
3. Contribute a practical set of policy recommendations that could serve as inputs in to the policy-making process.
4. Providing analysis about common factors of the successful WTE plants that are currently operational.
5. Elaborate an updated situation analysis of WTE plants in Thailand, success factors and the barriers

1.6 Research Methodology

This research provides an initial analysis of the elements for successful WTE in developing countries using Thailand as a case study. The research techniques for this study include desk reviews, semi-structured interviews with key informants, quantitative survey, and field visits. The first round of data collection was conducted in the form of semi-structured expert interviews, stakeholders were asked to identify major barriers and success factors linked with the development of WTE projects in Thailand.

- **Desk Review:** This requires gathering primary and secondary data from official government sources, research articles, newspapers, and books. I then created a database in order to analyze the status of WTE plants that have been developed or are in the process of development. From this database, I identified key stakeholders to conduct in-depth interview.

- **Semi-Structured Interviews:** With the help from an interpreter, semi-structured interviews were conducted with experts, including key energy officials, utility officials, academics, and WTE companies. The interviews resulted in a better understanding of WTE situation in Thailand. This knowledge was then used to develop a questionnaire for quantitative data collection with the same set of interviewees.

- **Quantitative Survey:** The questionnaire was sent to the same group of experts via email. The selection criteria for sampling prescribed that respondents should be in academia, project development and government sector, all in relation to WTE. Three WTE plants were selected for the identification of barriers and success factors, which can be paralleled and compared with the existing challenges and complexities that developing countries are faced with.

The twenty-two experts that informed my research included policy makers, academia, project developers and consultants. I applied the Snowball Sampling Method to select the experts for the conduct of interviews and quantitative survey. The method requires the identification of a number of stakeholders that are considered experts in the field of WTE. Then the first group of informants is asked to suggest other informants that are appropriate for the study. Because Snowball Sampling is a non-probability sampling method, the method has limitations due to the inability to make statistical inferences from the sample to the population. In other words, it is impossible to generalize that the results I obtained from the interviews and surveys of the stakeholders are representative of the opinions of the population. Nevertheless, the purpose of this research is not to generalize the findings but to develop an in-depth exploration based on consultations of experts in the field of WTE.

In-depth interviews were conducted among different stakeholders from the government, academics and WTE companies. Of the 22 experts interviewed (Table 2), seven were from industry and private companies, four were from government ministries, and eleven were from the social scientific community.

Table 2: List of Interviewees

	Organization	**Position**
	Academics	
1	The Joint Graduate School of Energy and Environment (JGSEE)	Assistant Director, External affairs,
2	The Joint Graduate School of Energy and Environment (JGSEE)	Researcher
3	The Joint Graduate School of Energy and Environment (JGSEE)	Associate Professor
4	The Joint Graduate School of Energy and Environment (JGSEE)	Researcher
5	The Joint Graduate School of Energy and Environment (JGSEE)	Researcher
6	Asian Institute of Technology (AIT), Energy School of Environment, Resources and Development	Assistant Professor

7	Asian Institute of Technology (AIT), Environmental Engineering and Management Program School of Environment, Resources and Development	Professor
8	Unit on Waste Treatment, Chulalongkorn University	Director of Research Unit on Waste Treatment and Water Reuse
9	Researcher Energy Research Institute, Chulalongkorn University	Researcher
10	Researcher Energy Research Institute, Chulalongkorn University	Researcher
11	Researcher Energy Research Institute, Chulalongkorn University	Researcher
	Industry/Private Organizations	
12	Sindicatum sustainable resources	Managing Director, Biogas
13	PJT TECHNOLOGY CO	Chief engineer
14	AIKAN, Solum Gruppen	Project Developer
15	Danish Energy Management	Director
16	Pitsunulok Plastic to Fuel Program	Engineering Director
17	Siemens Water Technology	Senior Application Engineer
18	Ramboll engineer consultant	Department Head
	Government	
19	Development of Environment and Energy Foundation	President
20	Department of Industrial Works,	National Program Officer
21	Pollution Control Department	Researcher
22	DEDE: Department of Alternative Energy and Efficiency	Renewable Energy Expert

- **Field Visits:** I made field visits to three WTE plants (Table 3) selected from the database of WTE plants that I developed (Table 1). The plants were selected based on technology and the willingness of the staff to help with this research. Using these criteria, the plants are listed in Table 3:

Table 3: Waste-to-Energy Plants Selected for Field Visits

	Technology	**Name**	**Location**	**Output**
1	Landfill gas	Zenith Green Energy Landfill gas (LFG)	Kampaeng Saen District, Nakhon Pathom	8.5 MW
2	Anaerobic Digestor	Rayong City Municipal Anaerobic Digester	Muang district, Rayong	Non-operational
3	Incinerator	PJT TECHNOLOGY CO., LTD. (Incinerator 1)	Muang District, Phuket	7.00 MW
	Incinerator	PJT TECHNOLOGY CO., LTD. (Incinerator 2)	Muang District, Phuket	7.00 MW

Chapter 2

Literature Review

2.1 Literature Review

The importance for appropriate WM has received international attention in the past decades because of its adverse effects on the environment and society. MSW management in most low- and middle-income countries is a matter of public and institutional concern. Inadequate solid waste management is one of the main reasons for environmental deprivation especially in urban areas (Rogoff, 2011; DEFRA, 2013). Most municipalities are seriously lacking waste treatment options, policy measures, and institutional arrangements. This is reflected in the lack of sanitation of public areas, the poor collection of waste from streets, increased informal and unregulated activities, waste discharge into waterways, and open dumps. Poorly managed waste causes leachate that contaminates ground water, drinking water, and soil causing grave environmental and economic constraints as well as the spread of terrible odor and diseases (Kaosol, 2009, Unnikrishnan, et al., 2010). This situation is aggravated due to the economic and institutional weaknesses that most municipalities in developing countries face.

MSW refers to all waste that is collected from the residential, industrial and the institutional sector. Dhokhikah (2012) states that MSW is the primary type of waste generated globally, estimated at 5.2 million tons annually, of which 3.8 million tons come from low to middle-income countries (Dhokhikah, 2012). According to a 2012 report by the World Bank, global solid waste generation is projected to increase from 3.5 million tons per day in 2010 to more than 6 million tons per day by 2025, this represents a 70% increase (World Bank, 2012). In this same report it is estimated that the global cost of management of these quantities of waste will also have a enormous increase: from $205 billion a year in 2010 to $375 billion by 2025, in which developing countries will be subject to the harshest cost increases (World Bank, 2012). The United Nations Agenda 21 affirms that sustainable waste management (SWM) "presents a unique opportunity to reconcile development with environmental protection" (UNEP, 1992).

Municipal solid waste management (MSWM) is a multifaceted undertaking, which requires organization and collaboration amongst households, communities, private enterprises, and government (Richardson, 2003). The World Bank considerers appropriate MSWM to be fundamental for public health, environmental and social security as well as economic growth (World Bank, 2012). The mismanagement of MSW tends to worsen in certain regions because of rapid growth of population that concentrate in urban areas, industrial growth, changes in consumption habits, and educational limitations.

MSWM is normally handled by municipal authorities and represents the largest budgetary expense item for many cities (UNEP, 2013). Unfortunately developing countries lack clear strategies when it comes to SWM. Common MSW problems are: no separations at source, inefficient collection processes, open dumped landfill, and no control of gas emissions and leachate from landfills (Udomsri, 2011; SPREP, 1999). In addition, UNEP-GEAS (2013) states that data on waste generation and composition in developing countries are largely unreliable and insufficient. Without accurate data the difficulty to design thorough strategies or to make judicious financial plans concerning WM is of the upmost importance. In this regard the indicators with which MSW is measured must be improved.

MSW indicators take in to account the amount of waste generation that a given population generates, this data is used to analyze and measure the development of WM processes and institutions like integrated waste management schemas. These indicators also allow the calculation of the future of waste generation. MSW generation indicators have the potential to improve the capability of MSW management policymaking by the government. Obtaining up to date statistics of MSW generation could also advance national data on waste sector greenhouse gas emissions (Kawai, 2013).

2.2 Waste-to-Energy (WTE) Overview

Besides reduction, WTE is one of the best ways to address waste generation problems as well as to promote renewable energy technology (Chiemchaisri, et al., 2006, Kates and Parris, 2003). According to a 2013 reports by the UNEP-GEAS, in the past decade, most countries have shown interest to develop WTE. To consider WTE facility expansion, careful diagnosis and planning is required for the project to be successful. Most countries that have had a successful WTE plan have also implemented ISWM. According to the Environmental Protection Agency (EPA):

> "*An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions*." (EPA, 2002).

The goal of integrated solid waste management (ISWM) is to manage all types and sources of solid waste, combining different technologies and waste management in accordance to waste management hierarchy. The Earth Engineering Center based of previous research, established the hierarchy of waste management (Figure 1). Resource recovery is at the top of the WM options. In the 2000 Millennial Summit of the United Nations three of the eight Millennium Development Goals (MDGs) emphasize on waste management and resource efficiency implications (Ezeah, 2012).

WTE has many different social and economic advantages that are of great interest for low and middle-income municipalities:

- Waste quantity can be reduced by 60% up to 90%, this is subject to the different WTE technologies and WM practices that are implemented;
- Because of the reduction of waste, the use of land for landfills is minimized.
- Transportation costs of waste to WM sites can be reduced

- Significant reduction in environmental degradation.

The correct type of feedstock for the plants is fundamental and when improper waste is used cause malfunction of most WTE technologies. According to various authors, success of any energy recovery plan is related directly to accurate determination of solid waste composition (Tatarniuk, 2007; Williams, 2010). The types of WTE technologies that are currently used the most in developed and developing countries are thermal process (the conversion of the MSW in gaseous, liquid and solid products by inorganic chemical reactions like heat) and Biological (decomposition of the organic fraction with the absence of air). There is a plethora of different technologies that utilize different feedstock, which will be analyzed in section 2.3.

When applied correctly, ISWM minimizes the portion of waste that is not suitable for energy recovery that can cause malfunction or low performance. To achieve an ISWM system significant changes in the current situation are required. Figure 1 ranks the preferred approaches to waste management, with waste reduction being on the top of the hierarchy (most preferred) and unsanitary landfills at the bottom (least preferred).

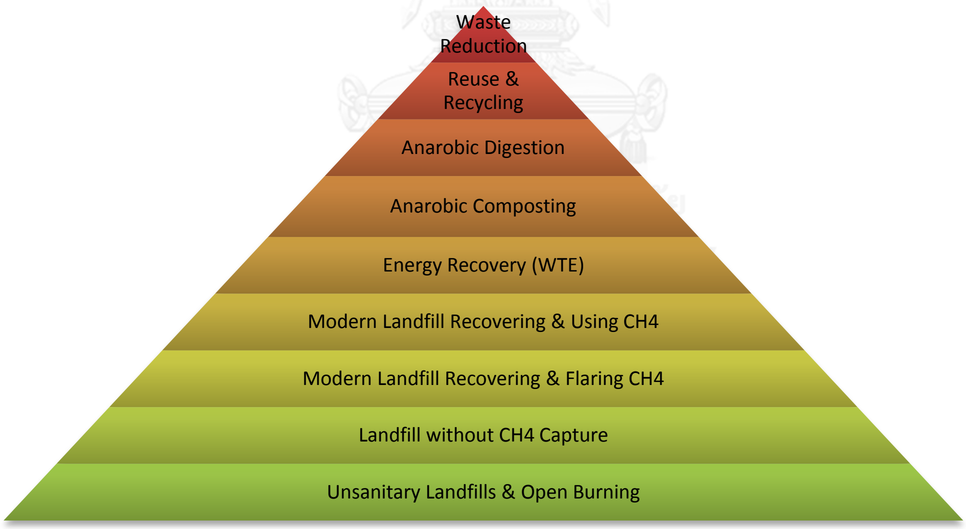

Figure 1: Hierarchy of Waste Management

ISWM must aim to address social and political issues through: governmental provisions, legislative mechanisms, public health and different stakeholder participation. Much emphasis must be placed on waste reduction as well as recycling and reusing MSW as much as possible. WTE presents its self as the not only an option in the ISWM scheme, but also as a tool to use waste as a renewable resource and an economic gain.

