IMPLEMENTATION OF SYSTEM DYNAMICS AND MULTI CRITERIA DECISION ANALYSIS FOR FOOD AND BIODEGRADABLE WASTE MANAGEMENT: THE CASE OF OITA CITY IN JAPAN

BY

BABALOLA Micky Amune

61112001

Supervisor:
Professor Dr. PISHVA Davar

A DISSERTATION SUBMITTED TO

GRADUATE SCHOOL OF ASIA PACIFIC STUDIES

RITSUMEIKAN ASIA PACIFIC UNIVERSITY (APU)

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY IN ASIA PACIFIC STUDIES

Beppu, Japan, 2015

DEDICATION

To God Be The Glory

Commit Your Works To The Lord,

And Your Thoughts Will Be Established.

-Proverbs 16:3(NKJV)

PREFACE

This dissertation with the title "*Implementation of System Dynamics and Multi Criteria Decision Analysis of Food and Biodegradable Waste - the Case of Oita City in Japan"* is the result of a PhD study conducted at the Graduate School of Asia Pacific Studies in Ritsumeikan Asia Pacific University from the period of April 2012 to September 2015 and the following manuscripts were prepared during the study for publication in an academic/scientific journal. Chapters 4 - 7 are based on these manuscripts and they comprise all the distinct contribution used in solving the overall research problem.

I. Sanga-Ngoie K. and Babalola M.A., 2012. *A Multi-Criteria Decision Analysis of Food and Biodegradable Waste Management Options in Japan*. The 2012 Asia Pacific Conference (RCAPS). Ritsumeikan Asia Pacific University, Beppu, Japan. 7th - 9th, December 2012, Conference Proceedings, page 62-65

II. Babalola M.A. *A Multi-Criteria Decision Analysis Methodology for Food and Biodegradable Waste Management Options in Japan. (Under review).* Manuscript submitted to: Waste Management; International Journal of Integrated Waste Management, Science and Technology (ELSEVIER, ISSN: 0956-053X)

III. Babalola M.A. *A Benefit– Cost Approach Based Multi Criteria Decision Analysis Of Food And Biodegradable Waste Treatment Alternatives In Oita City, Japan.* Manuscript prepared and ready for submission to: Waste Management; International Journal of Integrated Waste Management, Science and Technology (ELSEVIER, ISSN: 0956-053X)

IV. Babalola M.A. *Application of GIS-Based Multi-Criteria Decision Methodology for Exploration of Suitable Site Options for Anaerobic Digestion of Food and Biodegradable Wastes in Oita City, Japan.* Manuscript prepared and ready for submission to: Waste Management; International Journal of Integrated Waste Management, Science and Technology (ELSEVIER, ISSN: 0956-053X)

V. Babalola M.A *A System Dynamics Based Approach To Help Understand The Role Of Food And Biodegradable Waste Management In Respect Of Municipal Waste Management System In Oita City.* Manuscript in progress and intended to be submitted to: Waste Management; International Journal of Integrated Waste Management, Science and Technology (ELSEVIER, ISSN: 0956-053X)

ACKNOWLEDGEMENT

I want to extend my heartfelt thanks to everybody who helped in the successful conclusion of my doctoral study. My most and foremost gratitude goes to my supervisor Prof. Dr. SANGA-NGOIE Kazadi, for his advice, patience, and understanding throughout the process of this study. Also, my sincere gratitude goes to my co-supervisor Prof. Dr. PISHVA Davar for his dedication, guidance, and great support while writing my dissertation. If not for their invaluable advice and comments, I could not have been able to complete my study.

I am indebted to Prof. Dr. ARII Ken especially, for his thoughtfulness, assistance and invaluable contribution throughout my stay in Ritsumeikan Asia Pacific University (APU). My Thanks goes to Prof. Dr. MAHICHI Faezeh, and Prof. Dr. QIAN Xuepeng for their insightful help, encouragement and useful suggestions for improving my research work. My sincere appreciation also goes to Prof. Dr. FELLIZAR F.P.J. for his encouragement, fatherly support and counsel.

I am also indebted to APU and MEXT program for their financial support and without which I would not have achieved this height. Thank You.

Secondly my heartfelt gratitude goes to my parents and family members and most of all my sister Mrs. OGBEIDE Jane and her husband, for their encouragement I received throughout my studies at APU. Even though miles away, they never failed to check on how I am doing.

I am very grateful to that special person, SZABO Gabriella who is always by my side like a shadow, even throughout my stay at APU, guiding and encouraging me all through the way. Your encouraging words gave me strength and ability to carry on whenever I am down. Thank You.

Finally, my gratitude goes to my friends Dr. ODOEMENA Anthony, Dr. MBEREGO Seth, Dr. KUMARA Kudabadu J.C., and others too numerous to mention. Their company and comments are of outstanding significant input to this study as well as my student's life. Of course, also big thanks to BANKOLE Abidemi, SUTTLES Sarah and VARNEY Megan for doing all the hard work of proofreading.

Above all, I am exceedingly grateful to God for His guidance, protection, blessing, mercy, and love throughout my study and stay in Japan.

ABSTRACT

The increased focus on material recovery in Japanese cities has led to the increase of resources from waste materials for varied uses. Recently, energy recovery from wastes has been recognized as a possible option in Oita city. Utilization of all types of municipal wastes is essential in order to maximize the full potential of material recovery from municipal wastes. In Oita city, incineration remains the main method of treating large amounts of food and biodegradable waste (FBW) which has led to unintended negative consequences. In spite of the fact that, most easily achievable improvements have almost certainly been put into operation. The question that remains is how can food and biodegradable waste systems be further expanded, improved and optimized with regard to socio-cultural, economic, technical and environmental performance. This study examines the potential contributions and benefits that the separate treatment of FBW could make towards achieving sustainable waste management targets. System Dynamic (SD) and Multi Criteria Decision Analysis (MCDA) approaches were used in analyzing the existing data and knowledge on FBW to underline the existing limitations and challenges in order to develop sustainable solutions and practical suggestions. The result shows that anaerobic digestion is the best treatment option for FBW with regard to resource generation. This was followed by incineration. Composting and landfill were the least favored. The result also indicates that about 13.36 km^2 in the entire area of Oita city is suitable for the location of the anaerobic digestion plant. Additional results indicate that strengthening of regulation for sorted waste and the reduction in the amount of FBW treated in incineration will improve the current MSW management system in Oita city. This implies that the use of anaerobic digestion plant will increase the efficiency of incineration. The study further concludes that any regulation less than the proposed result will yield less benefit to the MSW management system as a whole. This study has two major contributions, namely: it provides a platform for assessing, developing and planning any FBW management project; and, it can be used for testing the impacts of various policy measures and management strategies for FBW management.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AD	Anaerobic Digestion
AHP	Analytical Hierocracy Process
CI	Consistency Index
CR	Consistency Ratio
FBW	Food and Biodegradable Waste
FBWM	Food and Biodegradable Waste Management
FWRL	The Food Waste Recycling Law
GIS	Geographic Information System
MAFF	Ministry of Agriculture, Forestry and Fisheries
MCDA	Multi Criteria Decision Analysis
MCE	Multi Criteria Evaluation
MOE	Ministry of Environment
MSW	Municipal Solid Waste
PCM	Pairwise Comparison Matrix
RI	Random Consistency Index
SD	System Dynamics
SMCA	Spatial Multi Criteria Analysis
SWOT	Strength, Weakness, Opportunity and Threat
WMRD	Waste Management and Recycling Department

CHAPTER ONE:
INTRODUCTION

1.1 Introduction

The generated quantities of Municipal Solid Waste (MSW) from developed countries have been on the increase over the years, and it is largely due to the unsustainable production and consumption of natural resources. Food and biodegradable waste management is not an exception. Mostly, the throwing away of this waste may be perceived as a familiar and easy predicament. In this information age, it barely seems possible that waste disposal should present any significant challenge, but many factors (such as environmental problems, cost of waste management, negative impacts on human health and global scale, as well as social disturbance) make it a complex problem of enormous magnitude for even a developed nation like Japan.

A significant portion of the MSW stream in Japan is food scraps and biodegradable waste (e.g. green or garden, paper, vegetable and wood waste). Annually, a growing amount of food waste worth ¥11 trillion (US$85.6bn) is generated in Japan due to increasing standards of living, imported luxuries and population growth. The yearly food-related biodegradable waste generation in Japan was 19 million tons in 2006, with food waste being 11.3 million tons of the total waste of which 6 million tons is considered edible by the government (MAFF, 2007). About 60% of this food related waste comes from food industries while the rest 40% is from households and small food-related businesses. Hence, it can be viewed from a monetary standpoint as ¥57,000 per person per year and in the total mass of 151kg per person per year (Stuart, 2009). According to MAFF (2007), Japan, wastes the same amount of food produced locally from the fishery and agricultural industries.

The Japanese preference for the high-class and their affection for raw food (raw eggs, sashimi, sushi, etc.) and particularly fresh fruits and other food introduce many logistical problems, which can result in massive heights of waste mentioned above. Another sphere of the immense collection leads back to the lifestyle in Japan that dwells on the importance of speedy food supply chains to obtain food from the sea or farms at a minimum attainable time since cities are far from the production source. Also, it is impossible to keep such delicacies fresh without wasting large amounts due to standards of food quality and date of expiration (best-before dates).

Creation of these wastes is quite beyond the managing competence of municipal governments as well as local authorities. Municipalities are at present struggling with the issues related to large amounts of food and biodegradable waste, the concerned costs, the disposal methods and the impact of wastes on the local and global environment. Another complication in the waste disposal problem is the difficulty in finding sites for new processing and disposal facilities. In spite of the limits of Food and Biodegradable Waste Management (FBWM) issues and the problems associated with it, the Japanese government instituted the Food Waste Recycling Law system since 2001 (MAFF, 2007).

A framework for improving FBWM strategies and a campaign were introduced in 2000 with changes already being seen in various Japanese cities. The primary reason for these changes is to facilitate the reduction, recycling and reuse of food waste, and the Food Waste Recycling Law stipulates the responsibilities to be rendered by food-related businesses founded on a set of criterion. Conversely, there is also an increasing plan in waste prevention measures to reduce, recycle and reuse the amount of Food and Biodegradable Waste (FBW) from households collected by local authorities. The government's Waste Management and Recycling Department (WMRD), which is financed by the Ministry of the Environment (MOE), is an essential agent in controlling waste generation, promoting reduction, reuse, recycling, and appropriate disposal systems "with a view to preserving living environments and making effective use of natural resources" (UNDP, 2013). WMRD consequently has initiated both the Establishment of Sound Material-Cycle Society and the Food Waste Recycling Law, but still there are serious challenges and issues faced by this department, for instance the increasing scarcity of room and landed resources for finishing waste disposal (waste treatment facilities locations), inappropriate waste disposal (waste treatment methods and unlawful dumping), as well as clashes involving different areas over long-distance transport of waste and the concern of waste treatment amenities. In line with these situations, this study examines the potential contribution that the separate treatment of FBW could make towards achieving environmentally robust waste management system and resource recovery efficiency.

1.2 Background of the Study

Waste management is a general issue in all the municipalities in Japan. Food and biodegradable waste management is not an exception to the issues associated with waste management. Of late, there are growing demands on sustainable approaches for FBWM and integrating policies that aim at practicing sustainable sound material recycle. The development of a FBWM system is an extremely complicated and difficult task due to multi-factors, unforeseen variables, objectives, dimensions and the active character of waste management insecurity. Moreover, it is necessary to take into account socio-cultural ideas with regards to local knowledge, economic feasibility, technical skills and environmental information aspects.

In Japan, the management of food and biodegradable waste as a resource has become tremendously valuable due to an increasing scarcity of food, energy recovery from waste and a demand for natural resources, which should also lead to sustainable wellbeing with regard to socio-benefits, a friendly environment and economic viability. General waste management development, use and management decisions involve multi-conflicting objectives, dimensions and criteria. Nonetheless, these problems present windows of opportunities for municipality to find solutions concerning the community and the private sector; linking innovative technologies and disposal methods; and involving awareness rising, campaigns for behavior changes and education.

There is no doubt that inappropriate disposal of FBW will cause serious environmental or ecological, socio-cultural and economic problems. Air pollution can stem from inadequate solid waste incineration; soil contamination, in addition to surface water and groundwater pollution can be caused by disposal of FBW in improperly built landfills. These kinds of pollution can lead to a variety of diseases in humans, thus threatening public health, which is a cause of apprehension. There is also a steady decrease in waste budget of municipal government leading to difficulties in municipal solid waste management (include FBW); these have also placed increasing pressure on infrastructure as well as the establishment accountable for waste management.

The waste management law in Japan stipulates that municipalities have to be responsible for the treatment and disposal of their own waste. As such, local government bears the cost of waste management. In Oita City waste from households and small businesses are collected by the local authorities while waste from large businesses and commercial centers are handled by private collectors. It is very interesting to notice that in Oita city, more emphasis is placed on the amount of waste to be treated or disposed of rather than the source of where these wastes are generated.

FBW consists mainly of food, kitchen, garden and other forms of waste biomass. In Oita City FBW is sometimes referred to as waste biomass, and it constitutes a substantial fraction of the MSW. In 2011, 44,901 tons of FBW waste was collected in Oita city, which is equivalent to 39% of the total amount of the MSW burnable waste (Oita City, 2012). The statistics on FBW are inadequate in the contest of Oita city, mainly because only the total amount from households is considered. The total generated FBW from small businesses (restaurants, cafeterias, small, shops etc.,), supermarkets, convenience stores and large food-processing plants are not reflected in the statistics. Although only a small amount is treated biologically, the rest is mostly incinerated.