2.3 Technologies

Currently there are many technologies that are available for WTE recovery, but most are based on two different types of conversion processes:

2.3.1 Thermal Conversion: This process converts MSW into energy in the form of heat, fuel, or electricity using different thermochemical processes. This method is useful for types of waste that has a significant percentage of organic non-biodegradable matter as well as low moisture content. Thermal conversion of wastes can occur in three different ways:

- Incineration
- Pyrolysis
- Gasification

2.3.2 Biological Conversion (Anaerobic Digestion or Biomethanization): The biological conversion process uses a microbial and enzymatic action to degrade the organic component of waste. Bacteria that are naturally present in the waste decompose the waste in the absence of air in a process called anaerobic digestion or biomethanization, producing biogas. Biogas consists of mainly of methane and carbon dioxide.

2.3.3 Others: other technologies that are becoming more popular include pelletization, plasma-arc, and Refuse Derived Fuel (RDF).

Incineration

Incineration involves the combustion of waste in the presence of oxygen. The process helps reduce the quantity of municipal solid waste and harnesses the energy it contains. The environmental issues that are the main problems with this technology are the atmospheric emissions, particularly nitrogen oxides, sulphur dioxide, and hydrogen chloride (Tatarniuk, 2007). Special filters with high maintenance costs are used to capture these toxic gases.

Despite the fact that in recent years the incineration process has "modernized", incineration plants remain an important sources of pollution when not all of the environmental safeguards are applied. Avoiding this pollution problem is close to impossible even with the most sophisticated incineration technology. Incineration has been proven inefficient for controlling emissions in countries and municipalities that do not have the sufficient budget for operation and management. According to Kumar (2000) for developing countries the most important issue that must be addresses in order to solve the thermal combustion process is the reduction in the moisture content and non-combustible materials that are common in waste streams that are separated at source ineffectively. Due to the many environmental problems that incineration produces, the South Asian Association for Regional Cooperation (SAARC) Dhaka Recommendation on Waste Management (October 2004), countries agreed that incineration is the least effective way to treat the region's MSW and should not be considered (ADB, 2011).

The essential components of any incineration technology are:

- Feed system,
- Combustion chamber
- Exhaust gas system
- Residue disposal system

Four different types of incinerators commonly used:

- Mass-fired combustors
- Refuse derived fuel combustors,
- Modular combustion units, and
- Onsite commercial and
- Industrial incinerators

Table 4: Advantages and Disadvantages of Incineration

Incineration	
Advantages	**Disadvantages**
• Maximum effectiveness when used with high calorific value waste, pathological wastes, etc. • Plants can be continuously fed • Potential for energy recovery when amounts of feedstock are high • Moderately silent and fragrance-free • Minimum land area required. • Waste transportation costs are reduced. • Reduce volume by 80-95% and reduce weight by 70-80%.	• Unsuitable for high moisture content, low calorific value and chlorinated waste. • Moisture affects negatively the energy recovery capabilities, thus other types of fuel might be needed for correct combustion • Toxic metals are present in the ash that is emitted; like SOx, NOx and chlorinated compounds that range from HCl to Dioxins • The costs are high for operation and management. • The personal that operates the plants must be highly trained • Small power stations are not efficient for energy production • Usually because of pollution emissions from the plant cause public obstruction and

Source: Tatarniuk, (2007); Rogoff et al, (2012); World Bank (2012)

Pyrolysis and Gasification

Unlike the conventional incineration process, pyrolysis and gasification heats the MSW at high temperatures under controlled conditions, creating gaseous, solid and liquid residues that can then be combusted. In these processes, there are two major benefits that should be highlighted: the production of valuable intermediary products that can be used for industrial process and energy and the destruction of MSW. This process is currently preferred instead on incineration because the end products are easily managed and stored.

Pyrolysis:

Known as the thermal breakdown of carbon-based material with no oxygen, therefor there is no direct burning. Products of pyrolysis include sync gas (carbon monoxide and hydrogen), pyrolysis liquids, and solid residues. Syn gas is an effective substitute for natural gas. This fuel can be used in internal and external combustion engines, fuel cells. Pyrolysis liquid and solid can be used as fuels. Different studies and advances in pyrolysis development show that this type of advanced technologies can mitigate pollution that can be formed by collecting potential emissions. Nevertheless, an environmental shortcoming is that the pyrolysis process of MSW still produces ash, which still requires disposal in landfills.

Gasification:

Gasification of MSW is a unique technological process that separates waste into its basic components. Unlike pyrolysis, the gasification process requires some oxygen. A regulated amount of oxygen is introduced, this results in an oxidation produces with an adequate amount heat that allows the process to be self-supporting (Tatarniuk, 2007). For this process to occur, temperatures surpass 700^{o}C and includes fractional combustion of a carbonaceous fuel, this can produce combustible fuel gas that has high amounts of carbon monoxide, hydrogen and some saturated hydrocarbons (mostly methane). The end result is a type of fuel that is ideal for any internal combustion engine and can generate electricity (Tatarniuk, 2007).

Table 5 : Advantages and Disadvantages of Pyrolysis/ Gasification

Pyrolysis/ Gasification	
Advantages	**Disadvantages**
• Converts waste to gaseous or liquid fuel products that can be used by conventional engines and boilers. • In contrast to incineration pollution can be minimized by using different types of technology • Requires relatively small amounts of energy because of the heat that in produced • There is higher potential for energy recovery, making this process much more effective than any conventional incinerator technology • Gases produced by pyrolysis can become much more valuable with oil price increases in the future. • Requires very little energy. • The products of gasification are very useful for making products including methanol, ammonia, and diesel fuel. • The process is highly energy efficient (60% to 90% conversion efficiency). • Waste volume is reduced by about 90% and only 8-12% ash is produced compared to 15-20% for incineration. • Environmental problems that occurs in traditional incineration plants are mitigated	• High viscosity of pyrolysis oil may be problematic for its transportation & burning. • Moisture content in the feedstock has adverse effects on energy recovery • Capital costs and operating costs are significant and products do not have high value. • Requires a large number of skilled personnel. • Complex operating systems. • Difficult to produce consistent heterogeneous feedstock from MSW. • None of the products of pyrolysis have great value and capital costs and operating costs are high. • The use of municipal waste as feedstock has had only limited success and no successful field tests in full scale with MSW have taken place.

Source: Source: Tatarniuk (2007); Rogoff et al. (2012); World Bank (2012)

Anaerobic Digestion or Biomethanization:

Anaerobic digestion utilizes the decomposition of organic material in the privation of oxygen to produce two major products: biogas (composed mainly of methane) and stabilized sludge. This technology uses closed reactors (digesters) where the parameters are controlled to favor the preparation of anaerobic fermentation. Anaerobic digestion is one of the most viable options for recycling the organic fraction of solid waste. This process is regarded by the international community as appropriate for treating wet organic waste in developing countries (UNEP, GEAS, 2013).

Table 6: Advantages and Disadvantages of Anaerobic Digestion

Anaerobic Digestion	
Advantages	**Disadvantages**
• Energy recovery with production of high-grade soil conditioner. • No power requirement unlike aerobic composting, where sieving and turning of waste pile for supply of oxygen is necessary. • Because of the capsuled system used the gasses that are produced can be utilized, as well as controlling and mitigating GHG. • Odorless, rodent and fly menace, visible pollution and social resistance. • Usually inexpensive and easier to operate and manage	• Low heat production makes the destruction of pathogenic organisms harder. But with new thermophilic temperature systems this can be fixed • To be fully effective there must be only organic feedstock • Separation at source and effective municipal waste management is fundamental for this process to work correctly

Source: Tatarniuk, (2007); Rogoff et al, (2012); World Bank (2012)

Landfill Gas:

Landfill gas recovery is the most widely used form of biological conversion technology. The MSW is basically left as is with no efforts made to increase gas production; gas is simply captured as it is generated. Generation of methane from a sanitary landfill is similar to anaerobic digestion, but without operational control of the process; this is because landfills usually generate landfill gases (mainly methane, CH4, and carbon dioxide, CO_2) without intervention from an external process. The MSW is just deposited in the landfill and methane is produced by the natural decomposition of waste. The methane that is produced can be used as a fuel for combustion (Unnikrishnan et al., 2010). For energy recovery to be viable, there needs to be about 35% methane concentration in the gas produced.

Sanitary landfills have the advantage to control leachate and odors as well as vermin, these factors cause an adverse effect on the environment; currently in developing countries there is a push to replace open dumpsite with sanitary landfills (Chiemchaisri, 2007). Sanitary landfills are by far a better option than open dumping but still cannot be considered a sustainable way of managing waste. This is because the lifespan of a landfill is around 20 years and requires large amounts of land space.

Table 7 : Advantages and Disadvantages of Landfill Gas Recovery

Landfill Gas Recovery	
Advantages	**Disadvantages**
• This is the cheapest WM option. • Operation and management does not require a highly trained staff. • Natural resources are returned to soil and recycled. • It converts humid marshland in to valuable land areas that have an economical gain. • Gas collection can be a source of revenue while also reducing odors, vegetation damage, and fires. • Low maintenance and operation costs compared to anaerobic digestion	• Landfills can easily pollute soil and Groundwater by leachate leaking. • Only 30-40% of methane gas that is produced can be collected and utilized. • Substantial cause of: carbon dioxide & methane, making it highly contaminating. • Big lots of land are needed for proper function of landfill. • Significant transportation costs. • High potential of methane explosions. • Local and separated at source feedstock is required in order to have higher methane gas recovery.

Source: Tatarniuk, (2007); Rogoff et al, (2012); World Bank (2012) requires

2.3.3 Latest WTE Technologies

The WTE technological advancements in the last three decades have advanced exponentially, thus allowing different municipalities adapt to their particular WM necessities in a case-by-case setting. The following is a synthesis of different technologies that are making great strides in the proliferation of WTE around the world.

Plasma-arc (Pyro-plasma process):

Plasma-arc technology decompose MSW in to very simple molecules, this is achieved without the use a traditional thermal process extremely high temperatures and in an oxygen-starved environment. All the bio degradable and non-biodegradable fractions of MSW are decomposed by a heat source called a plasma arc flame, via a technology known as plasma gas (Kumar, 2000). A plasma gas is the hottest sustainable heat source available, with temperatures ranging from 2,700 to 12,000–F (1,482 to 6,649–C) (Rogoff et al, 2012). Currently there are diverse plasma arc systems proposed for the treatment of hazardous waste because the more traditional method has proven to be deficient (FCM, 2004).

Plasma technology has been considered a clean technology with potential for generating electricity and other derivative products such as architectural tiles, bricks for construction, making it economically viable. Some of the benefits of using plasma technology are that inorganic waste components are melted and vitrified in a glassy solid residue, such as rock, which is highly resistant to leaching and organic materials (plastic, paper, oil, biomaterials, etc.) are converted to synthesis gas (syngas) with heating value approximately one-quarter to one-third the heating value of natural gas (natural gas has a value of approximately 1,040 Btu/standard cubic foot) (Rogoff, 2011). Because the gas and solid by-products can be utilized, the requirements for the construction of landfills are removed. The rest of the byproducts that are produced in this process, such as scrubber water and cyclone catch material; can be recycled into the process for reprocessing to alleviate disposal requirements.

Fermentation:

Fermentation uses the natural biological conversion from wood, agricultural residues, grass, and the organic portion of municipal waste to produce ethanol. (Tatarniuk, 2007).

Refuse Derived Fuel (RDF):

Refuse Derived Fuel (RDF) is a form of fuel that is produced from the conversion of MSW into combustible material. The process of producing RDF converts waste from poor-quality fuel into an energy-rich fuel that has improved consistency, storage and handling characteristics, and calorific value. Through steps such as segregating, crushing, shredding, screening, magnetic separation, the waste is eventually enriched in its organic content and then compressed into pellets, bricks, or logs. Karagianidis (2012) distinguishes between three sources of waste applicable for RDF production: residential waste from private households and small enterprises, commercial waste, and industrial waste. Commercial and industrial waste usually has a homogeneous but very producer-specific composition. Recyclable, combustible, and non-combustible fractions are often segregated already at source. Residential waste, because of its diverse material fractions, requires more processing to produce RDF (Diem, 2012).

Hydrolysis:

According to Rogoff and Screve (2012), hydrolysis is a chemical decomposition process that uses water to split chemical bonds of substances. Plant-based materials containing cellulose are typically used as feedstock for this process. These include forest material, sawmill residue, agricultural residue, urban waste, and waste paper.

Aikan:

Aikan is a patented technology by the Danish firm Solom Group that converts discarded organic resources into biogas and fertilizer, both of which can be used for economic gain. This is achieved in a single workflow, removing the need for the constant movement of material. It is a robust, reliable and flexible process and can be set up as an income-generating business. This technology utilizes advanced anaerobic digestion processes through in-vessel composing (IVC) (Solum Gruppen 2014). Compared to landfills, incineration and traditional ways of dealing with biological waste, this technology reduces CO2 emissions much more efficiently. Aikan technology could be a solution that adapts perfectly with the underlying conditions that Thailand and other developing countries have in common.

Other unique advantages according to the Solum group are (Solum Gruppen 2014):

- Utilizes all types of MSW and is not affected by impurities that can be present in the waste stream
- Assimilates simply with existing landfills and incineration facilities.
- Different flows and characteristics of feedstock does not hinder performance.
- Requires a proportionately low investment because of low operating costs and provides a high return on investment.
- Work better due to the hot and humid climate conditions
- Produce high methane quality without H_2S
- Produce high value nutrient rich and sanitized compost
- Minimize costs for disposal at landfills
- Minimize the MSW volume, no landfill gas, no percolate
- Handle many different waste fractions of waste at the same time
- Allow for post sorting of MSW fractions without health hazards
- Produce energy with a high electricity output 40% (incineration 25%)
- Increase the heating value of RDF
- Creates jobs (without health hazards) – more jobs than landfills

An Aikan plant was in the pipeline in Thailand in Songkhla province with cooperation with the Danish Industrialization Fund for Developing Countries and Solum Group, but the project has yet to materialize. The project as of now is suspended due to a lack of participation between the Solum group and the local municipality decision makers. The delay is due to, according to a source that wished to remain anonymous, the requirements of "under the table fees" which have caused difficulties in the developmental stages.

2.4 Parameters for Determining WTE Development:

The crucial purpose of WTE development is to ensure efficient production of energy in accordance to the available feedstock and its energy content. For this reason, the selection and implementation of suitable WTE technologies in any country need careful diagnosis of existing waste management practices in each particular municipality. The success of any energy recovery effort is directly related to accurate determination of solid waste composition. According to Rogoff et.al (2012), the main parameters for WTE development include quantity (how much waste is generated), quality (physical and chemical characteristics of the waste) and the technology that is implemented. Numerous and diverse sets of data of MSW are required to inform appropriate selection of the technology. Begum (2012) outlines the following list of important physical parameters for WTE project development:

- **Size of population:** the size of population determines the amount and the composition of MSW feedstock.

- **Waste composition:** Determines the type of WTE technology that will be utilized taking in to account the amount of biodegradable and combustible waste. When the correct WM and WTE plans are established MSW is highly efficient as an energy resource.

- **Chemical composition:** takes in to account the physical and chemical properties of the MSW stream. The levels of carbon and nitrogen must be analyzed as well as the volatility and toxicity.

The technical feasibility of WTE depends on the range of waste parameters and is given in Table 8. The parameter values indicated are required for the adoption of specific waste treatment methods (CPHEEO, 2000; Begum 2012).

Table 8: Range of Waste Parameters for Different WTE Technologies

Waste Treatment Method	**Basic principle**	**Important Waste Parameters**	**Desirable Range**
Thermo-chemical conversion -Incineration -Pyrolysis -Gasification	Decomposition of organic matter by action of heat	Moisture content Organic / Volatile matter C/N ratio Fixed Carbon Total Inerts Calorific Value (Net Calorific Value)	< 45 % > 40 % < 15 % < 35 % >1200 k-cal/kg
Bio-chemical conversion	Decomposition of organic matter by microbial action	Moisture content Organic	>50 % > 40 %
-Anaerobic Digestion/	Natural process involving the	Volatile matter C/N ratio	

Bio-methanization	biodegradation of organic material in the absence of oxygen		

Source: CPHEEO (2000)

According to different authors (WEC, 2012; WB, 2008), economic factors that must be considered when planning a WTE facility are:

- **Capital Costs**: the initial investment is the highest one and can fluctuate significantly depending on the technology and the residues that this produces.
- **Operating costs**: This cost is mostly linked to the actual amount of waste that will be treated, thus does not have a significant influence in the final cost of a WTE facility.
- **Economic feasibility**: For a WTE project to be well-received by all stakeholders, it must have an attractive return on investment.

Furthermore, it is crucial to take into account the entire social, economic and environmental issues that may occur during the development and implementation process of WTE power plants. Because WTE plants can release negative effects to surrounding communities, public opposition could potentially cause the facility to close if there are significant damages to the environment around the plant.

2.5 Waste- to- Energy (WTE) in Developed vs. Developing Countries

Developed countries currently have been very successful in WTE development; this is due to effective financing and high social awareness on WTE's benefits. Developing countries are far behind primarily because of weak government support and the lack of awareness by the communities (World energy council, 2013). WTE plants are capital-intensive and require high maintenance costs and highly trained operators, as well as political and governmental backing. The world economic council finds that Asia, Latin America, and South Africa are projected to have the highest MSW growth worldwide (WEC, 2013). Countries in these regions currently destine most of the municipal budget to WM, mainly towards collection. This has an adverse effect on the actual disposal of waste. In the case of developed countries most of the WM budget is used towards the disposal and treatment of MSW (UNEP, 2012).

The ways that developed and developing countries manage waste are directly tied to how these societies understand and treat waste. This study finds that there are 3 main differences among developed and developing countries with regard to waste management:

- **Population:** The 2012 World Population Data Sheet shows that nearly all-future population growth will be in the world's less developed countries. In contrast, developed countries as a whole will experience little or no population growth in this century; this is directly linked with the amount of waste that will be generated.

- **Financing:** Budget and tipping fees are high in developed countries, whereas in developing countries budgets and tipping fees are insufficient for municipalities to properly manage waste.

- **Education/Awareness:** Developed countries have higher percentages of recycling and separation at source. This is because the practice has been ingrained as a social norm through policies, fines, and long term educational campaigns

While there are similarities in waste management characteristics and services between cities in high-, middle-, and low-income countries, waste managers should be aware of differences between cities of different levels of disposable income (Taparugssanagorn et al., 2007). The Asian development bank (ADB) in their 2011 report, The ADB, in their 2011 review of waste collection systems in 16 Asian countries, proposes the following typologies that are categorized according to GDP per capita.

Table 9 : Waste Collection Typologies by Gross Domestic Product Per-Capita

Particulars	Low-Income Countries	Middle-Income Countries	High-Income Countries
GDP ($/capita/year)	< $55,000	$5,000–$15,000	> $15,000
Average consumption of paper and cardboard (kg/capita/year)	20	20–70	130–300
Municipal waste (kg/capita/year)	150–250	250–550	350–750
Formal collection rate of municipal waste	< 70%	70%–95%	> 95%
Statutory waste management framework	No or weak national environmental strategy, little application of the statutory framework, absence	National environmental strategy, Ministry of the Environment, statutory framework but insufficient application, little	National environmental strategy, Ministry of the Environment, statutory framework set up and applied, statistics

	of statistics	statistics	
Informal collection	Highly developed, substantial volume capture, tendency to organize in cooperatives or associations	Developed and in process of institutionalization	Quasi-nonexistent
Municipal waste composition (% weight basis)			
• Organic or fermentable	50–80	20–65	20–40
• Paper and cardboard	4–15	15–40	15–50
• Plastics	5–12	7–15	10–15
• Metals	1–5	1–5	5–8
• Glass	1–5	1–5	5–8
• Moisture content (%)	50–80	40–60	20–30
• Caloric value (kcal/kg dry basis)	800–1,100	1,100–1,300	1,500–2,700
Waste Treatment	Uncontrolled landfills > 50% Informal recycling 15%	Landfill sites > 90%, start of selective collection, organized recycling 5% coexistent informal recycling	Selective collection, incineration, recycling > 20%
Informal Recycling	Highly developed, substantial volume capture, tendency to organize in cooperatives or associations	Developed and in process of institutionalization	Quasi-nonexistent

Source: ADB (2011)

2.6 Waste-to-Energy (WTE) in Developing Countries

The urgency to address the problem of MSW management is high on the agenda in most developing countries. In emerging economies, such as Thailand, Vietnam, Malaysia, Indonesia and India, growth in urbanization, per capita incomes, changing consumption patterns, increase levels of waste have placed a strain on municipalities' response. Traditionally, MSW management is perceived to include only collection and disposal, without placing an emphasis on energy recovery. Schwarz-Herion (2008) finds that MSW management in developing countries has little emphasis on the concept of "resource recognition", i.e., treating waste as a potential resource. Currently waste treatment options are being explored and several projects are currently in the pipeline. But there are several structural problems in the ways MSW is managed that must be addressed in order to further develop WTE projects.

The amount of waste that is generated in each country depends largely on the per capita income and consumption habits. According to an article in waste management world (WMW), studies reveal a critical threshold: when a counties average annual income is greater than $3000 per capita, the typical characteristics of a consumerist society can be seen (WMW, 2010). It is at this point that waste becomes a serious problem for potable water as well as air and soil quality especially near landfills.

Several building blocks must be laid down in order to promote WTE in developing countries, including progressive policy, good governance, and public acceptance (Sutabutr, et al., 2010; Sajjakulnukit, et al., 2002). Ineffective waste management and unregulated disposal of solid waste is prevalent in developing countries (Dhokhikah, 2012), especially in rural areas where the traditional practice of waste disposal has been to dump the waste in open landfills. Most municipalities in low- to middle-income have serious difficulties in managing the growing amounts of waste causing environmental and economic loses. This problem is particularly serious in urban areas were solid waste is disposed of in uncontrolled dumps and burn piles (Rogoff and Screve, 2012; Marshall, 2013; Fobil, 2005).

Among these problems include:

- Deficient policy, planning, and regulatory framework, implementation bodies, and human resources.
- Collection and disposal are ineffective
- Open dumpsites are the prevalent method of waste disposal
- Limited budget allocation for SWM.
- Limited land availability for landfills.
- Weak public cooperation.
- Unreliable waste generation data.

The Asia-Pacific is the most heavily populated regions in the world. Yearly about 700 million tons of total solid waste is generated; it is estimated that about 30–50% of the generated waste remains unattended this represents a significant loss of potential resources and capital (World Bank, 2008). AIT (2013) compares cities with different levels of income using parameters that include the waste generation rate, collection rate, recycling methods, and municipal expenditures for waste collection as shown in Table 10. For example, in terms of MSW generation rates, developed cities generate more than 1 kilogram of solid waste per capita per day while developing countries produce about half of that generation.

Table 10 : MSW Generation Characteristics in Asian Cities by the Level of Development.

MSW Characteristics	Less-developed cites (Less than 2,000)	Rapidly developing cities (2,000-15,000)	Developed cities (16,00-30,000)
MSW Generation (kg/capita-day)	0.3-0.7	05-1.5	>1.0
MSW Collection rate	<70%	80-95%	95-100%
Recycling	Informal	Formal and informal	Formal
Expenditure from Municipal budget (%)	15-40	5-25	1-5

Source: AIT (2013)

For developing countries, the structure of the waste management system, especially the informal sector, is an issue that needs to be analyzed every time a WTE or WM scheme is applied. The social and economic aspects of the informal sector, commonly referred to as scavengers or miners, are vulnerable to diseases and toxic elements. Obvious problems that these working conditions present are the lack of sanitary conditions that adversely affect the health of these workers. Even though the unregulated waste pikers can help increases the recycling rate and reduces the cost of local waste management; the system operates independently, outside of rules and regulations of the local government (Medina, 2000). This affects not only waste management but also the overall potential of recovering energy and materials from MSW.

The economic benefits as well as the positive environmental effects that WTE potentially have for developing countries are substantial. According to the ADB (2011) report, the South East Asian region generates an estimated 8 million tons of compost that represents $709 million in potential resource. This amount of waste could potentially produce an approximate 3,340 million kilowatt-hours/year of electricity, primarily from biogas. The same report finds that the actual market value could reach $701 million/year. If clean development mechanisms would be applied up to $218 million/year could be accumulated. Additionally, 27.88 million cubic meters of landfill volume could be divested from landfills prolonging their life span and saving WM budget for municipalities (ADB, 2012).

Options such as capturing methane gas from landfill to be utilized as a renewable energy source can greatly enhance the economic benefits of waste management, but there are certain limitations faced by developing countries that must be considered. Only sanitary landfills are suitable for energy recovery but landfills are not a sustainable solution to waste generation due to land shortage. Currently developing counties are heavily promoting sanitary landfills and is gradually replacing open dumping. Still there are numerous inadequate landfills causing environmental problems as well as a loss of potential methane capture for WTE. Even though landfill gas (LFG) is an option for energy recovery, it is not sustainable solutions due to the lifespan of these projects are limited, large areas of land are needed scarce.