In Oita city, reduction in the amount of MSW going to incinerators is largely being achieved through the recycling of glass, paper, Pet bottles, metal and some individual compost of food and kitchen waste while the requirement for a significant reduction in FBW going to incinerators has re-enforced attention on agro, kitchen and food waste recycling and reuse to produce feed for pigs, cows and poultry and also fertilizer for farmers. The efficiency of these approaches calls for concern and proper evaluation of the processes. In Oita prefecture, acquiring public approval and a site location requires enormous consultations and investments for constructing new incinerator facilities. Thus, it is sensible to seek and put into practice long-term incorporated FBWM strategies that guarantee a sustainable approach.

1.3 Research Statement/Problems

Recent developments in Japan have been promoting the utilization of biomass resources and food waste to achieve a sustainable, sound material recycle society and to increase the food dependency ratio. Since June 2000, the Japanese Government has come up with the "Sound Material–Cycle Society" in it positions on the "Biomass Nippon Strategy"[1]. Most prefectures in Japan, including Oita prefecture with its "Oita Zero Waste Strategy", have adopted this strategy. As such municipalities are responsible for the management of FBW, this has resulted in some complex schemes. In the background, these issues regarding FBW management system were identified:

a. As zero waste strategy is the guiding principle for municipal solid waste management in Oita city, it is often assumed that food and biodegradable waste recycling will be environmentally better than incineration, but the recycling facilities are often not available where the waste is generated. Therefore, incineration becomes the only method of treatment, which leads to the issues of extra energy for treating wet waste, pre-treatment and pollution control.
b. The legislation of waste management contains various requirements from pollution prevention to recycling of this waste and sets political targets for recycling in order to minimize the environmental damage caused by food and biodegradable waste management. These regulations are on large food-related business sectors only, which in turn increased the amount of illegal food and biodegradable waste disposal.
c. Some of the most easily achievable improvements have almost certainly been put into operation before now. The question is how food and biodegradable waste systems can be further extended, improved and optimized with regard to socio-cultural, economical, technical and environmental performance.

In spite of the increasing importance of research on integrated municipal solid waste management systems and the adaptation and reliability of related waste treatment facilities, there has been little research on the comprehensive assessment of FBW. It is

---

[1] The Basic Act for Establishing a Sound Material-Cycle Society （Act No.110 of 2000）

important to carry out a study that aims at evaluating, improving and developing on the current waste management systems. Therefore, this study aims at addressing these issues by exploring various decision making strategies, analyzing and simulating various factors influencing the current FBWM practices towards finding sustainable sound solutions.

1.4 Research Aims and Objectives

The aim of this study is to examine the municipal solid waste situation in Oita city, Japan with the objective of increasing the understanding of the benefit of separate treatment of food and biodegradable waste. Particularly, this study tries to answers to these questions; (a) "How can food and biodegradable waste management (FBWM) system be further expanded and optimized with regard to environmental performance, economical reliability and social trust?" and (b) "What are the benefits of a separate FBWM as a component of the entire waste management system?" In line with this, this study examines the potential contribution that the treatment of FBW could make towards achieving sustainable waste management targets. This is done using System Dynamic and Multi Criteria Decision Analysis approaches with particular focus on FBW management practice in Oita city. The specific objectives:

a. To identify ways to improve the food and biodegradable waste management system
b. To investigate the technical feasibility of the continuous treatment of FBW using different waste treatment options.
c. To analyze various factors influencing the current FBWM practices.
d. To explore various policy scenarios for improving FBW Management

1.5 Significance of the Research

In Oita city the MSW situation has attracted attention among city dwellers. Prominent government officials, local authorities, environmental non-governmental organizations (ENGOs), social groups, institutions and waste management experts have voiced their concern about the situation of MSW in the city. The mass media is also not out of the demonstration, as newspaper, TV and radio programs on MSW issues are frequently featured. Apparently, there is a need for research in the area for a better understanding of the issues and to come up with a sound, sustainable solution. FBW is not an exemption, but it would be a greater opportunity if these wastes were used as resources rather than just waste.

Recently, emphasis has been placed on the biological treatment of FBW in order to maximize material recovery and energy utilization, and increase waste treatment efficiency, and reduce the GHG emission from waste. At the moment, incineration is the main process for discarding FBW in most cities in Japan (Izumi et al., 2010). One of the primary challenges is the reduction of the quantity of incinerated biodegradable waste, which is comprised of paper, garden, agro forestry, kitchen and food waste. According to Sawayama et al. (1997), extra fuel is needed to treat wet waste since is the most difficult fraction of municipal solid waste by direct incineration, given its highly decaying and moisture nature of over 80%. Besides, the predicament of incineration amenities associated with environmental and public health concerns due to air pollution are not particularly encouraged in urban settlement.

The majority of waste collected is burnt up, undermining the composition of the waste, and FBW disposal in landfills is no longer an acceptable practice in Japan. The developments of options and strategies to divert food waste from incinerators have therefore been introduced (Matsumoto et al., 2009). In contrast, electricity generation by incinerating facilities has been developed throughout Japan, and in order to optimize the efficiency of these incinerators, food and biodegradable waste could be treated independently from other wastes, utilizing the separating techniques currently in practice meanwhile, this partition practice can play a fundamental part in redirecting FBW elsewhere from disposal facilities like incinerator and landfills. Taking these facts into consideration, a different treatment method for FBW disposal techniques, instead of incineration is necessary and should be designed to prevent the spread of disease, optimize material recovery (energy recovery) and protect ecological quality.

In spite of the increasing importance of research on integrated municipal solid waste management systems and the adaptation and reliability of related waste treatment facilities in Japan, there has been little research on the comprehensive assessment of

FBW. Apparently, the media has been playing an essential role in attracting attention to the undisciplined practice of MSW in the city. There are a number of studies that have examined issues related to FBW management in Oita city. Morisaki (2011) reported on the factors affecting and nature of food lost in household wastes in Oita prefecture while Babalola (2011) considered the opportunity and potential of recycling FBW as a fundamental part of the MSW management system. Despite the contribution of these studies, the related FBW issues in Oita city remains under-researched, hence creating a knowledge gap and making it difficult to fully know the extent of the current situation of FBW in the city. It is significant to carry out a study that aims at evaluating, improving and developing the current waste management systems using a case study like Oita city. Therefore, this study aims to address these issues by exploring various decision-making strategies, analyzing and simulating various factors influencing the current food and biodegradable waste management practices towards finding sustainable sound solutions. Also, this will contribute to both the theoretical and practical aspects of MSW management systems in the city and country at large.

1.6 Limitation and Scope of the research

This study's focal point is based on current practices of food and biodegradable waste management (FBWM) and how the possibility and potential of using or treating FBW separately can help in improving the MSW management practices in Oita city, Japan.

However, this study considers specifically the amount of FBW generated and the policies, bodies and authorities involved in the MSW management system. FBWM in this study refers to the portion of MSW handled and treated by the local authorities, which is comprised of FBW from households, small food-related businesses, hotels, supermarkets, restaurants and convenient stores. FBW from large food-related industries, wholesale and retail facilities as well as those from establishments that have their own treatment facilities are not considered. Similarly, other FBW, which require special treatment, is excluded.

The study design is based on explorative, descriptive, and explanatory research, and a case study approach is used in order to understand the MSW stream and system (including FBW). Multi-Criteria Decision Analysis and System Dynamics (qualitative and quantitative investigative techniques) are the key empirical strengths of this study since they can be used to analyze, complement and validate the collected information, decision-making, planning, trade-off, and the final result.

1.7 Structure of the Thesis

Chapter 1: Introduction. This chapter introduces the background of the study, aims and objectives of study, the research statement, significance and limitations of the study and the brief study outlines.

Chapter 2: Literature Review. Chapter two examines the main issues (barriers and critical issues) considered in food and biodegradable waste management in Japan and the main solutions currently in use. It also includes concepts, criteria and the framework that are being discussed throughout.

Chapter 3: Methodology. This chapter presents and describes the general approach and methods adopted to address the objectives of the study. This chapter discusses the research philosophy, research design and methods underpinning this study in order to gain a better understanding of how and why they are applied. The initial discussion is based on the research philosophy and how it best fits the focus of the study. Furthermore, this chapter discusses the research design and methodologies, which include mix methods, action and case study research, and data collection and analysis procedures.

Chapter 4: Multi Criteria Assessment of Food and Biodegradable Waste Management Options. This chapter focuses on demonstrating how Analytic Hierarchy Process (AHP) approaches in MCDA can be used to address FBWM's challenging issues. It involves the establishment of the model structure (hierarchy structure), setting up of the initial weights, the pairwise comparison, and ranking of waste treatment options. Finally, the results, discussed and conclusions are provided.

Chapter 5: A Benefit Cost Approach-Based Multi-Criteria Decision Analysis of Food and Biodegradable Waste Treatment Alternatives in Oita city, Japan. This chapter uses the same approach with chapter 4 but with a slight difference in the procedure. The hierarchy structure is broken down into costs against benefits for further sub-problems and separate criteria. In this aspect, the complete basic ranking is employed where benefit and cost rankings are aggregated and merged in one ranking. First, the importance of benefits and costs are weighted, and then the weighted score of the cost analysis to produce the final result, discussion and conclusions divides the weighted score of the benefit analysis.

Chapter 6: Assessment of Potential Site for Siting Food and Biodegradable Waste Facility. This chapter focuses on a Geographic Information System-Based Multi Criteria Decision Analysis (GIS-MCDA) and how it is used to characterize and assess land suitability (siting of anaerobic digestion plant) in Oita city, Japan.

Chapter 7: Model for Evaluation and Analysis of FBWM in the Waste Management System. Chapter seven presents the implementation, formulation, and description of the System Dynamics model. The casual loop diagram and scenarios for the model are described in this chapter. Sensitivity and validation analysis is also conducted. The results are discussed and the conclusion presented.

Chapter 8: Conclusion and Recommendation. The chapter gives an overall conclusion based on four empirical chapters and their contribution to this study. Recommendations and suggestions for future research are also presented in this chapter. Finally, a combined reference list is given at the end of the thesis.

CHAPTER TWO:
LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the exiting literature on food and biodegradable waste management. Insights from these studies also form the basis for this study's theoretical framework. The first section examines the concepts related to food and biodegradable waste management in relation to municipal waste management. The second section focuses mainly on the theoretical and empirical perspectives. In addition, the chapter also covers some of the basic concepts related to food and biodegradable waste management (such as definitions, types, and treatment methods). The development of the chapter involved a special focus on the global trends of food waste, recent developments, perspectives on the role of regulatory policy, as well as food waste recycle law in Japan.

2.2 Waste management

The increases in the standards of living, population and economic development have led to an increase in the volumes of wastes that needs to be managed in both developed and developing countries. Notably, the problem of waste management in developed countries is often attributed to the escalation of per capita generation of waste substances (of various kinds) and some institutional difficulties. Some of the institutional difficulties are embedded in administrative issues related to decentralization, stakeholder management, and the enormity of the financial investment in physical infrastructure (incinerators, landfills and recycling facilities) (Zotos et al., 2009; Schubalar, 1996). In developing countries however, the problem of waste management are more severe. They are often related to the inefficiency of waste collection, treatment, transportation and disposal methods. These are further compounded by scarcity of resources, financial insufficiency, and human resources. As a result, wastes generated in both small and large city centers have somewhat turned into difficult and complex issues that need urgent attention. This is often a challenge that most local authorities and municipal managers have to face on a daily basis. It is also a complex issue that relies to a large extent on collaboration and organization among households, local citizens, communities, private enterprises and municipal authorities (Schubalar et al., 1996). Moreover, waste management is an essential duty that has significant cost implications for public health and the sustainability of the urban environment.

Wastes are generally described and grouped in numerous ways. These different classifications imply the need for some special treatment: each type needs to be dealt with in a unique and effective manner. This is one of the complex challenges involved in waste management. As an example, solid wastes include any discarded material in a solid or semisolid state and insoluble materials (e.g. liquids and gases in containers). Other examples of solid waste include, industrial waste, agricultural refuses, wastes from institutional-establishments (such as hospitals and schools), construction and demolition waste, mining residue, municipal waste, and sewage sludge. Dealing with all such wastes is referred to as solid waste management. This often involves the organization and control of waste generation, source separation, waste collection, storage, transport, recovery, processing, disposal and treatment (Nathanson, 2008). In general, solid waste is classified into different types, depending on its source. The four main types include:

- Municipal waste (nonhazardous) consisting of demolition, commercial and household waste
- Hazardous waste consisting of industrial waste
- Bio-medical waste consisting of clinical and hospital waste
- Special hazardous waste consisting of explosives, radioactive materials and e-waste

2.3 Definition of Waste Management in Japan

Waste is defined in various ways depending on each country's waste management legislation; as such, it is defined in Japan by the Waste Management Law (Waste Management and Public Cleansing Law of 1970) as "ash, refuse, bulky refuse, waste oil, carcasses, excreta, waste acid and alkali, sludge, other unsanitary and unneeded matter, that are either in a liquid or solid form (i.e. apart from waste polluted by radioactivity in addition to radioactive waste)". In order to ensure suitable treatment, the wastes are categorized into "municipal solid waste" and "industrial waste" with separate regulations and systems (UNEP, 2013). Basically, in Japan MSW is considered to be the same as "General Waste"; further illustration of the definition of the two categories is given in Figure 2-1. The Waste Management Law stipulates that all municipalities should handle their "general waste or MSW" that is created inside the municipal region. As such, municipalities should have their own waste treatment and disposal facilities. In general, waste from household and small business is collected by local authorities only while private sectors collect those of large businesses and commercial waste and in some cases handled themselves.