The current scenario for developing countries and WTE projects is positive, especially when taken in to account that WTE markets will expand to 29 billon US dollars by 2015(WEC 2013). Despite the discussed barriers to WTE development, private sector's interests are gravitating toward developing countries. The 2013 Global Status Report by REN 21 (Fig. 2) shows that, since 2012, developing countries are now investing more in WTE projects than developed countries (GSR, 2013). Governments and private companies are interested in investing in well-managed WTE facility because of its high potential for returns on investment.

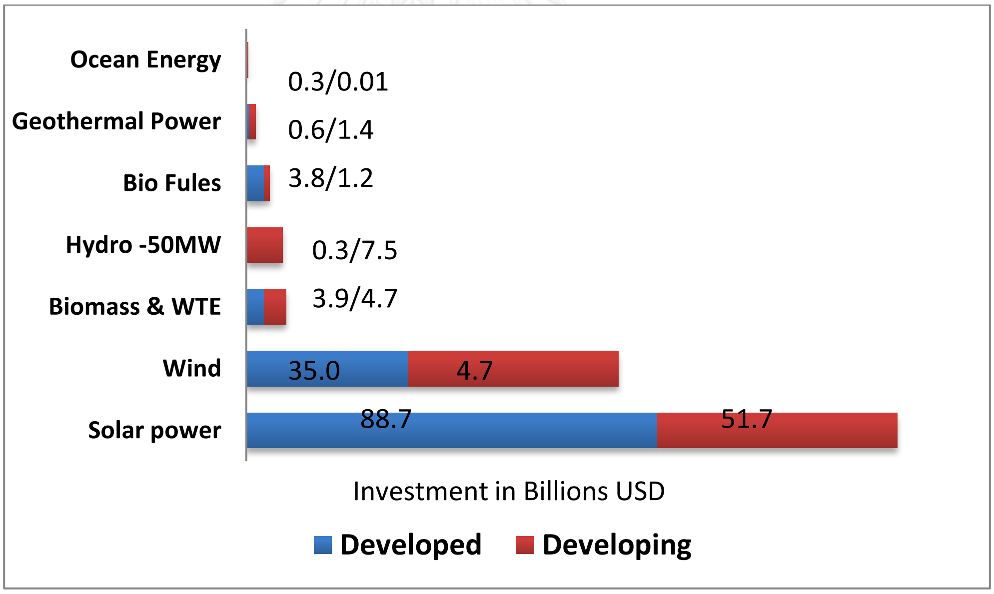

Figure 2 : Global Investment in Renewable Energy by Technology
Source: REN21 (2013)

2.7 Waste-to-Energy (WTE) in Developed Countries

WTE in developing countries has long been viewed as not only a fundamental part in WM but also as a reusable resource, especially the European Union (EU). The Waste Framework Directive (2008/98/EC) is the principal legislation that focuses on WM in the 27 European Member States (EU 27) (Perez-Reigosa, 2010). All EU member countries must comply with this legal framework. Countries such as Norway, the Netherlands, Denmark and Sweden and different EU members have adopted WTE plants successfully. As well as the EU legislation, individual countries have also adopted policies banning organic waste in landfills because of environmental concerns (Williams, 2011; Sarasini, 2009).

According to the Confederation of European WTE plants report of 2010, The EU 27's 2020 renewable energy target is 2700 TWh. The report estimates that about 95 TWh of can possibly be supplied by WTE. Incineration with energy recovery could provide an estimated of 60 TWh (4%). The total an amount of renewable energy could be enough to supply 22.9 million homes electricity and 12.1 million inhabitants with renewable heat (CEWEP, 2010). Currently there are 420 WTE plants throughout the EU that treats MSW with thermal process (CEWEP, 2010). In 2011 Denmark (54%) and Sweden (49%) were the countries with the greatest proportion of their municipal waste sent to incineration plants.

The key success factor for the EU is a mix of policy's geared towards waste minimization, e.g., bans on plastic bags, organic waste going to landfills, and in some countries an overall ban on landfills. The Landfill Directive (1999/31/EC) obligates the EU Member States to reduce the amount of biodegradable waste sent to landfill to 50% and 35% of 1995 levels by 2013 and 2016 respectively (for some countries by 2020). The Waste Directive 2008/98/EC reflects the EU sustainable development strategy and brings new challenges to MSW management systems.

Sweden is at the forefront of WTE management and is largely considered a example of what correct WM should be. In addition to the discussed policies, Sweden has implemented carbon taxation, which makes burning coal and oil as a source of energy much more expensive, thus obligating several power plants to convert MSW as a substitute feedstock. Sweden is so successful at WTE that it imports MSW from Norway because of a shortage of its own. Only 4% of Sweden's waste goes to the landfill and the incinerators that are in operation have reduced harmful emotions by 90-99% (Paulson, 2013).

2.8 Success Factors for WTE Development

Even though each project is unique to some extent, there are fundamental factors that must be considered in order to successfully commence a WTE project. For example, Rogoff et al. (2012) point out that if a municipality or community want to implement a WTE facility, it is necessary to have an implementing entity (e.g., a county, municipality, authority, electric utility, waste hauler or contractor). Several studies have shown that successful waste management depends on reuse, recycling, and recovery (Schübeler, 1996; Achillas, 2011). For successful implementation, it needs the services of knowledgeable in-house staff and consultants, as well as active support of the community's decision-makers and public (Rogoff et al., 2012). European data consistently shows that countries with high WTE implementation have a correspondingly higher level of recycling (Canadian WTE Coalition, 2010). In summary, effective WTE development relies on a combination of several success factors (Williams, 2012; Mongkolnchaiarunya, 1999; Perez-Reigosa, 2011; Achillas, 2011; Rogoff, et al, 2012):

- An implementing government agency or private project developer with political commitment capacitated to assume the management and operation of the project.
- A high level of recycling
- Markets for the recovered energy and recovered materials.
- A project site that is environmentally, technically, socially, and politically acceptable.
- Safe and effective waste collection and disposal
- Sustainable financing
- Effective contributions from the government and society

This list of success factors was used as a basis for this research in order to determine different factors that can be modified for countries in the low- to mid-income range.

2.8.1 Policies Favorable to WTE

The clearest action that can be taken by a government for the development of WTE projects is to analyze and implement policies that can incentivize WTE. Through a combination of fines and tax reductions on society and industry policies can help change the cultural and educational thinking of a nation. Based on literature review, this study compiled policies that are favorable to WTE development from Achillas (2011), Mongkolnchaiarunya (1999), Williams (2011), Rogoff et al. (2012), Abeliotis (2011), Tongsopit (2013) and summarizes them below:

- **Recognition of WTE as a Renewable Resource**

  Recognizing WTE as renewable energy source is easly the most important step for WTE development and can be seen in the policies that are implemented on the local and national level.

- **Renewable Portfolio Standards (RPS)**
  These policies force utility companies to supply consumers a certain amount of energy from renewable sources.

- **Appropriate Landfill Tipping Fees**
  An important driver of not only WTE but also WM in general is tipping fees. When tipping fees are elevated there is more money for the collection transportation and disposal, also with high tipping fees there is a stronger incentive to create less waste and separate properly from the source.

- **High Landfill Taxes and Fees / Bans on Landfilling**

  High landfill taxes drive-up gate/tipping fees paid to landfills and help encourage recycling and waste-to-energy. In Europe, these have proven to be extremely effective at diverting wastes from landfills and encouraging growth in the WTE industry.

- **Absence of Cheap Domestic Sources of Energy**

  Abundant sources of cheap traditional energy sources can put WTE at economic disadvantage for both power generation and heating. Many countries, particularly those under development that rely on imported fossil fuels, already have strained resources and suffer as a result.

- **High Price of Electricity**

  High electricity prices generally means that the country relies on imported sources of energy, this creates a necessity for not only WTE but also renewable energy's and lessens the dependence on foreign sources as well as saving money.

- **Ample Supply of Waste**

  For a WTE plant to work efficiently there must be a steady flow of waste so that the project not only is economically viable but environmentally needed. A steady waste feedstock assures the WTE plant will have enough resources to be able to produce energy continuously.

- **Public Participation Support**

  Most authors agree that public participation is a fundamental success factor for WTE (Achillas, 2011). The pool of research shows community participation is vital for confronting most problems arise. Mongkolnchaiarunya (1999) identifies the role of communities in WTE development, including problem identification, planning, and resource mobilizing, implementing and finally evaluating processes. In countries where there is an efficient recycling campaign and social environmental awareness WTE facilities are successful.

- **High Recycling Rate**

  Communities that tend to be better at recycling tend to also be better at recovering energy from waste. Some authors state that WTE competes with recycling. But this is not completely true because much of the recyclable waste, such as a glass and metals, cannot be converted into energy. In fact, different authors state that communities that rely on WTE maintain on average have a higher recycling rate than other communities (Williams, 2011; Rogoff et al, 2012). Furthermore, WTE plants offer additional opportunities to recycle because of the increased handling of waste streams.

- **Collection**

  Successful waste management programs depend on safe and effective waste collection and disposal. Collection of MSW can either be in mixed bags or in separate bins. Mixed bag collection is the most widely applied method; however separate collection is a prerequisite for successful material recovery (Abeliotis, 2011).

- **Improve MSW Indicators**

  Accurate data on the volume of solid waste is one important requirement for successful WTE development. Based on their extensive research on the growing solid waste problems in developing countries, Rogoff and Screve (2011) concluded that it is currently impossible to arrive at a more accurate estimate given the paucity of existing waste stream data in the developing nations and the inaccuracy of common definitions of different waste streams from country to country. MSW generation is a fundamental indicator since municipalities usually prepare annual budgets on MSW management based on annual MSW generation (collection).

2.9 Overview of MSW Policy, Management, and Situation in Thailand.

Thailand, like many other thriving economies has significant problems that arise from its growing population, consumption habits, and demand for energy. The Kingdom is divided into 78 provinces in 5 regions; the total land area is 513,120 square kilometers. Thailand's has a population of 67 million people with a gross domestic product (GDP) growth of 6.4% (Boonpa, 2013). In Thailand, like other developing countries, most waste management plans are seriously lacking waste treatment options, policy measures, and institutional arrangements (Sutabutr, 2012; Cherdsatirkul, 2010; Vanapruk, 2009; Kaosol, 2009; Sajjakulnukit, et al, 2002). MSW has been commonly disposed of in open dumpsites, which lack precautionary environmental measures. Open burn piles and unsanitary landfills are still the most common waste management methods in Thailand (Menikpura, 2012).

Thailand currently produces 53,240 tons of MSW per day (Thailand State of Pollution Report, 2011). According to Menikpura et.al (2013), MSW will grow annually 0.2 million tons because of population growth, expansion of communities, tourism and consumption habits. As of 2012, Annual (MSW) generation of Thailand reached 15.11 million tons, of which 12.69 million tons (84%) is collected. 47% (5.97 million tons) of the collected waste was disposed properly into sanitary landfills, while 53% met improper ways of disposal such as open dumpsites (Jacob 2012, Menikpura, 2013). Another source shows conflicting information on final destinations of the waste. Cherdsatirkul (2012) estimates that in 2008 about 78% of Thailand's MSW disposed in non-regulated open dumpsites, while only 9.4% of the waste generated was recycled and about 10% of the MSW in Thailand was properly treated in sanitary landfills and other proper technology facilities.

Thailand's waste generation per capita is the highest in the Asia Pacific Region. The average amount of waste generation per capita is 0.63 kg/ day with slight differences among localities: 1.5 kg/capita/day in Bangkok, 1.0 kg/capita/day in municipalities and Pattaya city, and 0.4 kg/capita/day outside municipality areas (Boonpa, 2013). MSW has 64% of organic matter, 17% Plastic and 8% of paper.

In the decade of the 1990's, WM in urban areas in Thailand was disposed of in unregulated and open dumpsites. Chiemchaisri 2007 states that during the past twenty years, there has been a gradual improvement in waste disposal practice but there is still a serious difficulties and inefficiency's to be solved. According to Kaosol (2009), Thailand's solid waste management strategy is focused on bulk collection and mass disposal. Recently, the Thai government has attempted to implement an "integrated waste management system" that includes

- Source reduction
- Waste recovery e.g. material recovery, composting
- Incineration
- Final disposal

Thailand's energy demand is 153,332.16 billion kWh (Energy Statistics of Thailand, 2012). The net generation is projected to increase to 346,767 GWh by 2030 (DEDE, 2012). The installed capacity of renewable energy in Q_1 – Q_2/2013 was 3,343 MW, accounting for 10.1% of total power capacity in Thailand. Currently WTE total capacity is 1.45 MW, and the growth of WTE plants is slow and inefficient. Presently energy from MSW accounts for 1.4% of primary energy production with an installed capacity of 47.48 MW (as shown in Fig 2 and 3) (DEDE, 2013).

Different provinces and municipalities have tried to install and operate MSW anaerobic digestion, incineration, and landfill gas plants. However, nearly half have failed (Cherdsatirkul, 2012). According to my survey of VSPP database and other sources, there have been 23 WTE facilities, 13 have gone out of operation, and 10 are still operational. All though the government has set an ambitious goal in its last energy development plan of 400 MW, still there are major problems to address. The shortage of waste treatment options, policy measures and institutional arrangements are the principal barriers that the country faces in order to achieve successful WTE projects (DEDE, 2013).

The problem of most of Thailand's MSW disposal is seen in its operation and maintenance stages. The machinery is gravely inadequate and plant maintenance is a constant problem. This is a result of improper technology adoption and inadequate project income to support the project, which stems from the inability to collect the disposal fee (Boonpa, 2013). A study conducted by Worawongkaisee et.al (2011) found that, in the case of the Phuket incineration plant, the poor quality of the feedstock led to difficulties at the stage of operation and maintenance. This is "because the feedstock is not sorted at the sources and hence its high humidity causes the plants to operate at low efficiency and release high levels of emissions" (Worawongkaisee, 2011).

These problems deteriorate people's trust in the overall environmental management of the incineration plant even though the plant meets other environmental standards, including dust, exhaust, and waste water. The social problems of the Phuket MSW Incineration Plant are linked nauseous odors, pollution around the area of the plant as well as hazards to health of the community, "the dust that causes eye injury". In the case of the island of Phuket, incineration is currently the only option they have to manage their waste because of the difficulty and cost to transport waste to the main land.

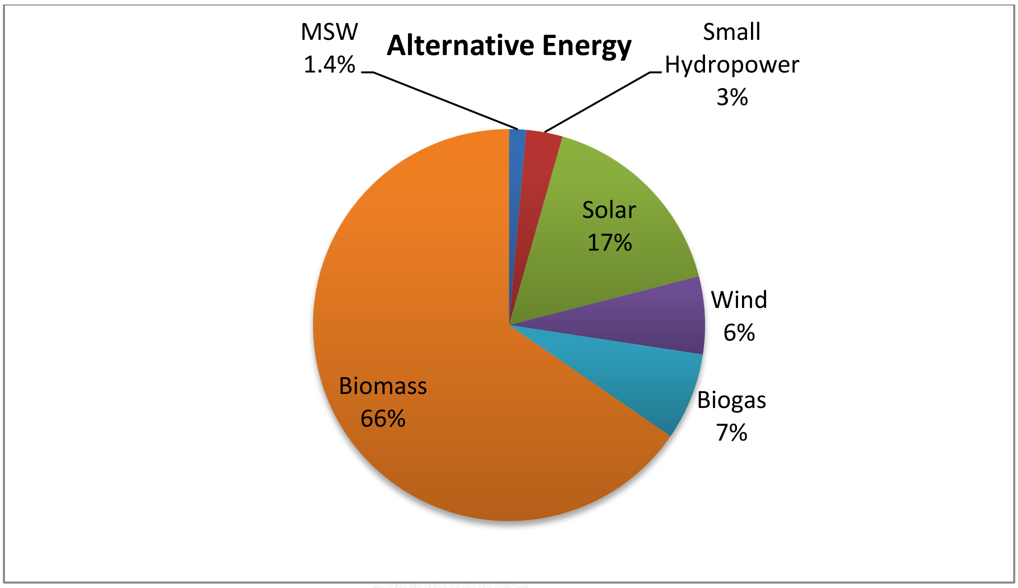

Figure 3 : Percentage of Alternative Energy's in Thailand
Source (DEDE, 2013)

Thailand's Ministry of Energy estimates that the potential of power generation from biomass, MSW and biogas could reach 3,700 MW. This would be from around 25 municipalities that produce more than 100 tons of waste per day. Therefore, there is a very high potential to convert that MSW to useful energy. The total recyclable potential of MSW in Thailand is around 3.86 million tons/year; of this, around 0.74 million is treated using WTE technologies (Cherdsatirkul, 2012).

Since 2006, there has been further progress in WTE development in Thailand (Fig 4). This progress has been stimulated in part by the incentive called "Adder", which was introduced in 2007 by the Ministry of Energy to stimulate renewable in a 7 year time frame from the commercial operation date (COD). As of 2009, the Adder for thermal conversion process such as incineration was increased to 3.50 Baht/kWh, which is paid on top of the wholesale electricity purchasing prices for VSPP.

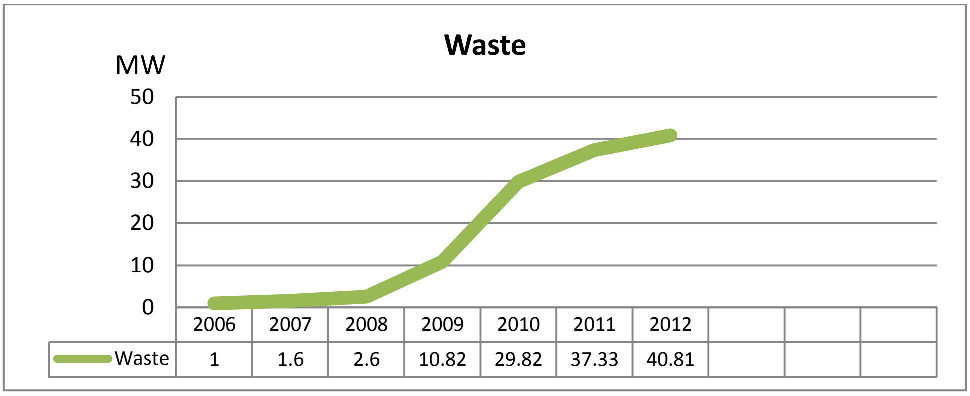

Figure 4 : Growth of WTE in Thailand
Source: Tongsopit (2013)

There have been almost 50 projects for WTE submitted to the utilities to receive Adder. The majorities have been from Very Small Power Producers VSPP (MW ≤ 10). However, identifying actual numbers of project execution from these approved projects is a significant challenge (Jacob, et al., 2012). Thailand currently has 3 techniques for recovering energy from MSW: Landfill gas (8), Incineration (4), Anaerobic Digestion (3).

The role of environmental and waste management is seen in the 2007 Constitution of Thailand. This Constitution contains provisions affirming the rights and obligations of the people in relation to their participation in waste management. In addition, a draft Master Law for the Promotion of Waste Reduction, Reuse and Recycling has been produced in order to control waste management from generation until final disposal. The principles of ISWM, waste reduction, prevention and recovery, polluter pays principle, and public rights have been incorporated to promote efficient waste management in Thailand (Pollution Control Department, 2009). The drafted master law under the 2007 constitution provides the public right to be involved in waste management through processes such as waste reduction, separation, re-utilization. It also affirms the rights of the citizens in the access to information and the rights to build up networks to co-ordinate activities.

MDGs prompted the execution of national 3R Strategy (reduce, reuse and recycle) in most developing nations (United Nation, 2010). Siriratpiriya (2011) concludes that Thailand needs to strengthen the 3Rs and indeed this principle is upheld in the current constitution and in the draft master law. Regrettably, the response to 3R has been weak due to inadequate orientation in governmental policy, low public awareness, and the lack of pertinent technology. The United Nations identifies Homes and commerce sectors a fundamental part in the sucsesful application of the 3r principal. Consequently, education of the social an industrial sectors on the importance of WM from the source is crucial and one of the most difficult aspects to tackle. Improvement of environmental awareness among population may be achieved through both formal and informal education and mass media program (UNEP, 2012).

2.9.1 Waste Classification in Thailand

There are a number of ways that waste can be classified, Pariatamby and Tanaka (2013) classify waste in Thailand into 3 types: municipal waste, industrial waste and agricultural waste. Alternatively, waste can also be classified based on the source of waste generation, its physical appearance, its harmful tendencies, and its utilization and disposal techniques. The definitions in Thai law of waste, which include solid waste, hazardous substance, hazardous waste, and infectious waste, are described below (cited in Pariatamby and Tanaka (2013):

- **"Waste** means refuse, garbage, filth, dirt, wastewater, polluted air, polluting substance or any other hazardous substances which are discharged or originate from point sources of pollution, including residues, sediments or remainders of such matters, either in a solid, liquid or gas state [National Environmental Quality Act, B.E. 2535 (1992)].

- **Solid Waste** means used paper, worn out cloth, discarded food, waste com-modifies, used plastic bag and food container, soot, animal dung or carcasses, including other matters swept from roads, market places, animal farms or other places [Public Health Act, B.E. 2535 (1992)].

- **Hazardous Substance** means explosive substances, inflammable substances, oxidizing and peroxiding substances, toxic substances, pathogenic substances, radioactive substances, and genetic transforming substances, corrosive substances, irritating substances or other substances, whether chemical or not, which may cause danger to human-beings, animals, plants, property or the environment. [National Environmental Quality Act, B.E. 2535 (1992)].

- **Infectious Waste** means body parts or carcasses of humans and animals from surgery, autopsies and research; sharps such as needles, blades, syringes, vials, glass ware; discarded materials contaminated with blood, blood components, body fluids from humans or animals, or discarded live and attenuated vaccines and items such as cotton, other cloths and syringes; waste from hospital and veterinarian wards [Regulation of Ministry of Public Health B.E. 2545 (2002)]."

For the purpose of this research, municipal solid waste is analyzed for the possible utilization for energy. According to the Thailand Pollution Control Department, municipal solid waste refers to "unwanted materials and/or substances generated in a city or municipal area and the components of which generally include food/ organic waste, infectious waste, hazardous waste, and packaging waste."

2.9.2 Policies for Municipal Solid Waste Management in Thailand

National policies on municipal solid waste management generally aim at the control of waste generation rate, waste segregation, material recovery and waste disposal technology that will have minimum impacts on local residents (Sharp et al., 2012). By this standard, the Thai drafted a master law, is therefore considered quite advanced in stating its objectives to promote waste reduction, reuse, and recycling. The vehicles through which these objectives can be achieved include the national waste management plan and the provincial environmental quality management action plan. The national targets for reduce, reuse, and recycle under the national 3Rs strategy are shown in Table 12. The objective of the government is to increase recovery rate from 22% to 30% by 2016, 62% by 2021, and 90% by 2026. However, many local governments have not introduced WTE technologies to achieve the government goals because they lack the necessary technical capacity and they are unsure whether the technologies can be implemented in their area.

Table 11 : Targets for Reduction, Reuse, and Recycling

Strategies	**Reduction targets (%)**		
	1-5 years (2012 – 2016)	**5-10 years (2017 – 2021)**	**> 10 years (2022 – 2026)**
1. Waste reduction	1	3	5
2. Utilization of solid waste and recycling materials			
2.1 Material recycling	20	22	25
2.2 Waste to energy (thermal recovery)	5	10	15
2.3 Biodegradable recovery (composting, anaerobic digestion)	5	30	50
3. Total recovery	30	62	90
5. Total achievements (targets 1, 2)	31	65	95

Source: PCD (2011)

The regulations related to municipal solid waste management (SWM) in Thailand can be classified into three levels: national, provincial, and local levels (UNEP, 2004). At each level, there are a number of laws/acts, regulations, standards, and technical guidelines overseeing the supervision of solid waste generated in the country. Siriratpiriya (2013) details the Constitution of the Kingdom of Thailand B.E. 2550 (2007) and points out the advanced environmental management and provisions:

- (Section 56): Public right to access information and to participate in the prevention and alleviation of public hazards.
- (Section 73): National conservation of natural resources and the environment For the planning of any project or policy that might cause a serious impact on the quality of the environment, on natural resources, and on the health of the people,
- (Section 67): Comprehensive public hearings before implementation must be held before they are initiated.
- (Section 86): The State shall promote and lend support to research and development and make use of alternative energy that is naturally acquired and advantageous to the environment.
- (Section 290): Local governmental organizations have powers and duties in connection with the promotion and maintenance of the quality of the environment.
- (Section 287): Local governments must report its work to the people to enable public participation in monitoring its administration and management.