Figure 2-1 Definition of Waste base on the Waste Management Law in Japan source: Adopted from UNEP, 2013

2.4 Food and Biodegradable Waste Management

Taking into consideration the aim and objectives, this research will focus on the food and biodegradable part of municipal solid waste, and in this contest, food waste will cover all food related waste while biodegradable waste will cover any other forms of organic waste. Municipal solid waste is described as consisting of inorganic and organic refuse (daily used and discarded items) from homes, harmless solid waste from business use, food factories, industrial and institutional organizations (including schools and hospitals), market and yard waste, containers with product packaging, and street sweepings. However, agricultural wastes and sewage sludge are not included in municipal waste management (Nathanson, 2008; Schubalar et al., 1996). On the other hand, the biodegradable waste aspect of MSW consists of food and kitchen waste, green waste, garden waste, paper and some parts of agricultural waste.

However, since there is no definite definition for food and biodegradable waste, the definition of FBW is based on the definition of food waste view expressed above. Food waste can be described as any food stuff that is uncooked or cooked, and surplus food leftovers that are discarded or otherwise intended to be discarded. Biodegradable wastes are the organic remnant created through the management, storage and sale, preparation, cooking and serving of foods that are capable of going through aerobic or anaerobic decomposition (EU 1999 pg.5). Also, it can be seen from the contest of food loss[2] as described by Hodges et al. (2011) that "food waste is the subset of food loss that is potentially recoverable for human consumption" (pg38). Gustavsson et al. (2011) defines it as food losses occurring through the food supply chain (postharvest[3] to post-consumption) that specifically leads to edible food for human consumption due to consumer and retailer behavior.

[2] Hodges et al., (2011, pg. 38) defines food loss as a "subset of postharvest loss and representing the part of the edible share of food that is available for consumption at either the retail or consumer levels but not consumed for any reason". With regards to this study, food waste and food loss are assumed to be the same.
[3] "This system comprises interconnected activities from the time of harvest through crop processing, marketing and food preparation, to the final decision by the consumer to eat or discard the food".(Hodges et al., 2011, pg38)

2.4.1 Global Trend of Food and Biodegradable Waste

The increase in growth of global food supply chains (postharvest to final household consumption) and the importance of efficiency and food safety in recent years have stimulated a significant increase (Hodges et al., 2011) in food and biodegradable waste to a great extent in medium- and high-income nations, meaning that food is abandoned even though it is still good to eat (consumption stage). Conversely, in low income nations it is the opposite, and in all these processes about one-third of the edible parts of consumable food worth about 1.3 billion tons per year are either lost or wasted globally (Gustavsson et al, 2011).

According to Gustavsson et al., (2011) food waste in both developing and developed countries is high and more than 40% of the food waste occurs at both the postharvest and processing level and retail and consumer levels respectively (see Figure 2-2). The total food waste generated at consumption level in developed countries - 222 million tons - is approximately equivalent in amount of money to the worth of the 230 million tons of the entire food manufactured in sub-Saharan Africa (Gustavsson et al., 2011).

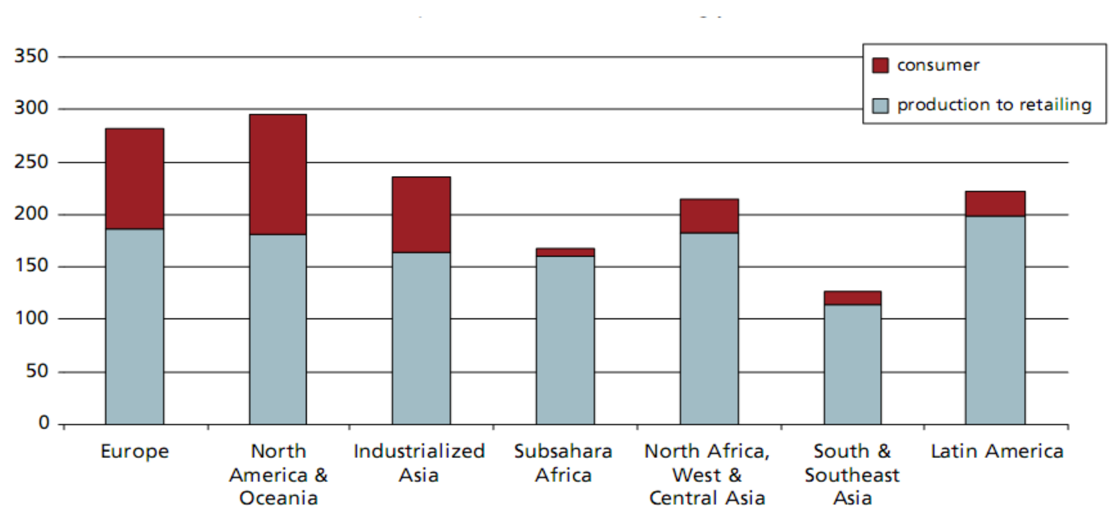

Figure 2-2 Regional per Capita Food Waste at Postharvest and Consumption Stages source: Gustavsson et al., (2011)

2.4.2 Food and Biodegradable Waste Management in Japan

In Japan, the largest source of FBW comes from the food industrial sectors, followed by supermarkets and convenience stores. As a result, convenience stores and hotels are responsible for 6 million tons of the total 19 million of FBW. The yearly generation of food waste in Japan was 11.3 million tons in 2006 with a reduction of 10,000 tons from 2005 and about 19 million tons of food related waste in total, of which 6 million tons is considered edible by the government, and 11.3 million tons comes from the food-related industries and households with 7.7million tons (MAFF, 2007).

FBW in present times are concerns for both the government and the general public, but it could be seen as a greater opportunity if these wastes are used as resources rather than just waste. As such, approaches to food waste management are being re-evaluated in and across Japan as a result of the introduction of incinerating energy reduction schemes in Tokyo, Osaka, Sapporo, Fukuoka, etc. At the moment, incineration is the main process for discarding and volume reduction of food waste in Japan (Izumi et al., 2010). Most of these wastes are collected and incinerated. FBW disposal in landfills is no longer an acceptable practice in Japan, possibly due to a lack of landed resources and the environmental impact associated with landfills. The development of options and strategies to divert food waste from incinerators has therefore been introduced (Matsumoto et al., 2009).

The primary reason for these changes is to facilitate the reduction, recycling and reusing of FBW due to the worries and vulnerability of the Japanese food supply, since the actual food produced locally from the fishery and agricultural industries is mostly wasted (MAFF 2007). Although the volume of the FBW in Japan is high and at the same time on the increase, the food supply in Japan with an average of 2,548 kcal per person per day is quite low compared with that of USA with an average of 3,900 kcal and that of the world with an average of 2,808 kcal (Stuart, 2009). According to MITE (2008) and MAFF (2007), food waste is about 30% of total MSW disposed, and the recycling rate of food waste remains about 10%. In order to promote food and other biodegradable waste reduction and recycling, the "Law for Promotion of Recycling and Related Activities for the Treatment of Cyclical Food Resources" were legislated. The law specifies that the obligations of each party involved in recycling and treatment of food resources should be carried out based on criteria set by the law. The law stipulates that all sectors (from households to large food related industries) should be positively engaged in recycling and reduction of food and other biodegradable waste. There is also an emerging plan in waste prevention measures to reduce, recycle and reuse the amount of FBW from households collected by local authorities. A summary of the law is given in the section below.

Article 1[4]

1] Title of the law: Law Concerning Promotion to Recover and Utilize Recyclable Food Resources (Food Recycling Law)

[2] Date put into force: May 2001 (promulgated in June 2000)

[3] Purpose: To prevent and reduce food waste discharged from food-related businesses, thereby decreasing the amount for final disposal, as well as to promote the recycling of such waste as fertilizers and animal feeds.

Outline of the Law

The law provides for measures to be taken by food-related businesses.

(1) *Food waste to be regulated*

[1] Unsold or uneaten food waste generated in the process of distribution and consumption

[2] Leftover plant and animal food generated in the process of manufacturing, processing and cooking food products (excluding kitchen waste discharged from households)

(2) *Food-related businesses to be regulated*

[1] Businesses engaged in manufacturing/processing food products for wholesale or retail sales

e. g. Food manufacturers, greengroceries, department stores, supermarkets

[2] Restaurants and other food-service businesses

[4] Note: Unless indicated otherwise, the information in this section comes from Ministry of Economy, Trade and Industry, towards a 3R-Oriented Sustainable Society: Legislation and Trend 2007. http://www.meti.go.jp/policy/recycle/main/data/pamphlet/pdf/handbook2007_eng.pdf (accessed and retrieved 09/01/2015)

e. g. Cafeterias, restaurants, hotels, Japanese-style hotels, wedding centers, floating restaurants

(3) *Role of parties concerned*

[1] Food-related businesses

All Food-related businesses engaged in manufacturing and distributing food products or providing restaurant services shall carry out recycling of food waste (through prevention of waste generation, and reduction of final disposal), and raise the recycling rate by 20 %.

[2] Consumers

Consumers shall prevent generation of food waste by improving their methods of buying and cooking food and by using recycled products.

[3] The national and local governments

The national and local governments shall implement measures to promote recycling of recyclable food resources.

(4) *Target of recycling and parity of measures*

[Aims to increase the recycling rate to 20% by FY2006]

[1] Prevention: preventing generation of food waste

[2] Recycling: using food waste as raw materials of fertilizer, animal feeds, oil and fat products or methane.

• Fertilizers: compost made by aerobic fermentation, organic fertilizer made by drying

• Animal feeds: feed for livestock or aquarium fish made by pressure steaming, aerobic fermentation or dehydration through frying

• Oil and fat products: cooking oil, soap

• Methane: biogas made by anaerobic fermentation of kitchen waste (composed of methane gas (about 60%) and carbon dioxide gas (about 40%)), used as fuel

[3] Reduction: reducing the amount of food waste by dehydration, drying, fermentation or carbonization (roasting)

2.4.3 Generation and Classification of Food Waste in Japan

In Japan food wastes are grouped into two categories; general waste (MSW) and industrial waste. General waste (MSW) is comprised of household waste, waste from food services (restaurants, cafeterias, hotels, etc.), retailing industries and food distribution businesses while the food waste from food manufacturers is considered as industrial (as illustrated in Figure 2-3). Food waste consists of food waste generated in the process of manufacturing, such as leftovers, plant and animal byproducts as well as those generated in the process of distribution and consumption (e.g. kitchen waste, expired, unsold or uneaten food waste).

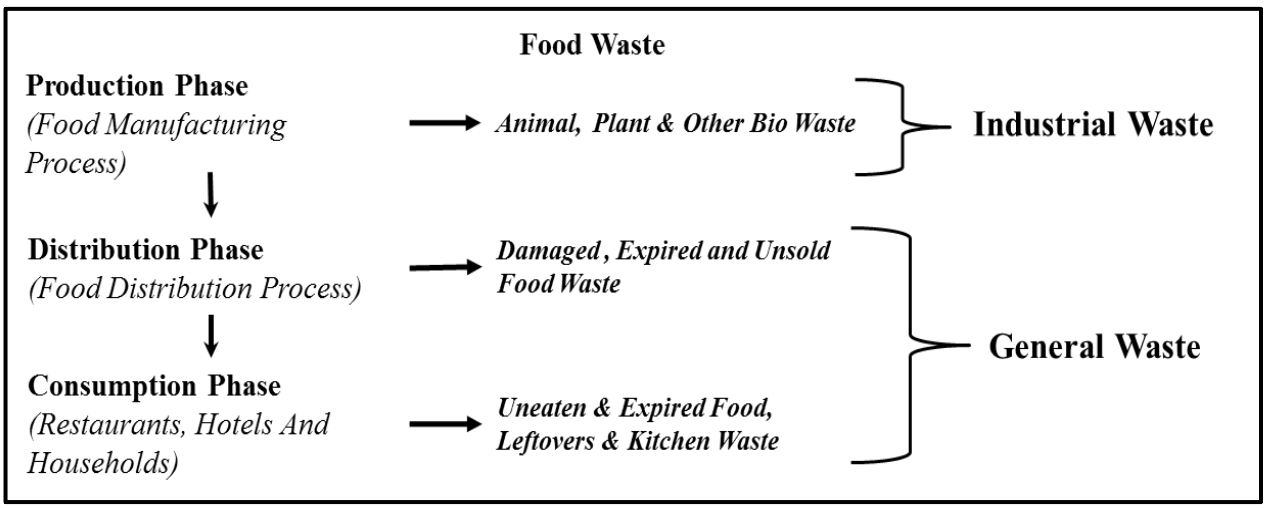

Figure 2-3 Generation and Classification of food Waste in Japan According to Food Waste Recycling Law. Source: UNEP, 2013; MAFF, 2007

The Food Waste Recycling Law (FWRL), which was passed in 2001, stipulates the responsibilities to be executed by food-affiliated business[5] grounded on set criterion. The obligation for food-related businesses is to recycle 60% of all food waste by 2006, but by the end of 2006, recycling was 1% short of the set target (59%), which showed the same level as 2005, illustrated by Figure 2-4 below. Considering the FBW generation in different sectors among food-related business, manufacturing generates the largest at 44% of the annual total with 4.9 million tons per year. The eat out industries generate the

[5] MAFF (2007) describes food related businesses as any businesses engaged in food processing, distribution, sales, operating restaurants, and catering".

second largest at 27% of the annual total with about 3 million per year, food retailing stands within 2.6 million tons per year and food wholesaling within 7.4 hundred thousand tons per year at 23% and 7% respectively. See the illustration in Figure 2-5.