According to the Pollution Control Department (2009), while the draft master law is in the enactment process, MSW management in Thailand is currently regulated under the following laws:

- Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992) is the central environmental law governing environmental standards, including planning, and monitoring environmental quality and establishing a system for environmental Impact Assessment (EIA).
- The Public Health Act B.E. 2535 (1992) is the most comprehensive law dealing with MSW, it gives local administration the legal power to enact control ordinances and regulations that aim to MSW and protect environmental sanitation. The law encompasses collection, transportation and the disposal of waste.
- The National Health Act B.E. 2550 (2007) specifies that state agencies have the duty to reveal and provide data and information to the public, and individuals shall have the duty to cooperate with state agencies in creating a good environment.
- The Hazardous Substance Act B.E. 2535 (1992) is a legal basis to control the import, export, manufacturing, storage, transport and disposal of hazardous substances. The Act governs the methods of managing hazardous materials, hazardous waste and infectious waste.

2.9.3 Barriers to WTE Projects in Thailand

Vanapruk (2010) lists a number of barriers to WTE development in Thailand: the lack of comprehensive governance, insufficient budget for investment, operation maintenance, affordable access to technology, inadequate feedstock for WTE technology, and public opposition. These have been the major obstacles that different municipalities have had to face but the two major issues that have prevented more WTE from progressing are the lack of public awareness and lack of political motivation. Even though Thailand has shown desires to promote WTE, increasing utilization of waste for energy has yet to see a major push forward.

Besides the barriers listed above, another major barrier lies in the process that the developer has to go through to acquire the necessary permits and licenses to operate the plant. Cherdsatirkul (2012) lists 8 government agencies involved in MSW regulation (Table 12). This research adds 4 additional agencies to the list, making the total of agencies involved 12 agencies.

Table 12 : List of Agencies Involved in WTE

	Agencies	Department	Division	Role
1	MONRE	ONEP	Office of National Environmental Board	Formulate policy and plan for environmental conservation and administrative management
2	MONRE	ONEP	Office of Environmental Impact Evaluation	Appraise EIA on government and private project
3	MONRE	PCD (Pollution Control Department)	Solid waste and night soil management section	Monitor MSW management by municipalities
4	MOPH	Department of health		Issue MSW management standard and monitor management by municipalities
5	MOIN	Department of Industrial Health	Registry division	Give license for new factory
6	MOI	(DEDE) Department of local administration		Supervise BMA and other local municipalities
7	BMA	Department of cleansing	Technical and planning division	Provide legal advice on MSW disposal waste project
8	Municipalities			Responsible for disposing of MSW & give license to private sector
9	MOE	Department of Energy		Give subsidy to waste to energy project

		Development and Efficiency		

Source: Cherdsatirkul (2012)

2.9.3 Current State of WTE Projects in Thailand

The potential for WTE in Thailand is promising. Because of the overwhelming volume of waste, political will is growing from the obvious necessity to tackle the waste generation problem. WTE facilities are a three-part solution to waste generation problem. WTE have immense potential for simultaneously preventing emissions of methane, increasing electricity supply, as well as being a revenue-generating option. For these reasons, the Thai government has shown interest to promote WTE.

Currently, WTE plants based on incineration and gasification technologies produce 19.84 MW, landfills produce 24.51 MW and biogas systems (anaerobic digestion) produce 3.12 MW, combining to a total installed capacity of 47.48 MW of WTE plants (Fig. 5). Vanapruk (2012) states that, in some cities, anaerobic digestion plants can be easily developed as the technology is easy to understand, thus facilitating public acceptance. But in Thailand, according to interviews with Thai MSW treatment operators and government officials in the Pollution Control Department, almost all anaerobic digestion plants are suspended or have had to close. Indeed, one previous study highlights the difficulties of operating an anaerobic digestion WTE plant in Thailand. Cherdsatirkul (2012) found that the Rayong Municipality integrated waste management system, which comprises a sorting system and anaerobic digestion, has faced operating problems due to inappropriate waste feedstock into the anaerobic digester. The waste feedstock should compose mainly of organic waste, but plastic, metal waste remains a major component and cannot be sorted out completely.

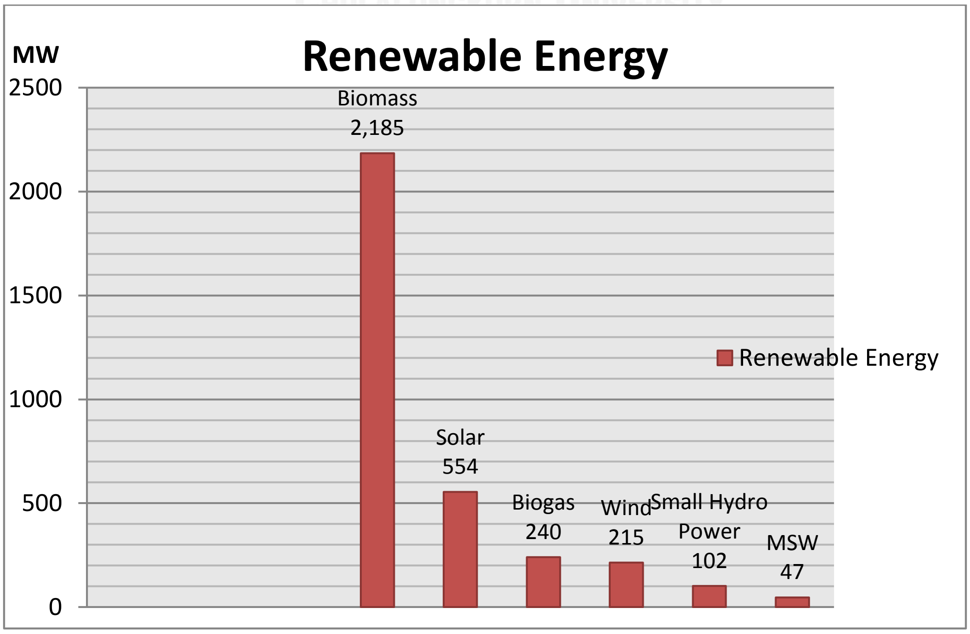

Figure 5 : Renewable Energy Production in Thailand
Source: DEDE (2013)

In regard to incineration plants, currently there are only two operating incinerators in the country, and both of them located on Phuket Island. They have faced serious backlash from the surrounding communities. The “not in my backyard” (NIMBY) sentiment has become a common protest among the population that is affected by the gases released from the incineration plant. Worawongkraisri and Tongsopit (2011), in their case study of the Phuket WTE plant, found that odoriferous conditions resulted from incomplete combustion of the high-humidity waste in the incinerator. Due to the sub-optimal operating conditions, including high-humidity waste and poor maintenance, the first incineration plant stopped operation after 9 years. Currently there are two plants producing 7 MW each but they are controversially successful in the sense that it is more of a means to dispose of waste then to generate electricity.

There are two flagship projects in Thailand for WTE, both of which are based on landfills: the Zenith Green Energy Project and Bangkok Greenpower Co. Ltd. Both projects are owned by Sindicatum Sustainable Resources. These projects have all the elements for successful WTE. They have strong concession contracts with the local municipality ensuring a sufficiently robust waste stream; public support is high because both plants employed only Thai citizens as well as providing education scholarships for further technological advancement. The company also does public outreach in the form of awareness campaigns and providing information about the plant. For a landfill gas project to be successful there must be at least 500 times of waste per day and this means that landfills have to be large as well as sanitary. However, landfilling method still leads to environmental, economic and social burdens. The major drawbacks to these projects are its dependency on large amounts of land for a landfill, as well as the contamination of the ground soil from leachate.

Chapter 3
Results

3.1 Stakeholders' Insights on Barriers and Success Factors.

<u>Survey answers</u>

Section 1:

Stakeholders were asked 4 specific yes or no questions regarding the current situation of WTE development in Thailand.

Q1. Do you consider that Thailand has successful waste to energy projects?
Q2. Are current government incentives sufficient for the increase in WTE projects?
Q3. Would community-based projects be more effective for waste management and WTE development?
Q4. Do you consider the goal of increasing WTE production to 400 MW by 2021 possible?

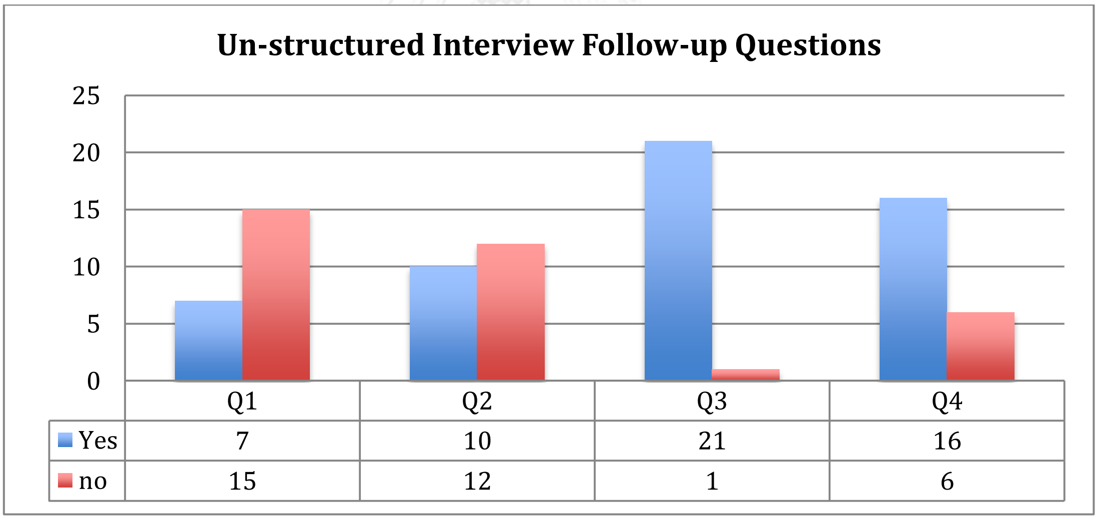

Figure 6 : Un-structured Interview Follow-up Questions
Source: Author's analysis with data compilation from survey results.

Out of 22 interviewees, 15 interviewees (68%) stated that they did not consider that Thailand had a successful WTE project. Seven of the interviewees considered that Thailand had some examples of successful WTE projects but only to a certain extent. The plants most frequently referred to as examples included the incineration plant in Phuket and the anaerobic digestion plant in Rayong. The overall conclusion from stakeholders was that incineration plants were not the solution for Thailand due to considerable drawbacks from the public and inefficient management. The majority of stakeholders agreed that as of now "Phuket WTE plant is more of a means to dispose of waste than to generate energy." The majority of interviewees expressed that this was more of a "controversially successful project" and did not consider it as a proper example of WTE development. Being an island, Phuket has limited options for managing waste, thus it has implemented incineration technologies not only to produce energy but also to eliminate waste.

In regard to the adequacy of government incentives, 10 respondents considered that current incentives were sufficient to promote WTE in Thailand. "Thailand has the best political incentives in the region" said an academic. It must be noted that Thailand was the first country in the South East Asia to implement the Adder program, better known as feed-in tariffs for renewable energy projects. Thailand also has an Alternative Energy Development Plan that aims to increase the installed capacity of MSW power plants to 400 MW. On the other hand, 12 of the participants agreed that there should be other measures to supplement the financial incentives, such as waivers of other permit requirements. According to one interviewee who wished to remain anonymous, "the selling rate of electricity may be sufficient but it needs more."

An overwhelming 95% of respondents agreed that community-based projects were more effective for waste management and WTE development. This is consistent with the analysis presented by South Asian Association for Regional Cooperation (SAARC) countries that have agreed to promote community-based approach to WTE development. Source segregation of waste with separate collection and resource recovery systems are the best start for successful waste management and thus WTE (ADB, 2012). State policies should involve all stakeholders in a community to co-operate, especially the general public directly affected by the project. People are more likely to cooperate if a project is profitable and when they feel involved in the entire process of development. Waste management policies and projects must begin by informing the people of the benefits to guarantee agreement and co-operation.

When asked if the country's goal to increase WTE output to 400 MW by 2021 was achievable, 16 respondents (73%) agreed that it was possible and only 6 respondents (27%) considered that the barriers were too deep-rooted and could not be fixed. The sentiment that WTE have great potential in Thailand is seen not only in the interviews and surveys but also in the literature. Although Thailand has had a rocky start to WTE development, many lessons have been learned that future projects can incorporate into their planning. Considering That Thailand has only been really promoting WTE for "the last 5 years" further positive development is expected among stakeholders.

Section 2:

Stakeholders were presented with the first set of barriers developed from the initial unstructured interviews. The barriers ranged from economic, policy, social, administrative/ government. Participants were asked to score low, medium and high (1 to 3) in order of importance for the different aspects that affect WTE development in Thailand. Specific barriers included Q1) financial feasibility, Q2) Access to loans and capital, Q3) Ownership of waste stream, Q4) Ownership of WTE plant, Q5)

Education/awareness, Q6) Separation at source, Q7) Government support/priority, Q8) Complex permitting issues, Q9) Tipping fees and Q10) Lack of transparency.

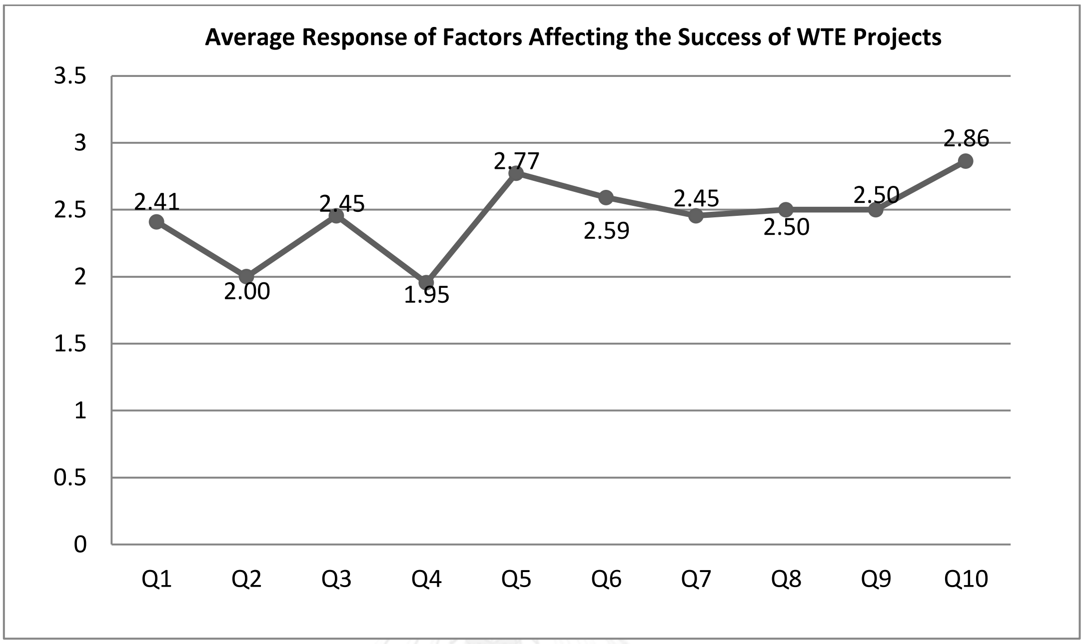

Figure 7 : Average Response of Factors Affecting the Success of WTE Projects

Q1) Financial feasibility	Q2) Access to loans and capital,	Q3) Ownership of waste stream,	Q4) Feasibility ownership of WTE plant,	Q5) Education/awareness,
Q6) Separation at source,	Q7) Government support/priority,	Q8) Complex permitting issues	Q9) Tipping fees and	Q10) Lack of transparency.

(Q1) Financial Feasibility: Financial feasibility received an average score of 2.41, which is of medium importance. Different stakeholders stated that WTE development should be economically feasible without having to rely on external schemes such as CDM. According to a stakeholder who wished to remain anonymous, such a scheme “does not quite address the economic sustainability of a project.” In many cases, transportation of waste to designated waste management centers is highly expensive, making most WTE projects not economically viable at the present. When asked what would be a push forward for WTE implementation, stakeholders agreed that promoting public-private partnerships to implement infrastructure projects in different stages of municipal waste management such as collection, transport, recycling, composting, and WTE, is extremely necessary. The overwhelming view is that WTE is highly desirable and that the key issue for scholars and practitioners is to find ways of making it more effective. A public-private solution to the waste problem in Thailand may be the best option for a country that is facing various administrative barriers.

(Q2) Access to Loans and Capital: Access to loans and capital among the interviewees was not of upmost importance, receiving an average score of 2.00, the second lowest score. This result is because the country has implemented various financial mechanisms that are already in place. In fact, Thailand was the first country to implement feed-in tariffs for renewable energy as well as import tax suspension for renewable energy technologies.

(Q3) Ownership of Waste Stream and (Q7) Government Support/Priority: both scored 2.45 leaving them still in the medium range of importance. It is important to point out that ownership of the waste stream is influenced by lack of transparency, in the sense that waste concession contracts with waste providers and WTE project developers are subject to "under the table negotiations" (as expressed by a stakeholder). Waste concession contracts that guarantee waste volumes and price over the life span of a project are vital, and must address the potential for shortfalls in waste feedstock. The problem with waste ownership, logistics and environmental issues in Thailand and the inability to have a sustainable feedstock for the plant is one of the main reasons private WTE developers have to back out of possible projects. As for government support, stakeholders agreed that the government had had a good start but more decisive and strategic actions would be needed in order to change the social attitude toward waste (which affects how it is disposed at source) and to step up private sector's investment in WTE.

(Q5) Education and Awareness: Education and awareness received the second highest average score of 2.77. Education and awareness are the backbone to a successful WTE. High levels of education and awareness have a stronger and lasting effect on the development of WTE because it encourages participation and gives the community a sense of ownership of the project. A public that is better educated on the benefits will be more likely to demand actions from public officials and policy makers at the federal, state, and local levels to effectively manage waste. For a WTE project to succeed, the community must feel ownership of the project. It is not only the municipal government's responsibility. There is resistance to WTE production as long as communities are not aware of the benefits. Waste management awareness is obtained through the distribution of comprehensive information, ensuring the people know the objectives, strengths and weaknesses of the project. Also, education encourages creative responses to any shortcomings.

(Q6) Separation at Source: Separation at source received the third highest average score at 2.59. Stakeholders agree that all WTE projects in Thailand depend on proper separation at source. When waste is properly managed, the local governments should foment separation at source and utilize to the greatest extent the WTE technologies that are currently operational. This could be done with various types on educational and awareness campaigns that focus on the three R's. However, the existing relationships between local governments, the so-called "waste mafia", and the recyclers fundamentally come into conflict with the effort to promote 3Rs. Fujii (2008), in his study of the potential of 3Rs in Thailand, documents how Bangkok's

1990s attempt to promote recycling failed because of the strong protests from the recyclers and how the local government's official effort at promoting recycling may have led to his murder.

(Q8) Complex Regulation (permitting issues): Most interviewees agreed that the bureaucratic system for acquiring different types of permits was difficult to the extent that some possible investors backed out. This is the case of a Danish project, which failed to materialize due to the burden of the process.

(Q9) Low Tipping Fee: In most municipalities tipping fees are low and do not cover the expenses necessary for an efficient waste management. When we consider that Thailand waste management is grossly underfunded, it is easy to see why WTE projects face significant difficulties. Currently in Thailand's municipality, tipping fees are low and do not represent the real cost of an efficient WTE project. As of 2014, the municipal tipping fee is 20 baht per month, regardless of amount of waste generation or socioeconomic status, and in some rural municipalities people do not pay. To increase the tipping fee in Thailand is highly unlikely because of political and social reasons.

Politicians will not implement higher tipping fee because of the political backlash that could potentially harm their political career. This problem is clearly seen at the local government level, where WM budget system is insufficient to put establish effective WM (UNEP 2005). Additional research is needed to determine stakeholder capability to pay for the waste management services in developing countries. Currently the motivation to pay for WM is limited because of ineffective functioning in the past.

(Q10) Lack of Transparency: As previously discussed, the lack of transparency is the most important barrier that Thailand has to face in order to reach full WTE potential.

In summary, this section shows that the lack of transparency scored the highest of all factors (score 2.86) and presents the most problems to society and WTE developers alike. The second most important barrier is education and awareness, (score 2.77). The two factors are further discussed in section 3.2.

Section 3:

In order to identify the main barrier that should be addressed so that WTE can develop with greater success, the interviewees were asked to choose the most important barrier to WTE development in Thailand. The results are shown in Figure 8. Public participation and lack of transparency receive equal scores at 36%. These two barriers were seen as the most important aspects to be considered and are further discussed in the section 3.2.

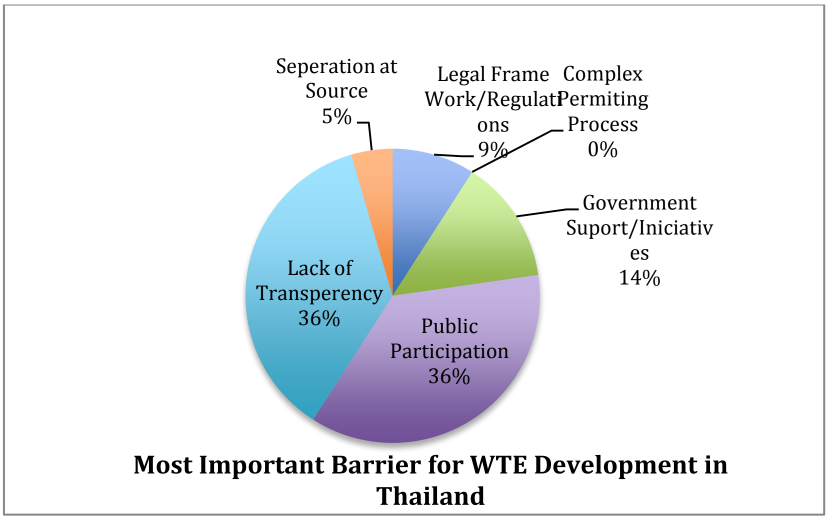

Figure 8 : Most Important Barrier for WTE Development in Thailand

Through the research methods conducted, including the questionnaire and in-depth interviews, this thesis has found 2 types of barriers to successful WTE and they are the: 1) lack of transparency and 2) public participation. The findings suggest that the steps necessary to resolve the issues to create a more functional WTE system in Thailand are to 1) improve transparency through the development and implementation of sound regulation and policy as well as 2) incorporate campaigns of public awareness and education about WTE.

Furthermore, this thesis finds that though Thailand has made significant progress in providing governmental support towards developing WTE, it still needs to further develop solutions to the lack of awareness and education regarding the benefits of WTE as well as legislative commitment. Another crucial requirement for the successful development of WTE plants is to develop different forms of technology that are adapted to local conditions and efficient to one or a number of different waste sources. Innovation and investment in WTE projects rarely occur without government-backed initiative.

3.2 Discussions

Lack of Transparency:

Because WTE project development requires partnerships between the local municipality who owns the waste streams, waste collection companies, and WTE developers, some degree of transparency is required for the involved parties to make judgment whether to go forward with the project. Transparency, in its most straightforward definition, means the provision of information to the public (Kosack, 2013). In the context of WTE development, transparency entails not only the government's disclosure of the information but also the government's requirements of the companies that are deemed to benefit from the contractual relations with the government agency to disclose information. The basic information related to waste that the local government should be required to disclose to the public includes: the amount of waste, its composition, the budget spent on waste disposal, contractual terms with waste disposal companies and contractual terms with WTE development companies, etc. However, these types of information are typically not available to the public. The lack of transparency in waste-related transactions give rise to the rise of the so-called local "waste mafia", which are influential business groups that have been able to monopolize waste disposal concessions.

Lack of transparency is a part of the administrative process all over the world; much of society and the economy are affected by this problem. Southeast Asia is one of the most corrupt regions in the world according to Transparency International's Corruption Perception Index 2013. Thailand was ranked 16th out of 28 countries in the Asia-Pacific region (Fig. 10), according to the Corruption Perception Index of Transparency International (2013). In Thailand, the lack of transparency happens mostly were state-related transactions take place, and the majority of the population is indifferent to the existence of corruption. A 2013 survey from 2,100 people throughout Thailand conducted by ABAC Poll Research Center, a Department of the Assumption University, found that 65 percent of respondents accept corruption as long as they also benefited from such activity. The same study concluded that this is "a dangerous attitude among the majority of people". The research said it believes that to change "unhealthy" attitudes, a "more truly democratic system" was needed and more transparency in the auditing system for the administration of the municipality budget (Maierbrugger, 2013).

Rank	**Country**	**Territory**
53	Malaysia	50
80	China	40
83	Mongolia	38
91	Sir lanka	37
94	India	36
94	Philippines	36
102	Thailand	35
114	Indonesia	32
116	Nepal	31

Figure 9 : Corruption Perception Index 2013
Source: Transparency International (2013)

In addition, there are some allegations that anti-corruption agencies are influenced by political maneuvers and conflicts of interest, causing the sector to flourish beyond imagination. A study by the University of the Thai Chamber of Commerce (UTCC) estimates that corruption in 2013 is likely to cost Bt235 billion to Bt329 billion, compared to of the country's overall investment and disbursement budget of Bt2.4 trillion. This total is based on claims by business operators who were surveyed, they claimed that they had to pay kickbacks equivalent to 25 to 35 per cent of their projects' cost in order to win government contracts. Almost 77 per cent said they would have to pay more bribes this year to win government contracts (Pratruangkrai, 2013).