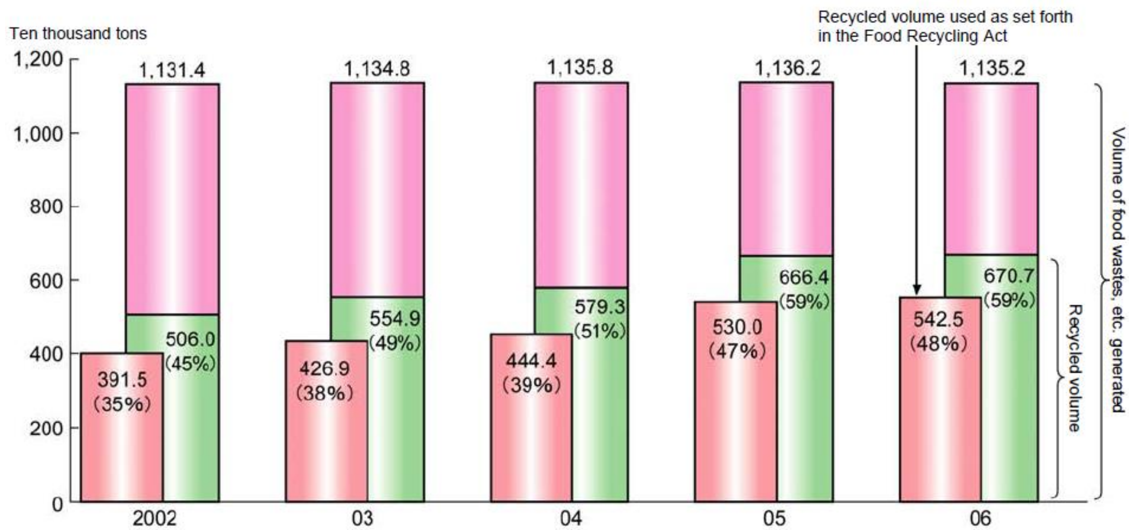

Figure 2-4 Recycled and food waste between 2002 and 2006 Source: Ministry of Agriculture, Forestry and Fisheries 2008 Annual Report.

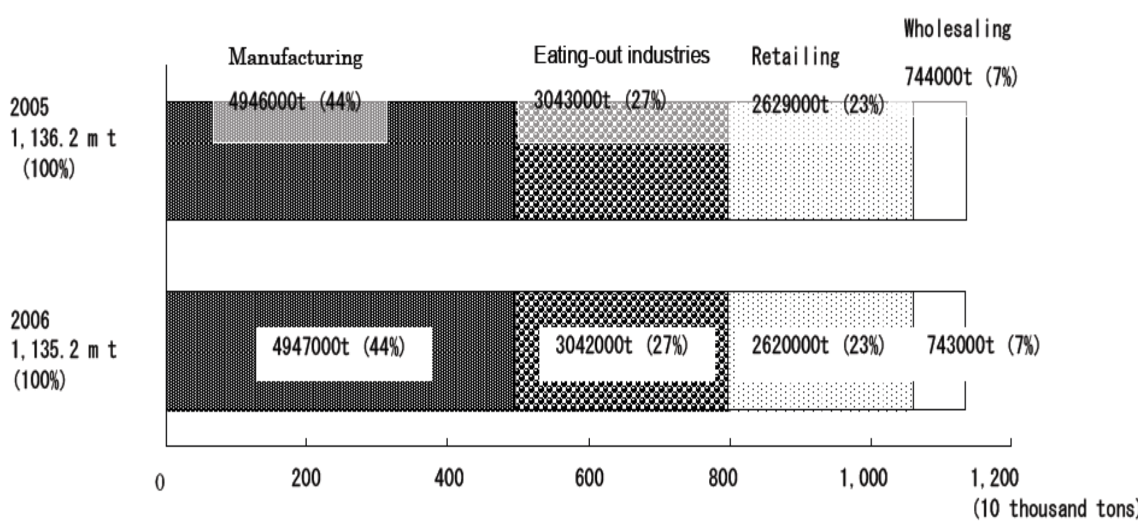

Figure 2-5 FBW Generation by Different Sectors in Food Related Businesses. Source: MAFF, 2007

Probably, the Japanese government targets these food-related businesses not just because it is easier for them to separate food from non-food but due to the amount of waste they generate. The Food Waste Recycling Law is different in critical ways when compared to those introduced in the EU and the U.S. The FWRL deals specifically with food, whereas the EU laws aim at biodegradable waste in general, including waste from parks and gardens. In the U.K., it is more indirectly concentrated on households rather than businesses, but they both have driving factors. The Japanese law is driven by the food sufficiency rate and waste while the U.K. law is driven by EU landfill directives that require member states to progressively trim down the total recyclable waste going to landfills (Knipe, 2005). FBW is recovered mainly for compost or feed in integrating the 3R activities based on FWRL. The FWRL guidelines clearly stipulate the meaning of recycling to be the reuse of food waste by composting or manufacturing animal food substance (feeds for animals) as renewable resources and the transportation of food waste to other places for the same purpose. Cutting food waste means to acquire precautionary actions alongside the food waste generation. Reduction means to trim down food waste both in weight and quantity by dehydrating and drying (MAFF, 2007). In the U.K., centralized composting treatment and anaerobic digestion are the main acceptable methods (Knipe, 2005).

2.4.4 Food and Biodegradable Waste Treatment/Disposal Options

The process of selecting the right FBW disposal method is a complex and complicated issue as many criteria and factors have to be involved, for example, public health, environmental, social, cultural, political, technological and economical concerns. Selection of the proper and right disposal treatment will not only save money and time but also help in reducing the environmental impact. It protects human health, raises no risk to water, air, soil, plants and animals, causes no aggravation through odor or noise and does not disturb the rural areas or locations of specific interest (airports). Moreover, this disposal method should potentially be located close to the waste generators as much as possible.

Numerous disposal methods have been adopted to treat FBW in different parts of the world, including Japan (Figure 2-6). Examples of the most well-known methods are open dumping, sanitary land filling, incineration and composting, among others. This study will stay with the usages of prescribed methods under the FWRL, for example, composting, animal feed, anaerobic digestion (or methanation), oil & fat products, and the two primary disposal methods in use, which are incineration and landfill (MAFF, 2008). Animal feed and oil & fat products will not be considered in this study. Subsequently, broad evaluation of the disposal methods will be put in the picture of SWOT (strength, weakness, opportunity and threat) analysis to facilitate the status quo.

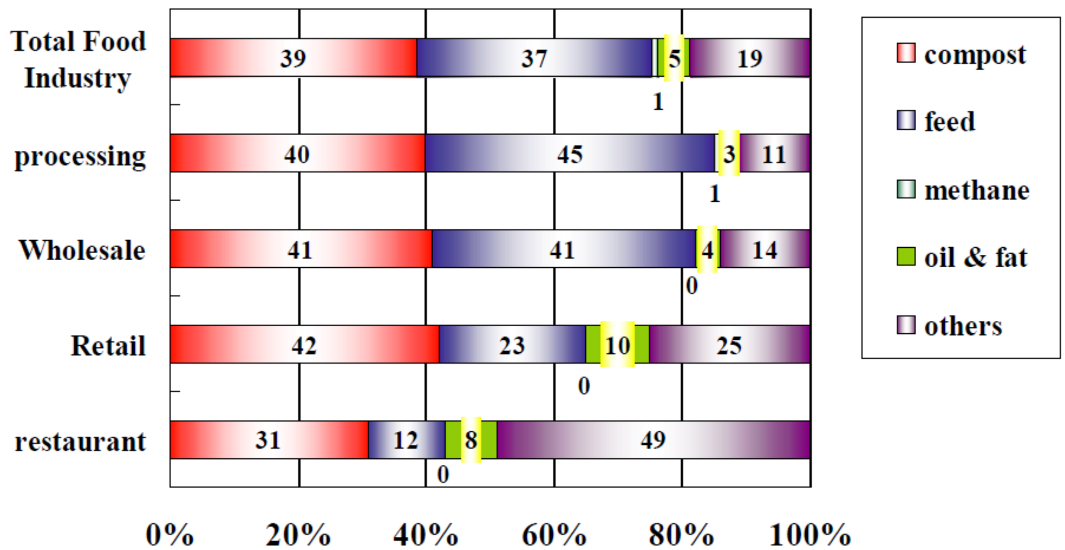

Figure 2-6 Various Methods of FBW in Japan Source: MAFF, 2007

2.4.4.1 Incineration

Incineration is the burning of any waste in a correctly designed furnace under the right temperature and operating conditions to reduce about 75% in weight and 90% in volume of waste (Nathanson, 2008). In highly populated areas, incineration is the most suitable and most economical waste-treatment method due to unavailability of large, suitable sites or sensible transportation distances for sanitary landfilling. In terms of economics sense, it is possible to design incinerator based on resource recovery or Waste-to-Energy facilities and operate an incinerator that recovers and makes use of the heat from combustion, producing electricity or steam (Rao, 1991; Nathanson, 2008).

Incineration is a chemical process that involves the oxidation of any hydrocarbon combustible waste to form mostly carbon dioxide and water, resulting in the release of heat (thermal energy). Carbon dioxide gas and water vapor (flue gas) are released into the atmosphere. On average, furnace temperatures are about 815^{o}C (1500^{o}F), but for some types of waste, temperatures up to 1400^{o}C (2550^{o}F) are needed to attain combustion. The waste usually has to stay in the furnace for about 1 hour (Nathanson, 2008).

Table 2-1 SWOT Assesment for Incineration

Strengths	**Weakness**
❖ Reduction in waste volume & weight ❖ Takes fewer landed space compared to landfill ❖ Power & heat generation ❖ Accommodation of large variation in waste composition & calorific value.	❖ Flue gas emission ❖ Large investment, high maintenance & op ❖ Environmental impact ❖ Waste residues, slag & ash issues ❖ High cost advanced technology for polluti ❖ Extra energy is required for some waste (v
Opportunities	**Threats**
❖ Revenue generation forms sales of power & heat ❖ Creates jobs ❖ Potential for renewable energy generation	❖ Ground & surface water pollution ❖ Might depend on the energy market for su ❖ The effect of low calorific value due to rec ❖ NIMBY syndrome ❖ Public health & accident risk

2.4.4.2 Composting

Composting is a natural technique of recycling nutrients from biodegradable waste (food scrap, leaves, yard waste, paper, wood, feathers, crop residue, etc.) into valuable organic fertilizer. This process is biologically carried out under prescribed aerobic conditions (the presence of oxygen) with the help of different microorganisms, together with fungi and bacteria by decomposing an organic substance into simpler substances. The populations' activity and size of microbial coupled with temperature, oxygen, moisture, material disturbance and organic matter determine the effectiveness of the composting process (Rao, 1991; Nathanson, 2008).

Composting is reasonably straightforward to handle and can be executed on an extensive variety of scales in roughly any geographic location (inside or outside environment). Possessing the possibility to manage most FBW (as well as restaurant waste, leaves and yard wastes, farm waste, animal manure, animal carcasses, paper products, sewage sludge and wood) and without difficulty in integrating into whichever waste management strategy. Nowadays, the use of composting, turning FBW into a precious resource is increasing swiftly around the globe as landfill space is becoming scarce and expensive and since people are becoming further mindful of the repercussions of landfill on the environment (Nathanson, 2008). Composting plays a significant role in redirecting FBW from landfills, thus reducing the production of leaching and methane gas. Besides, an effective composting program (centralizing) can produce high quality soil improvement with a variety of end users. Good quality compost can be used in agriculture, horticulture, landscaping and home gardening.

Table 2-2 SWOT Assessments for Composting

Strengths	**Weaknesses**
❖ Salable by-products ❖ Reduces weight & volume of FBW ❖ Soil conditional & organic fertilizer ❖ Decreases pollutants & prevents erosion ❖ Cleans up contaminated soil	❖ Time consuming ❖ Requires land ❖ Costly equipment ❖ Only biodegradable waste ❖ Aesthetics odor & pest issues
Opportunity	**Threat**
❖ Results in a variety of environmental benefits ❖ Financial benefits ❖ Potential to reduce or eliminate the use of synthetic fertilizer	❖ Marketing required for sale of by-products ❖ Alternative fertilizers are cheaper ❖ Smell & odor issues ❖ Rodents & stray pest can become problems

2.4.4.3 Landfill

The oldest way to dispose of waste is the landfill, and it has two types: dumps and sanitary landfills. Both are extensively used all over the world. A dump is an open hole in the ground or a land disposal site where any waste can be disposed without environmental protection. Dumps are vulnerable to open burning and pose a direct threat to public health, various animals (mosquitoes, rats, mice, cockroaches and flies), vectors of disease, and scavengers (Rao, 1991; Nathanson, 2008). Open dumping is prohibited in many countries; nonetheless, most of the waste is still disposed of or buried on land.

A landfill, or as some will call it, sanitary landfill is a cautiously laid out structure constructed into or on top of the ground in which waste is secluded. The rationale for a landfill is toward concealing the waste covering with a layer of soil with the intention that it will be secluded to keep it dry and to reduce contact with air. This, in turn, eliminates potential public health problems, odor, insects, and rodents, and reduces waste decomposition under this situation (Chiras, 2006). Landfill is not the same as a compost pile, where the rationale is to conceal waste in such a way that it will break down swiftly. Numerous new landfills harness potentially harmful landfill gas emissions and change these gases into a renewable source of energy.

Regardless of the anxiety towards the landfill, it will still continue to be the practice of solid waste disposal worldwide at a considerable rate for many years, primarily for economic reasons and technical requirement (Nathanson, 2008). Moreover, it is impossible to recover, reuse and recycle all waste materials (the law of thermodynamics). As a result, we cannot count on any other waste processing methods (e.g. incineration) without having waste residue of which the ultimate disposal on land or underground will be required, and certainly, there is no guarantee that other disposal methods are totally safe.

Table 2-3 SWOT Assessments for Landfill

Strengths	**Weaknesses**
❖ Cheapest means of waste disposal ❖ Takes any kind of waste ❖ Landfill gases as a renewable source of energy ❖ Job creation ❖ Filled land can be used for other purposes	❖ Pollutes water, air and soil ❖ Requires land ❖ Requires proper planning, design, and operation ❖ Aesthetics, odor, rodents, insects & pest issues
Opportunity	**Threat**
❖ Locating them away from groundwater supplies ❖ Financial benefit ❖ Potential to monitor for at least 30 to 40 years to guarantee that no leachate or landfill gases flee into the surrounding neighborhood	❖ Lower social acceptability ❖ Encourages waste production ❖ Difficult to keep dangerous chemicals from leaching out into the surrounding land ❖ Rodents & stray pest can become problems

2.4.4.4 Anaerobic Digestion

The process by which organisms break down biodegradable matter, without the presence of oxygen, is known as anaerobic digestion (AD) (Kevin & Lewis, 1997). Even if this happens naturally inside a sanitary landfill, the expression on the whole depicts a synthetically accelerated procedure in a closed container, resulting in a relatively stable solid and liquid residue called digestate or soil conditioner. AD processes any biodegradable wastes, together with inappropriate wastes for composting such as meat and cooked food, cardboard and paper, leaves and grass clippings, food scraps and leftovers, industrial effluents, sewage and animal waste (Khalid et al., 2011).

AD generates biogas of about 60% methane (CH_4) and 40% carbon dioxide (CO_2). This can be burnt to generate heat or electricity or can be used as vehicle fuel. It can then power the AD process or be sold to the national grid and for heat for residence. In addition to biogas, AD generates digestate (a solid and liquid residue) that can be used as a soil conditioner to fertilize farmlands. The quantity of biogas and the quality of digestates acquired will depend on the feedstock used. Additional gas will be formed if the feedstock is putrescible (capable of decaying). Sewage and manure yield fewer biogases as the animals, which produced them, have previously used up several of the energy substances (Hessami et al., 1996; Khalid et al., 2011).

The AD process takes place in an airtight container, called a digester, and it begins with the separation of waste into biodegradable and non-biodegradable waste, probably at the source of generation. The biodegradable material is shredded, slurred and then screened and pasteurized. It is then pumped into the digester, where microorganisms decompose the material (Braber, 1995). The first stage of AD is a chemical reaction called hydrolysis, where complex organic molecules are broken down into simple sugars, amino acids, and fatty acids with the addition of hydroxyl groups. Followed by acidogenesis, a biological process of further decomposing of acidogenic bacteria into absolute molecules, where volatile fatty acids (VFAs) occur and produce ammonia, CO_2 and hydrogen sulfide as by-products. Acetogenesis is another biological process where bacteria known as acetogens produces CO_2, hydrogen and primarily acetic acid and further digest the simple molecules from acidogenesis. Methanogenesis is the last biological process where bacteria known as methanogens produce methane, CO_2 and water. The optimum temperature is between 35^{o} and 55°C, the optimum pH level is around 5-8 and the C: N ratio between 25:1 and 30:1(Appels et al., 2008).

There is no doubt that AD technology is capable of processing biodegradable waste other than compost; however, there are limitations to the process as there are with other disposal methods. AD systems are best designed for biodegradable waste reduction or methane production. If the aim and objective is methane production, then there is not much significance in quality of the feedstock. Nonetheless, for most applications, the aim is to achieve maximum breakdown and a quality product at the end of the process.

Table 2-4 SWOT Assessment for Anaerobic Digestion

Strengths	**Weaknesses**
❖ Environmentally friendly compared to other waste disposal methods ❖ Takes any kind of waste ❖ Produces bio gases as a renewable source of energy ❖ Job creation ❖ Lower land requirement, reduces odor & recycling benefits ❖ Produces soil conditioner (digestate)	❖ Risk of fire and explosion ❖ High capital and operational cost ❖ Waste water may need to be treated before disposal ❖ Does not treat the entire waste, just a fraction of it
Opportunity	**Threat**
❖ Possible to take care of the wet portion of MSW which is less agreeable to incineration ❖ Reduces CO2 emissions, by displacement of fossil fuels & financial benefits from (future) elevated energy prices and/or buy back tariffs ❖ Possible for co-disposal with other organic waste streams (e.g. industrial wastes such as food processing waste and agricultural wastes such as manure)	❖ Probable risk to human health due to presence of pathogens ❖ Encourages waste production ❖ Information on economic and practical issues is not widely disseminated ❖ Cost: this is a substantial barrier, as AD is (slightly) more expensive than composting in many cases ❖ Might be a nuisance to the neighborhood

2.5 Theoretical and Empirical Perspectives

This study uses Integrated Solid Waste Management (ISWM) and Sustainable Waste Management (SWM) as the theoretical and empirical standpoints to explore and develop a framework that will function as a tool for examining the issues related to food and biodegradable waste management in Japan and Oita city in particular. The relationship between theory and case study is taken as a focal point for examination, interaction and application that can help in gaining more light and new theoretical understanding of the subject matter (Charmaz, 2004). The resulting models from the empirical standpoints are employed to examine and illustrate the causal relationships observed within the MSW management system in Japan. Qualitative research that is based on theoretical and empirical framework allows the researcher to examine and determine the questions, assumptions, and soundness of the viewpoint of the theory in regard to the considerations made through the study (Charmaz 2004).

2.5.1 Integrated Waste Management

Integrated waste management is an approach that is capable of increasing energy and material recovery efficiency from the waste stream as well as sound MSW management practices that permit the cooperation of the informal, private and public sectors in a more suitable position. The theory of integrated waste management (IWM) has been implemented in most developed nations. According to the UNEP (2005, pg7), IWM is defined as "*a frame of reference for designing and implementing new waste management systems and for analyzing and optimizing existing systems*", particularly "*on the concept that all aspects of a waste management system (technical and non-technical) should be analyzed together, since they are in fact interrelated and developments in one area frequently affect practices or activities in another area"* (UNEP 2005, pg7).

The concept involves a more holistic attitude towards waste management matters and is also linked with managing different MSW management activities together towards achieving optimum system efficiency based on economic, environmental, political, and social-cultural as well as technological criteria. As highlighted by Kollikkathara et al. (2009) and Seadon (2006), when wastes are managed in isolation (single waste streams), the end result is repeatedly inadequate and unsatisfactory. The need for a more holistic standpoint to solving MSW issues has given more attention to the concept of integrated waste management.

The first task in IWM is to consider all aspects of the formal part of the waste system within one framework and to produce a plan based on the objectives of the entire system. On this ground, the framework for modern integrated solid waste management systems is the solid waste management hierarchy, which specifies the precedence that should be given to key waste management activities that affect waste generation, treatment, and disposal.

In the early 1970s the principles of waste hierarchy were introduced into the European policy (1975 Directive on Waste and EU's Second Environment Action Program in 1977) by the European Parliament Council and the European Commission (Papargyropoulou et al., 2014). The waste hierarchy approach has been employed as the key MSW management framework internationally (both national and regional policies). Most industrialized nations have employed numerous forms of waste hierarchy; such as the ‘3Rs’ framework (promoted by Japanese government in other Asian countries) offer a similar concept to waste hierarchy by prioritizing the choices of reducing, reusing and recycling of waste (Sakai et al., 2011). The goal of waste hierarchy is to prioritize MSW management practices and processes depending on their ecological benefits and to be as environmentally friendly as possible. However, the waste hierarchy employed by most countries is similar to that of the UNEP, (2005) illustrated in Figure 2-7, with the most desirable choice being ***Prevention***, and at the bottommost of the reversed pyramid, the least desirable choice being ***Disposal***.

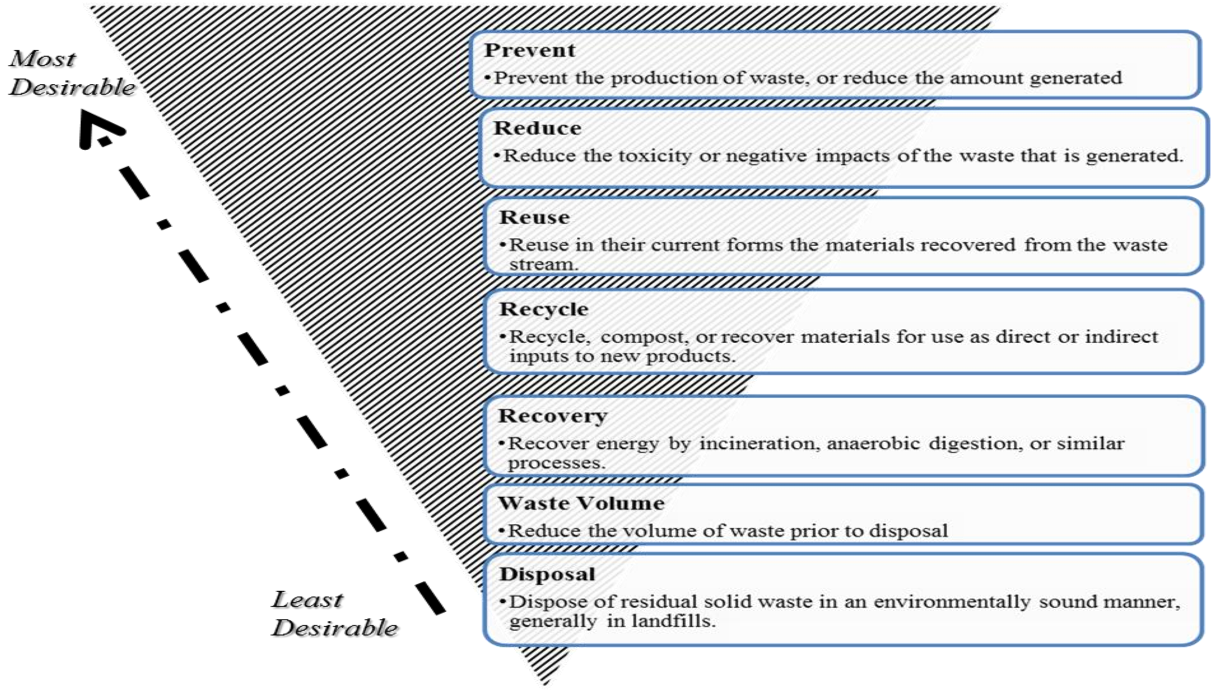

Figure 2-7 Municipal Solid Waste Management Hierarchy source: adopted from UNEP (2005).

2.5.2 Sustainable Waste Management

In the discourse of developing framework for waste management, much attention is paid to ecological impacts, economically feasible, socially acceptable and technically suitable (framework). As such Sustainable Waste Management (SWM) comes to mind. Sustainable waste management refers to the efficient use of substantial resources to reduce the amount of waste generated, and, in the cases where waste is unavoidable, it should be handled in a way that strongly contributes to meeting the goals of sustainable development in terms of environmental, economic, and social aspects (WASTE, 2001). The main objectives of SWM are to address problems of waste generation and material consumption through material recovery, recycling and reuse of resources, while at the same time minimizing waste. This involves the managing of resources in an economically effective, environmentally sound, and socially acceptable manner as well as the importance of stakeholders in the elements of WSM systems. Moreover, the foundation of the SWM approach is based on the waste management hierarchy. Four basic principles, as mentioned by WASTE (2001), are illustrated in the Figure 2-8 below.