Table 13 : Percentage of Bribes Paid

% Respondents	% Project value to win contracts
38.5	25
26.7	16-25
16.1	11-15
13.3	6-10
5.4	1-5

Source: Pratruangkrai (2013)

In many cases, Thai government officials who are tasked with regulating state-owned enterprises (an example includes EGAT – Electricity Generating Authority of Thailand) also hold positions in the Board of these companies and are paid large, additional payments and bonuses based on profits declared by the very companies that they are supposed to regulate (Vichit-Vadakan, 2010). This means that the government officials are serving the interests of the companies, not necessarily the people, which are who the government is supposed to represent. Vichit-Vadakan, 2010 also finds that an independent regulatory body was created but dose not have authority over tariffs. This body also lacks sufficient data, knowledge or human resources to provide adequate oversight of the investment plans, rendering it basically as a puppet entity without any real power for change and oversight.

WTE project developers often find themselves competing with each local waste collection business, which is typically a monopoly collector of waste from each local municipality with business ties to the local landfill operators. The incentive structure of the local waste collection business is to gather as many tons of waste as possible. As a result, successful WTE project developers so far in Thailand have been the municipalities themselves (such as the Phuket Municipality and the Samutprakarn Municipality) or the owner of the landfills (such as the case of Rajateva WTE plant).

An interview with a plant manager who wished to remain anonymous revealed that if WTE project developers are owned by a different company, they often face difficulties trying to establish partnerships with the local monopoly collector of the waste stream. For a WTE facility to be financially attractive, WTE investors require long-term concessions (15-35 years). Most concessions for foreign investors are short (1-5 years) and have limited relations with their providers of waste while the most successful LFG plants have excellent relations with their providers of waste and have concession for 10 years.

Public Participation:

The SWM is a social issue that requires high levels of social participation. Every person in living a society is directly or indirectly involved in the origin, development, and subsequent disposal of their waste. All elements of the society have clearly defined roles and functions of participation regarding SWM both as an individual and collectively. However, SWM is rarely solved through the tackling of existing social relationships in regard to waste.

According to the World Bank (1993), public involvement in planning and implementing projects through public consultation and participation is a key aspect for any development project to be successful. Public participation in the WM sector is limited in developing countries. According to Iakovou (2013), “public perception is a significant factor in the acceptability and future development of an industrial or commercial activity and can influence location choices”. It is a key factor of WTE success that a population understands the benefits of these projects. A public that is better educated on the benefits of WTE will be more likely to demand action from public officials and policy makers at national and municipal levels. The community must feel ownership of the project for it to be accepted and developed. For sustainable success, it should not be solely the municipal governments’ responsibility community’s must understand that they are fundamental aspects for WM and thus WTE development.

There will be continued resistance to WTE production so as long as the communities remain unaware of the benefits. Educating and informing the public will have a stronger and more lasting effect on the development of WTE because it encourages participation and gives the community a sense of ownership over the project. In the case of community-based solid waste management, an effective public participation can ensure active community involvement and therefore its ensured success and sustainability (Syazwina et.al, 2011). This action is also a vehicle in which the community can eventually take control over of the development process.

Waste management awareness is obtained through the distribution of comprehensive information, ensuring the people know the objectives, strengths and weaknesses of the project. Also, education encourages creative responses to any shortcomings. Mass media, including local television, radio, newspapers and leaf-lets in local languages, are important means to reach those who will be affected (World Bank, 1993). The World Bank recommends that agencies work through local, traditional decision-making institutions and leaders to disseminate information. And because the dissemination of information incurs costs, decisions need to be made regarding strategy and funding at an early stage.

Chapter 4

Conclusions and Recommendations

4.1 Success Factors for Developing Countries

Developing countries are actively seeking to apply the advancements made by European WTE companies in the last two decades. However, there are many obstacles to overcome. This thesis identifies key barriers to WTE development: the lack of transparency and community participation. In addition, all other aspects of waste management and waste-to-energy development must be improved to provide necessary conditions for successful WTE implementation. At the project level, WTE technology implementation depends on the following factors for it to be efficient (Sutabutr, et al., 2010; Vanapruk, 2010; Taparugssanagorn and Yamamoto, 2007):

- Composition of the waste generated,
- Potential location and
- Capacity of the proposed facility,
- Total cost of the system,
- Skilled staff,
- Stable prospect of planning environment,
- Market of the end product, and reliability of the technology.
- Policy and governance
- Public acceptance
- Incentives

Beyond project-level factors, an enabling environment is needed. Through analyses of secondary sources, the indicators for successful WTE promotion are shown in Table 14.

Table 14: Indicators for Successful WTE

Indicators	Source
1. High price of electricity	Shekdar, 2009; Williams, 2011
2. Absence of cheap domestic sources of energy	Williams, 2011
3. Ample waste stream	Williams, 2011; Tatarniuk, 2007
4. Public support	Williams, 2011; SPREP, 2009; Vanapruk, 2/ 0/ ; Shekdar, 2009; SPREP, 2009; Canadian WTE coalition; 2010, Kaosol, 2009
5. High recycling rate	Williams, 2011; Canadian WTE coalition, 2010

6. Efficient and appropriate technology	Williams, 2011; SPREP, 2009; Shekdar, 2009; Tatarniuk, 2007
7. Private Endorsement	Williams, 2011; CEWEP 2010; Shekdar, 2009
8. Effective management and maintenance	Shekdar, 2009; S. Udomsri et al., 2011; Schübeler, 1996; Achillas, 2011; Williams, 2011; SPREP, 2009; CEWEP 2010
9. High landfill tipping fees	Williams, 2011
10. Policies favorable to waste-to-energy	Swedish Waste Management, 2010; Schübeler, 1996; Achillas, 2011, Williams, 2011; SPREP, 2009; CEWEP 2010, Cherdsatirkul, 2012; Kaosol, 2009
11. Increase in local government's transparency in regard to waste-related transactions	Author's analysis in this research

Source: Author's analysis with data compilation from research

4.2 Recommendations

Successful waste-to-energy promotion requires every sector of the society to step up efforts at building an enabling environment for waste management and for WTE project development. The efforts start with municipal and central governments to define an appropriate policy and legal framework as well as to promote public participation and awareness campaigns. The broader public must also have a high level of awareness on the benefits of WTE and have a role to play from waste separation to participation in WTE projects. The recommendations below draw on my research findings and the existing body of knowledge on the key elements of successful WTE promotion.

Recommendations for Building an Effective Policy and Legal Framework

- Set up a Management Information System (MIS) which aims to increase waste collection efficiency.
- Implement a tipping fee based on the Polluter Pays Principle (PPP) concept, which means that the users pays the tipping fee in accordance to the amount of MSW that is produced.
- Conduct local campaigns to educate all ages on effective waste management with an emphasis on source-separation.
- Update and use solid waste management plans as important reference documents.
- Improve coordination in the management of solid waste.
- Re-examine and reconsider the level of regulatory limits required for all new sources of energy.

- Recognize the role and importance of the informal sector and provide long-term support in the form of health insurance or as well as other forms of savings, to which the informal sector can access.
- Provide sufficient incentives to encourage householders to escalate recycling/composting and reduce waste.
- Impose bans on plastic bags and bottles. Plastic bags have a tendency to clog up recycling sorting machines, are often contaminated with food, and the demand for recycled plastic is very low.
- Municipalities must encouraged the development of Integrated Solid Waste Management (ISWM) and promote Reduce, Reuse and Recycle (3R) programs in order to place a higher priority on waste prevention, waste reduction and recycling waste instead of trying to deal with growing amounts of waste through treatment and disposal.
- Issue laws to regulate the private sector, for example passing laws banning the use of certain types of non-recyclable materials (by comparing the true cost of managing such waste and the cost of alternative options), laws requiring producers to take back containers, etc.
- Provide tax incentives for businesses that engage in recycling.
- Set industry standards, for example, of packaging to be made from recycled content Promote investments in technology for use in plants that produce materials or products from recyclables
- Build long term public awareness via the national media. Different forms of media (particularly radio) have the power to reach a growing population. Awareness programs can improve governance by raising citizen awareness of social issues, enabling citizens to hold their governments' accountable, limiting corruption, and creating a civic forum for debate.
- Enhance the awareness of policy makers on WTE options. Decision makers that are better informed can lead to changing national socio-economic and industrial development policies and associated government programs in favor of improving solid waste management systems and WTE.
- Organize the collection of waste in order to drive waste from landfill to WTE. In Europe this has in many countries been done by landfill tax or by regulation
- Promote efficient energy use from WTE and potential usage for cooling purposes for households with AC units.
- Ensure effective WTE plants management and operation. Trained personal that could ensure effective WTE facilities, thus promoting public, private and national support.
- Provide subsidies for energy generation from WTE facilities
- Combine WTE with recycling program to ensure recyclables are collected as well.

Recommendations for Increasing Public Participation:

- The proposals intended to be implemented at the local or national level should seek the participation of all actors in society: central government, local governments, businesses, organized community groups, educational sector, in order to build consensus and facilitate cooperation and chart common strategies for the benefit of the society.
- Promote Community-Based Waste Management (CBWM) programs, with the aims to educate people on the benefits of separating waste at the source.
- Improve recycling programs and waste separation in order to have a waste stream that is appropriate for various WTE technologies
- Raise awareness of the public and decision makers: Effective management of solid waste requires the cooperation of the general public. Prioritizing and allocating more resources to, the solid waste management sector needs the support from decision makers and they in turn need to be pushed by public opinion.
- Implement local capacity building programs to enable citizens to be competent at their participation in different stages of waste management and WTE development.

4.3 Conclusions:

There is one thing in this world that we have in abundance — waste. WTE has the potential to become the best cost-effective waste disposal alternative, not only for developed countries but also increasingly for developing countries. WTE plants solve two major problems: recovering energy from waste and controlling emissions of major pollutants. They also provide a sustainable source of renewable, stable, and environmentally compatible energy. These benefits together should provide an impetus for energy recovery, especially in countries that are heavily dependent on fossil fuels and have waste management problems. Currently the WM and WTE market offer cleaner technologies that can avoid the generation of harmful by-products from the WTE plants, providing an effectively carbon neutral process and diversifying the energy mix of a country while battling the increasing waste problem.

Further studies are needed in order to provide evidence-based recommendations for government and society to advance sustainable WM systems. Different types of policies must be analyzed on a case-by-case basis in order to encouragement public perception to see MSW as a resource instead of burden. Aside each of the issues examined in this thesis, there is an encouraging and optimistic future; there is currently increased social as well as political consciousness about the importance of waste management, which a decade ago was difficult to imagine. Global economic trends also show that more money is being invested than ever before in WM and WTE. Thailand is an attractive country for WTE technology investors but there are elements that stifle its development. Thailand, as well as other growing economies, is in a unique opportunity to be able to leapfrog WTE technologies and policies. Considering the fact that Thailand has only started to fully promote WTE in the past 5 years, despite the failed attempts in some municipalities, the desire to further develop these forms of energy is positive. The Thai Government has set national energy policies and strategic plans for energy efficiency and alternative energy development that are promising.

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Education

2011 Chulalongkorn University, MA Environment Development and Sustainability, (in progress).

2010 Georgetown University. International Relations between the United States and Latin America. Certificate of completion.

2009 Facultad Latino Americana de Ciencias Sociales (FLACSO), Seminar "30 years of democracy in Latin America".

2003-2009 Universidad San Francisco de Quito, B.A. International Relations and Political Science. Minor in Environmental, Penal and international Law.

Professional Experience

2008-2014 Manager. Bastidas Construction. Quito, Ecuador.

• Selected most economic supplier of construction materials based on quality

• Managed resources on a specified budget

• Executed all necessary property registration documents

• Employed reliable staff to perform essential advertising propaganda

• Supervised construction workers on building site

2007-2008 Legal Assistant. Law Firm of Valarezo, Gangotena y Ponce.Quito,Ecuador.

• Produced legal contracts

• Processed certificates for Health Inspection services

• Registered certificates for trademarks in the Ecuadorian Institution of Intellectual Property

• Assisted Lawyers in commercial, civil and criminal law suits

• Translated Legal Documents from Spanish to English/English to Spanish

2005-2006 Legal Assistant. Notary 40. Quito, Ecuador.

• Revised legal contracts in order to comply with Ecuadorian regulation