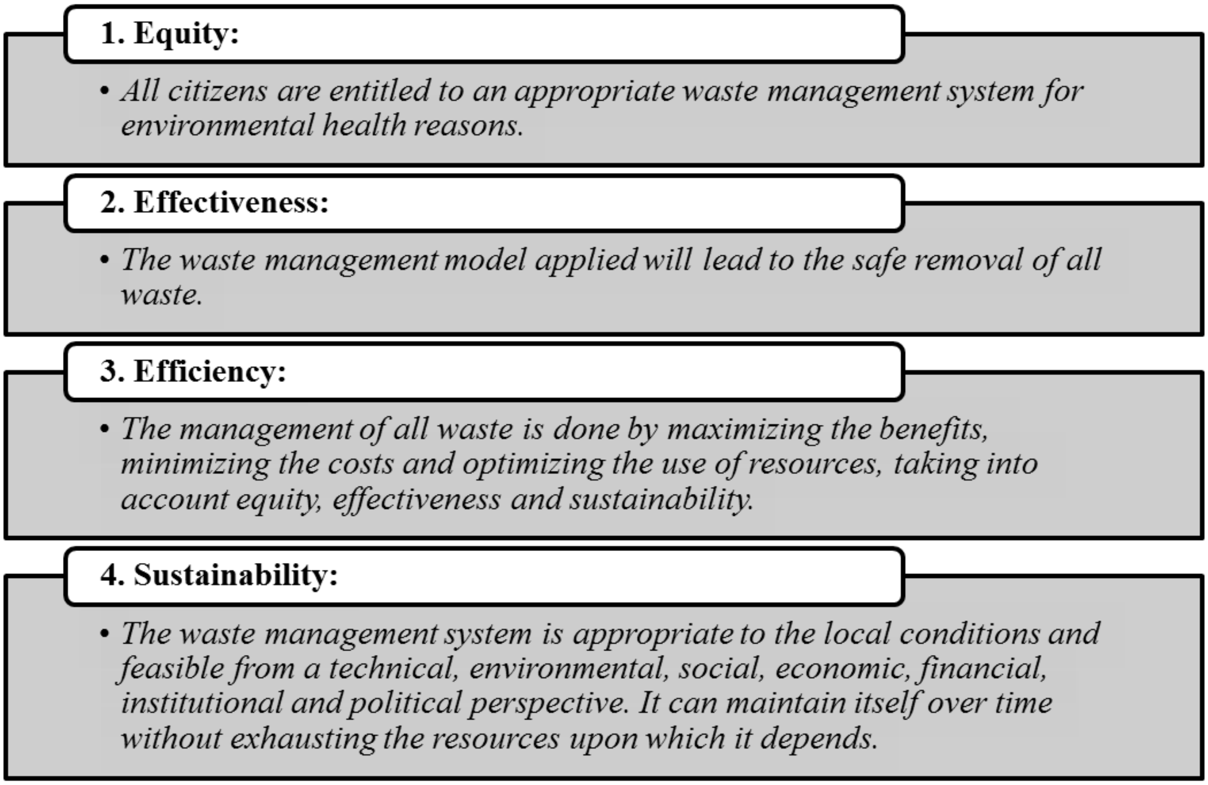

Figure 2-8 Basic Principle of sustainable Waste Management: adopted from WASTE (2001).

A similar approach to SWM promoted over the years by the Japanese government (the waste management law and recycling policy) is the Sound Material-Cycle Society (SMS). The definition of the SMS is based on the Fundamental Law to Establish a Sound Material-Cycle Society, meaning that *a society where the consumption of natural resources is minimized and the environmental load is reduced minimum, by restraining production wastes, promoting appropriate recycling of products, when they have become recyclable resources, and securing appropriate disposal of the unrecyclable resources, which means the disposal wastes as stated by the Waste Management Law* (Sakai et al., 2011;Yoshida et al., 2007).

Despite the extensive potential benefits connected to SWM approaches only a few countries are competent enough to carry out this practice. However, most of these practices in industrialized nations call for more incineration of waste rather than preventing waste, which is just a step above landfill in the waste hierarchy, given the fact that SMW practice is not an easy task to accomplish. On the other hand, the absence of SWM practices will lead to ecological damage, diminishing public health, and unavoidable GHG emissions, with social and cultural impacts eventually leading to economic loss.

2.6 Conceptual Framework

2.6.1 Conceptual Framework for Food and Biodegradable Waste Management in Japan

To facilitate understanding and highlight the problems associated with the present FBW management system, the System Think [6]approach (system dynamics) is employed, in view of the fact that the conventional food and biodegradable waste management approach considers waste generation, collection and disposal as independent operations, and yet, these components can influence each other since they are closely interlinked.

System Thinking presents us with a helpful means to understand the scale of complexity in food and biodegradable waste management problems better with special importance on the role of information feedback (Ford 2010). System dynamics, a tool based on system thinking, is proposed in order to analyze the relations among various variables while managing FBW, and in view of the fact that it is a deep-rooted method for studying and managing simple and complex feedback systems.

Morecroft (2007) and Sterman (2000) both highlight that system dynamics is about determining managerial structures in systems and making insights into the association of causalities. Moreover, it is an application within a framework that is founded on taking a part of the components in a system in order to understand the contest of feedback relationships within it and with other systems, instead of separately (Morecroft, 2007; Sterman, 2000). With respect to system dynamics, Causal Loop

[6] Systems Thinking has been defined as an approach to problem solving by viewing problems as parts of an overall system, rather than reacting to specific parts, outcomes or events and potentially contributing to further development of unintended consequences (Morecroft 2007; Sterman 2000).

Diagrams (CLDs) are applied to reveal the relationships of various systems. CLDs represent the information feedback in a system with *causal* meaning *cause-and-effect* relationship and *loop* meaning a closed chain of cause and effect that generates the feedback (Ford, 2010).

The approach mentioned above is applied to this conceptual framework to illustrate the relationship through causalities (cause and effects) linking various variables (criteria or factors) in the FBW management system as well as the extent of interconnectivity and their dynamic circular influence. In CLD terminology, a + or – sign on arrowheads are indicators showing positive or negative causal influence connecting two variables. However, the + sign symbolizes a cause-and-effect relationship where the variables change in the same direction while the – sign symbolizes a change in the opposite direction of two variables. For instance, a + sign linking population and food waste generation per capita illustrates that an increase in population will cause an increase in food waste generation per capita and vice versa. Also, the – sign linking illegal waste disposal and regulation enforcement illustrates that an increase of illegal waste disposal will cause a decrease in regulation enforcement.

2.6.2 The Existing System of Food and Biodegradable Waste Management in Japan

The existing food and biodegradable waste management model is an abstract and conceptual model adopted from MAFF (2007) and it variables are presented in Figure 2-9 with each arrow indicating an influence on one variable and on a different variable. The proposals are based on the food waste recycling law in Japan[7].

[7] "Food Waste Recycling Law"
"This law provides that: a) food businesses shall enhance source reduction and recycling of food waste, b) Food businesses that promote recycling and recycling facilities can be registered by ministry of agriculture". Minister of the Environment, Minister of Agriculture, Forestry and Fishery

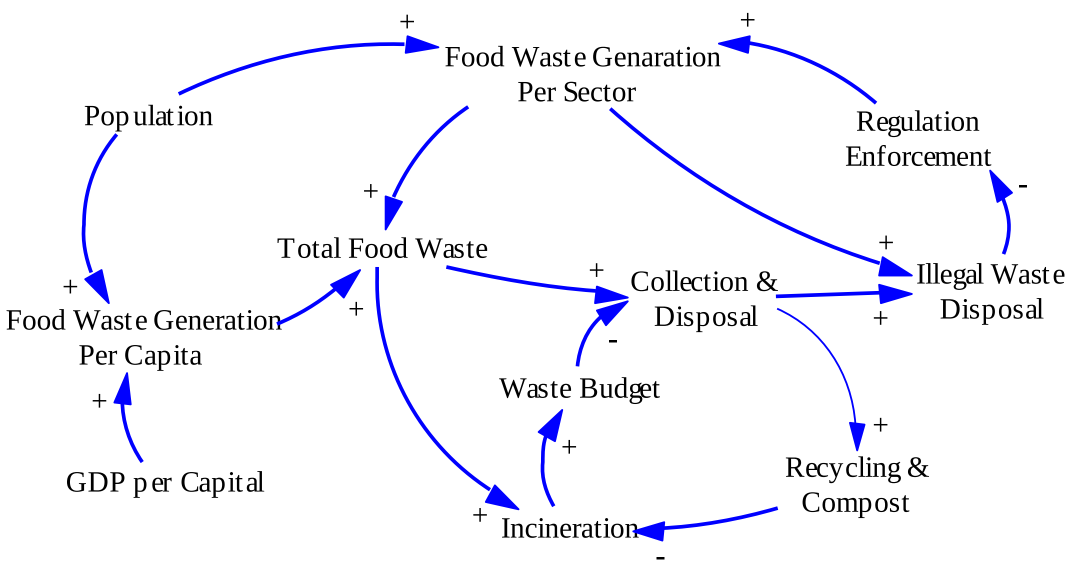

Figure 2-9 CLD of the Current Food and biodegradable Waste Management Model: adopted from MAFF (2007).

In Figure 2-9, the left loop shows that population has driven the per capita food waste generation through import of fresh fruit, affection for raw food and extremely high standard of living reflected by the GDP per capita. The amount of total food waste is the total food waste from other sector and those influenced by per capita consumption (mainly from households). The right loop deals with the influence of regulation enforcement on sectorial food waste generation with increasing regulation causing an increase in the amount of illegal food waste disposal. The lower loop shows that most of the food waste collected and disposed goes to incineration with a smaller amount going to recycling and composting.

Increased food wastes in incinerators have led to an increase in waste budget and, in turn, a decrease in the available amount allocated for collection and disposal consequently, the amount of illegal waste disposal has also increased. The fact that all the food wastes are sent to the incineration plant is inefficient, as more energy is required to burn them up. It is significant to mention at this point that the food waste management system creates no condition for revenue generation. The key basis of capital is from the municipal budgetary allocation, and it is necessary to institute food waste management and treatment systems to facilitate and optimize the efficiency rate of the incineration, to reduce emissions impact, and to create jobs and revenue that is capable of self-sustainability through by-products, and hence offsetting the enormous cost spent on incineration plants.

2.6.3 Introducing Anaerobic Digester as an Option to Food and Biodegradable Waste Treatment

Anaerobic Digester plants offer an efficient way to treat food and biodegradable waste volume, reduce the ecological impact and the amount of wet waste going into incineration plants, and to recover a significant amount of fertilizer and by-products for power generation.

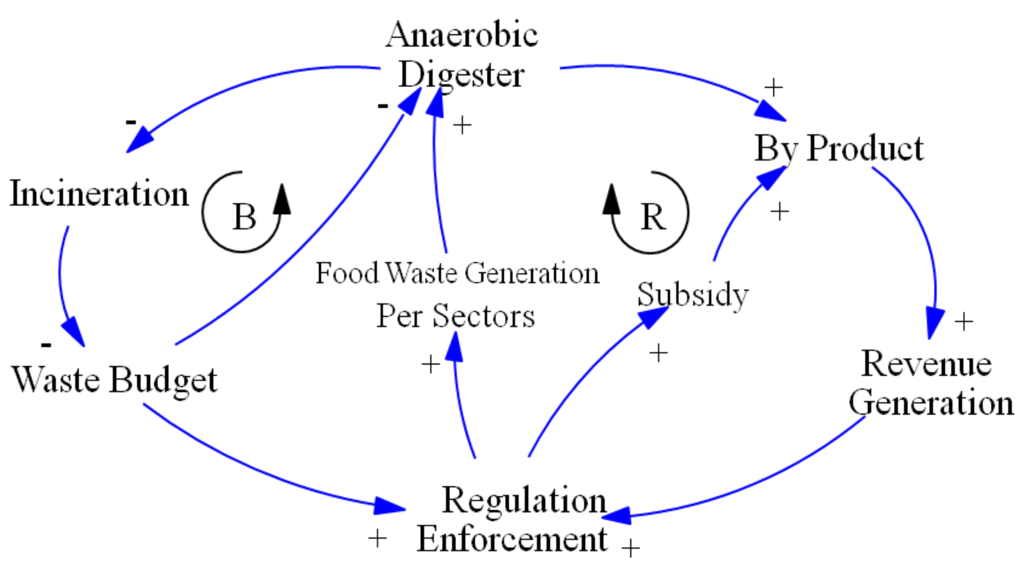

Figure 2-10 CLD for Suitability of Anaerobic Digester as a Treatment Option

The CLD in Figure 2-10 presents two sides. The right part shows a reinforcing loop (R) while the left part shows a balancing loop (B). In both cases, it shows how the use of anaerobic digestion as treatment for food and biodegradable waste can help to improve the entire waste system. In this hypothetical case, food and biodegradable waste from all sectors, including households, are sent to anaerobic digester plants where electric power, biogas, organic fertilizer and heat are produced that could be sold to generate revenue, which will be an added advantage for the regulation enforcement bodies. On the other hand, wet waste is taken out of the waste composition going into incinerator plants. This will increase the efficiency rate and reduce the waste budget amount allocated, making more funds available for accumulation and discarding so as to address the issues of illegal waste disposal.

2.6.4 Incorporating the Food and Biodegradable Waste Management Practice

The sustainability of an anaerobic digestion treatment system relies on the amount of waste from all sectors, most especially food-related businesses (either small or large), and the role played by the regulating enforcement bodies.

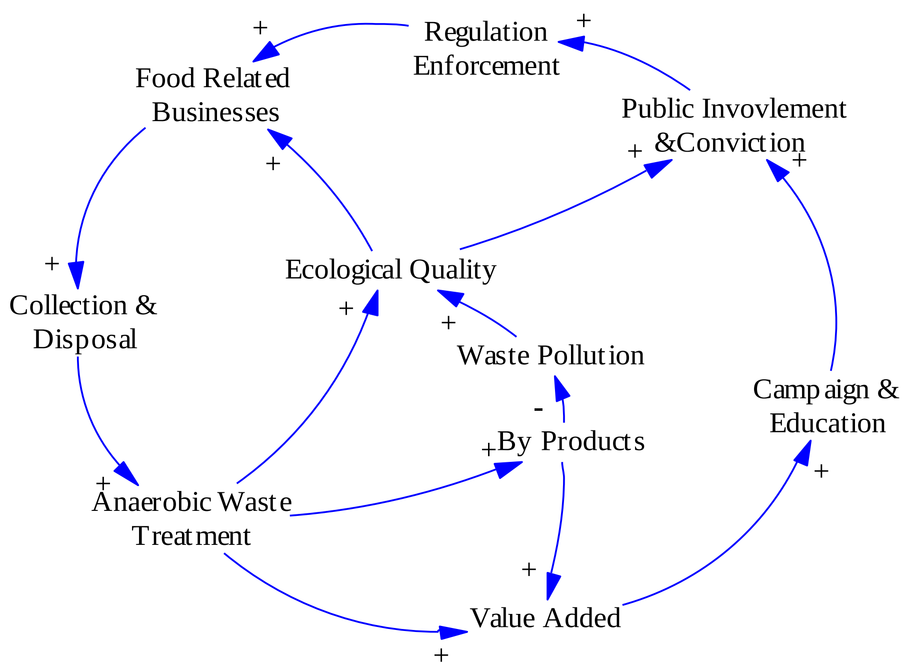

Figure 2-11 Incorporating the Waste Management Strategies

Regulation enforcement is vital for the fact that it is the connecting factor between public involvement and conviction and food-related industries as seen in Figure 2-11. Anaerobic waste treatment would yield by-products with less pollution to the environment and consequently have high value added (economic values). An additional level of incorporation is shown from the lower left, where campaign and education in food and biodegradable waste management plans is linked to public involvement and conviction, which brings about public conviction, acceptability, trustworthiness and siting of the treatment plant. In addition to the economic values of the by-products (biogas, heat, electricity and fertilizer), they are sources of revenue generation. This revenue then becomes a fraction of the funds for operation and maintenance, and also increases campaign and educational programs that will lead to ecological quality.

Support from Food-related businesses will increase the effectiveness of the collection and disposal measures, and at the same time improve ecological (environmental) quality due to anaerobic digester treatment of food and biodegradable waste. Also the proper collection and disposal (no more illegal disposal) measures that take place out of the incorporated system will be reinforced through public involvement and conviction of the capability of utilizing the anaerobic digestion system.

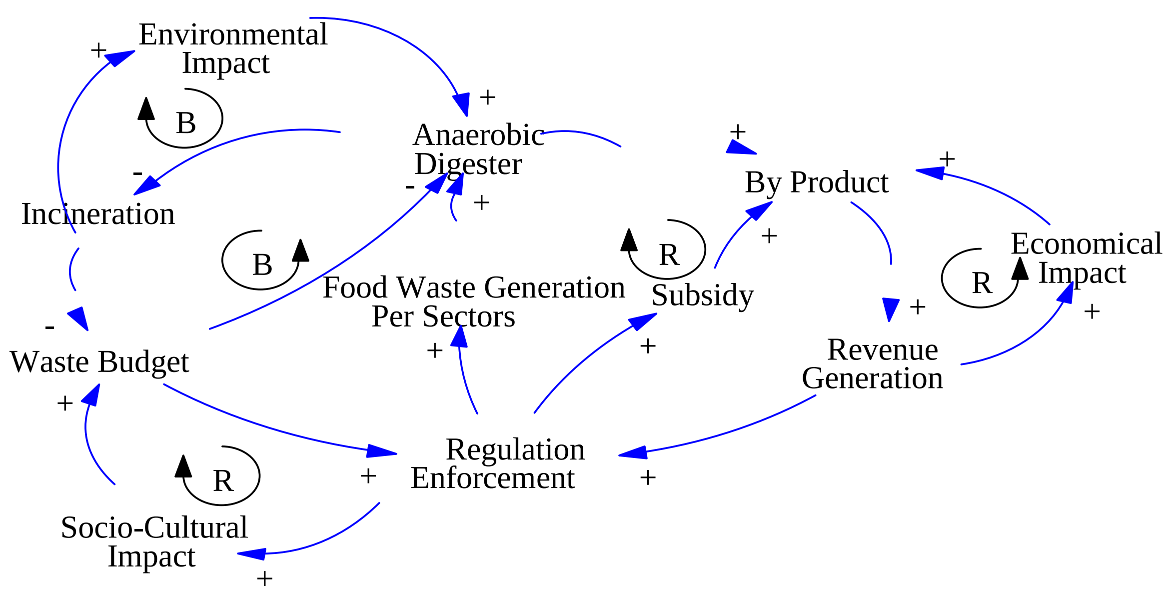

Figure 2-12 Sustainability of the Waste Treatment System

Be it a developed or developing country, there is an increasing awareness of a sustainable move toward FBW and incorporating strategies that will produce practical results in the long-term. Changing over to a sustainable FBW management system entails classification and application of regulation enforcement. The sustainable waste management system pays attention to the process and incorporates feedback loops, represents flexibility and redirects wastes from disposal to resources (Seadon, 2010). However, it is a responsibility that requires incorporation of environmental information, socio-cultural ideas based on local knowledge, technical skills and economic viability in order to comprehend the benefits of a well-organized food and biodegradable waste management system.

Figure 2-12 deals with the involvement of all three pillars of sustainability: the socio-cultural impact, the economic impact and the environmental impact in terms of ecology, trustworthiness and revenue generation respectively; otherwise, the system fails. The system's sustainability also depends largely on the amount of trade-off among these aspects

CHAPTER THREE:
RESEARCH METHODOLOGY

3.1 Introduction

There are different ways in which research is conducted in terms of philosophical assumptions, research designs, and methods. This chapter discusses the research design and methods underpinning this study in order to gain a better understanding of how and why they are applied. The initial discussion is based on the research design and how it best fits the focus of the study. Furthermore, this chapter discusses the methodologies, which include mix methods, action and case study research, and data collection and analysis procedures.

3.2 Research Methodology

The research method refers to an approach of inquiry that requires a set of strengths (research design and data collection) that can be used to achieve a range of research goals (Morgan, 2014). Creswell (2014) also defines research methodology as plans and procedures for research, which extend the stages from comprehensive assumptions to detailed methods of data collection, analysis, and interpretation. Research methods can be seen from two different aspects that is, the approach used to collect and analyze data (e.g. qualitative, quantitative and mixed methods), and the result and information gained from the data (research procedure/design), while the second aspect deals with the fundamental purpose of the research and the nature of knowledge obtained.

A qualitative research method focuses on a set of research goals that are typically inductive, subjective, and contextual i.e. providing detailed description illustrating the different perspectives of the researcher and research subjects. On the other hand, quantitative research methods emphasize deductive, objective, and general approaches, i.e. carrying out statistical testing to arrive at generalizations (Morgan, 2014; Petty et al., 2012).

The complex nature of research in municipal solid waste (MSW) management studies makes it complicated for a single paradigm/method to fulfill all the methodological requirements. Consequently, it is appropriate and necessary to combine the positivist paradigm (quantitative) with the interpretive paradigm (qualitative). The blending of the two paradigms from the pragmatist standpoint, offers the ability to combine the different strengths of qualitative and quantitative methods, provided that there is a clear link between the methods and the research questions (see chapter one) under study. Mixed research methods stand between qualitative and quantitative research methods because they combine elements from both research methods. A mixed method is an approach for implementing research that comprises of collecting, analyzing, and combining qualitative and quantitative study and data in a single study of inquiry (Creswell and Plano Clark, 2011; Creswell, 2014). Thus, the use of both the qualitative and quantitative methods is essential to comprehend the different characteristics of food and biodegradable waste management in the MSW management stream.

The motivation for using mixed method approach is due to various reasons. Mixed methods provide strengths that balance the weaknesses of both qualitative and quantitative research, thus offering a view of the issue of FBW management from the researcher's and the stakeholders' perspectives (Creswell and Plane Clark, 2011). Bryman and Bell (2011) argue that combining both qualitative and quantitative research provides a better understanding of the research problem and question. Creswell and Plano Clark (2011) also agree to this by saying that mixed methods research provides more evidence for studying a research problem as well as helping in answering questions that cannot be satisfied by qualitative or quantitative approaches alone. The logic of triangulation is another reason for using the mixed method (Bryman & Bell, 2011), since it permits the use of qualitative research to validate and complement quantitative research results or findings.

Therefore, since no single method could entirely capture all the significant features and aspects of this study, therefore a mixed method approach was used. Moreover, the mixed method employed in carrying out this study (collecting and analysis data) offers a valuable opportunity and insight in acquiring comprehensive information (data) from the different sectors of MSW management in Oita city.

3.2.1 Research Design

A research design can be seen as a master plan or road map of a research inquiry that shows and tells how the study in question is carried out. Thus, it is a framework for creating and actualizing evidence in a set of procedures that is appropriate both to a certain set of criteria and to the research question in a given research problem (Bryman and Bell, 2011). In other words, it is the research procedure created as a blueprint to inquire or find answers to research questions by analyzing, collecting, interpreting and reporting data in a given study. The research design consists of different frameworks for the research process in which these frameworks are kinds of inquiry within qualitative, quantitative, and mixed methods approaches that offer detailed direction for procedure in a research strategy (Creswell and Plano Clark, 2011; Creswell, 2014).

The research design of this study is based on a descriptive (explanatory) and investigative analysis type of research, which relies on the mixed method approach in data analysis, collection and interpretation of data, with the intention that desired information can be obtained with sufficient accuracy (Mitchell & Jolley, 2010).

In order to choose the design for this study, a comprehensive analysis of related literature and legal documents, research philosophical stand and methods were conducted, so as to understand the existing facts within this study. Given the fact that the research aims at analyzing the FBWM in Oita city, literature on food waste management and practices were reviewed to gain a broad awareness on what is already known and unknown, to identify gaps, and the way forward. Views from waste management staffs and documents from the Ministry of Environment of Japan (MOE), the Ministry of Agriculture and Forestry and Fishery of Japan (MAFF), were useful in gaining an understanding of the issues that are considered necessary to investigate. This provided the basis for choosing an action and case study research design to guide in the research procedure (the chosen methodology that formed a structure for the study), scope, and analytical techniques. Furthermore, sets of research questions were created to guide the research process. Practical issues considered in the research design included the research objectives, the resources and time frame of the research, and types of data available.

3.2.2 Action Research Design

Action research design is a type of an applied research that follows a distinctive spiral pattern starting with planning, acting, scrutinizing, and evaluating based on the understanding of a given problem in order to provide practical solution and theoretical knowledge. Action research was introduced in the 1940s by Kurt Lewin, who defined action research as the action taken in a spiral of steps to plan, act, observe, and evaluate the results of an action (McKernan, 1996; McTaggart, 1997; Parkin, 2009). Although, there are other definitions of action research, McTaggart (1997) goes on to describe action research as a way wherein a group of people can arrange a situation through which they can learn from their personal experience and make this experience accessible to others. McKernan (1996) views action research as an attempt to make the problematic social world understandable and to improve the quality of life in social setting, by solving the immediate and pressing day to day problems of practitioners. Also, Elliot (1981) in McKernan (1996) looks at action research as the study of social situations through improving the quality of action within it. Parkin (2009) sees action research as a means to bring about change in a specific condition, local systems along with real world environment, with the purpose to find solution to real life problems. In addition to these descriptions, Burns (1999) identifies action research as a research that is centered on real and practical concerns or problems of immediate concern to a particular social group or community. These definitions stress action research's philosophy of involvement, evaluation, and improvement in human profession and practical base areas, for example social satiations (local and community level) in education, leadership, management, occupational therapy, sport and public health care (McKernan, 1996; McTaggart, 1997; Parkin, 2009). In considering the benefits of implementing action research, Parkin (2009) note that it accomplishes changes by planning, involving, and working with people through providing adequate information to enable them to take responsibility for making changes to their situations.

Action research assumes a result-oriented and pragmatic standpoint over testing of theories. McKernan (1996), for example, argues that the main purpose of action research is to provide solution for the practical judgment of actors in problematic situations. Thus, he explained that the validity of these solutions generated have no scientific proof of truth as in their usefulness in helping practitioners to act more effectively, skillfully, and intelligently. Parkin (2009) also point out that as new knowledge is expanded or generated during the process of solving these specific problems, theories are also developed. As observed by Sandars and Waterman (2005) in Parkin (2009), the theory generated characterizes action research as a research design and significantly differentiates it from other change management approach (Pg 21).

Another argument in favor of implementing action research is that it has the possibility to increase the learning and understanding of practitioners and researchers alike of events, situations, and problems in order to increase the effectiveness of their practice (McKernan, 1996). As such, the spiral of steps in action research makes the procedure a learning cycle of improving practice and advocating for change. This distinctive feature gives those affected by the intended changes the major of responsibility for making a decision on courses of action that will possibly lead to improvement and for evaluating the result of strategies tried out in practice (McTaggart, 1997).

The use of action research in this study is fitting because of its focus on immediate concerns and practical nature. It holds particular appeal for gaining more understanding and exploring unexplored situations concerning the food and biodegradable waste management system in Oita city, consequently leading the study to develop solutions and theories that are suitable for use in the MSW management system.

3.2.3 Case Study Research Design

Case study research is created out of the desire to understand complex human and social phenomena in order to explain relationships, which exist in reality (Petty et al., 2012b; Yin, 2003). Yin (2003) identifies case study research design as an approach of exploring an empirical topic by following a set of specified procedures that is used in various situations to increase our knowledge of individual, group, and organizational, social, political, and related phenomena. Thus, Petty et al., (2012b) describe cast study research as the singular science that attempts to understand “what is unique of a case defined as ‘specific, a complex functioning thing’ whether it is a person, a clinic, a classroom, an institution, a program, a policy, a process, or a system”. Gerring (2007) went on to say that case study research is the thorough study of a single case where the aim of study is to clarify or illustrate a larger class of cases.

Considering how case study research should be conducted, Yin (2003) notes that it involves the application of methods from social sciences to practical problems with the intention to contribute to knowledge and theory in a given case. Thus, he concluded that each method has its distinctive strengths and weaknesses that is subject to three conditions: a) the type of research question, b) the control a researcher has over actual behavioral events and c) the emphasis on modern as opposed to historical phenomena. According to Petty et al. (2012b) case study research design has no specific data analytical approach and the choice of method(s) to be used depends on the research question and the focus of the case under study.

The benefit of using case study research design in a research such as FBW management is that multiple criteria and variables can be examined as well as the holistic description of the complicated nature of MSW management system. A case can be a single/one type of waste treatment technology, or several waste treatment facilities in a city, region, or country. In order to understand a case, a variety of data can be collected in most situations which includes document analysis, observation, and interview (Gerring , 2007; Petty et al., 2012b) For the purposes of this study, the researcher indulged in evaluation, descriptive, exploratory, and explanatory types of case study research through data collection using different sources of information and analytical methods.

3.3 Method of Data Collection

Collecting data from several sources makes the case study methodology a triangulated research strategy (Yin, 2003). Yin (2012) categorizes the following sources of evidence for data collection: documentation, archival records, interviews, direct observations, participant observation and physical artifacts. Both quantitative and qualitative data were gathered for this study using field observation and documentary analysis. The document used for this study include waste management policy documents of the Japanese government (Waste Management and Public Cleansing Law (WMPL)), documents that govern all Solid Waste Management issues including food waste management, legal documents for promotion of recycling and related activities for the treatment of waste, and municipal reports on waste management from Oita city (see chapter two). Consequently, the implementations of the strategies recommended by the majority of these policy documents are in place, but the impacts of these policies are another source for concern.

According to Yin (2012), observations are facts that do not rely on verbal activities, and this method facilitates the researcher to observe the situation under study directly. Direct observations were carried out, and they took place during field visits to waste treatment facilities, and recycling centers in Oita city. This approach was essential to confirm the facts and findings, as a single observation may contain several dimensions, each of which may be measured as variable (Gerring 2007). Particularly, to cross check information and facts documented, given that sometimes, what is observed might be different from what is documented. Also, the documents served as guidelines during the field observation. There was also a variety of published information and other online publications that yielded valuable data for the study. Thus, this study used field observation and documentary analysis to collect the data needed and the strengths of these two methods were used to enhance the reliability and strength of the data.

3.3.1 Data Analysis

For the stated aims and objectives to be achieved, the data analysis combined the key strength of System Dynamics and Multi-Criteria Decision Analyses, which facilitates an analysis and discussion of various useful FBW management solutions. Thus, both forms of analysis have the capability to encompass information collected, decision-making, planning, and to achieve monitoring and management of data.

3.3.1.1 Multi-Criteria Decision Analysis

Multi-Criteria Decision Analysis (MCDA) was embarked on to create a descriptive representation of the data gathered for the selection of the most suitable waste treatment/disposal facility and the best place to locate this facility. This technique is used in three stages (three chapters), in conjunction with environmental, socio-cultural, technical, and economic criteria leading to multi-criteria decision making as a tool. The first stage (Chapter Four) sets up the framework for the selection of a waste disposal facility using the Analytic Hierarchy Process (AHP) technique. The second stage (Chapter Five) is waste treatment technology assessment using cost benefit analysis also using the same AHP technique. The third stage (Chapter Six) analysis makes use of the thematic maps in GIS (a method of integrating GIS with MCDA); the approach follows three sequential steps rather than a fully integrated format, and the GIS technique is applied in site selection for the chosen waste treatment facility. An elaborate application and explanation is given in the corresponding chapters. The use of the MCDA approach helped to organize the entire case study as well as define alternatives and explanations where necessary. Consequently, data obtained was categorized based on their orientation and application on the three stages of analysis.

3.3.1.2 Systems Dynamics

The Systems Dynamics (SD) approach can be seen as a framework for illustrating and simulating the interaction of different elements in a system, and to capture the dynamic behavior of the system over time. SD uses constructed models that shows cause-and-effect loop and they illustrates the development of problems over time as well as the consequences of the proposed solutions. This is performed through incorporation of stock or reservoir (denoted by a rectangle), flows (denoted by tap, straight or curved lines), feedback and delays. Thus, SD emphasizes the dynamic behavior resulting from the delays and feedbacks of a system, leading to decision-making and information feedback principles. More detailed application, explanation, and illustration of SD are given in chapter seven.

CHAPTER FOUR:
A MULTI-CRITERIA DECISION ANALYSIS METHODOLOGY FOR FOOD AND BIODEGRADABLE WASTE MANAGEMENT OPTIONS IN JAPAN

4.1 Abstract

Dealing with large-scale Food and Biodegradable Waste (FBW) often results in many logistical problems and environmental impacts to be considered. These can become great hindrances when the integration of solid waste management is concerned. Extra care is needed, to plan such waste disposal or treatment services and facilities, especially in respect of ecological impact and issues. Decision making with regards to the sustainable use of these facilities also involves tradeoffs between criteria and a number of conflicting objectives, since increasing one benefit may decrease the others. In this study a Multi-Criteria Decision Analysis (MCDA) is presented to evaluate different waste management options and its applicability in Japan. The analytical process aims at selecting the most suitable waste treatment option, using pairwise comparisons conducted within a decision hierarchy that was developed through the Analytical Hierarchy Process (AHP). The results of this study show that anaerobic digestion should be chosen as the best FBW treatment option with regard to resource generation. The study also presents some conditions and recommendations that can enhance the suitability of other options like incineration and composting.

Keywords: Multi-Criteria Decision Analysis, Analytical Hierarchy Process, Food and Biodegradable Waste, Waste Treatment and Decision Making, Sustainability.

CHAPTER FIVE:
A BENEFIT– COST APPROACH BASED MULTI CRITERIA DECISION ANALYSIS OF FOOD AND BIODEGRADABLE WASTE TREATMENT ALTERNATIVES IN OITA CITY, JAPAN

5.1 Abstract

Although Oita city, Japan implements a Zero Waste Strategy as part of compliance to The Waste Management Law in japan, a large fraction of Food and Biodegradable Waste (FBW) ends up in the incinerator. The main aim of this chapter (study) is to investigate the technical feasibility of the continuous treatment of FBW using different waste treatment options in Oita city using a Benefit-Cost Analysis based on Multi-Criteria Decision Analysis (MCDA). In this regard, benefit-cost analysis based on Analytic Hierarchy Process (AHP), a Multi Criteria Decision Analysis (MCDA) approach, is used to select the most suitable FBW treatment technology. This study compares four FBW treatment alternatives recommended by the Food Waste Recycling Law such as, anaerobic digestion, compost, and landfill including the current practice in Oita City, which is incineration. The fundamental AHP is separated in two-hierarchy structures for benefit analysis and cost analysis. The criteria used in this two analysis are value added, safety, efficiency and social benefits for benefit analysis and cost of energy, cost of operation & maintenance, environmental constraints and disamenity for cost analysis. This study is based on the theoretical improvement and application of an incorporated FBW management system to facilitate the ability to compromise cultural, economic, environmental, political, social and technological concerns in a sustainable waste management system. The focal point is based on the present practices of FBW management system, the possibility of enhancing this current system through benefit-cost analysis (technology assessment) of waste treatment practices. The result of this study shows that anaerobic digestion has the highest overall benefit while composting has the least overall cost. The benefit-cost ratio result shows that, the most suitable treatment alternative will be anaerobic digestion follows by composting and incineration with landfill been the least favored. Sensitivity analysis shows no different result across four different scenarios. On the whole, three of the four alternatives are better than landfill, and the study recommend that composting could be combined with anaerobic digestion as an optimal FBW management option in Oita City.

Keywords**:** Anaerobic Digestion, Analytic Hierarchy Process, Benefit and Cost Analysis, Criteria, Food and Biodegradable Waste, Multi-Criteria Decision Analysis, Waste Treatment Technology

CHAPTER SIX:
APPLICATION OF GIS-BASED MULTI-CRITERIA DECISION METHODOLOGY FOR EXPLORATION OF SUITABLE SITE OPTIONS FOR ANAEROBIC DIGESTION OF FOOD AND BIODEGRADABLE WASTES IN OITA CITY, JAPAN

6.1 Abstract

In recent years, anaerobic digestion (AD) popularity has been on the increase as the main common technique for treating food and biodegradable wastes. The development of food and biodegradable waste management (FBWM) system using anaerobic digestion as a waste treatment plant involves a complete evaluation of the geographical area of Oita City with the view of nominating the most suitable site(s) that can at the same time meet regulation fulfillments and reduce environmental, socio-cultural, technical, public health, and economical costs. A Geographic Information System-Based Multi Criteria Decision Analysis (GIS-MCDA) is presented in the study to assess land suitability (siting of anaerobic digestion plant) and its applicability to Oita City in Japan. It combines Weighted Linear Combination (WLC) to obtain the best land suitability map using constraints and factors maps, with Analytical Hierarchy Process (AHP) technique to estimate the relative importance of factor weights. Through Cluster Analysis (CA), three suitable site options were produced and AHP ranking method was used to obtain the third suitable option as the best ideal local/site for anaerobic digestion as a waste disposal method. We conclude that an area of about 13.36km^2 from the entire case study area was the most suitable. The remaining two options are still suitable to be used for the intended purpose, but the whole decision will have to be trusted to the decision makers' judgment.

Keywords: GIS, Multi Criteria Decision Analysis, Anaerobic Digestion, Food and Biodegradable Waste

CHAPTER SEVEN:
A SYSTEM DYNAMICS BASED APPROACH TO HELP UNDERSTAND THE ROLE OF FOOD AND BIODEGRADABLE WASTE MANAGEMENT IN RESPECT OF MUNICIPAL WASTE MANAGEMENT SYSTEM

7.1 Abstract

The long term plan of any city in Japan is to become a material recycle society. Utilization of all types of municipal waste is essential toward maximize the full potential of material recovery from municipal waste in order to attain this goal. As such, municipalities are responsible for handling their waste management including food and biodegradable waste (FBW) and this has result in some complex schemes. In Oita city, incineration remains the main methods of treating large amount of FBW. In spite of increasing importance of research on integrated municipal solid waste management system and the adaptation of material recovery from related waste treatment facilities, there has been little research on the comprehensive assessment of the contribution of food and biodegradable waste management (FBWM). Thus, this study uses system dynamic approach to illustrate and investigate the benefit of separate treatment of FBW in the municipal solid waste (MSW) management system as well as to understand the dynamic interactions between all aspects and elements of the current MSW management system. The developed model includes total environmental benefit, motivation to manage waste and revenue from resources yield from treatment facilities in the waste management loop combined to form the total waste management budget. The result demonstrates that regulation strengthening on sorted waste and the reduction in the amount of FBW treated in incineration will improve the current MSW management system. It also indicate that the use of AD plant as a treatment for FBW would increase the efficiency of incineration and after the first five years the project will generate profits. It further conclude that any policy regulation less than the proposed result will yield less benefit to the MSW management system; thus making regulation strengthening a crucial part in the suitability of FBW management in the long run.

Keywords: Food and Biodegradable Waste, System Dynamics, Waste Management, Regulation Strengthening, Anaerobic digestion, Incineration

CHAPTER EIGHT:
CONCLUDING REMARK

8.1 Overview of the Study

The amount of FBW generated in the MSW management system is in need of urgent attention due to treatment issues and environmental concerns in Oita City. Most municipalities and local authorities in Japan are also confronted with these same challenges. FBW are generated because of Japan's preference for raw and fresh foods, fresh fruits, high living standard and improving quality of life. The influence and contribution of waste management policies and regulation are also causes for concern. There is a growing awareness on how to handle and reduce this FBW both at household and at food related industries. Some of the ideas raised to tackle these issues include material recovery through incineration. Encouraging reduction, reuse and recycling of FBW cannot be sustainable and successful because the existing facilities and practices are not designed to manage FBW separately.

Comprehensive FBW management plans require consideration of varied factors and issues. Decision making with regards to the sustainable treatment of FBW involves tradeoffs between criteria and a number of conflicting objectives. Favoring one may result to diminished importance of the others. Integrating environmental, socio-cultural, political, technical, and economic dimensions in the FBW management framework can reduce conflicts among stakeholders and promote optimization.

This study investigated the MSW situation in Oita City, with the objective of enhancing the appreciation of the benefits of separate treatment of food and biodegradable wastes. The study also tries to answer the following questions; (a) "How can food and biodegradable waste management (FBWM) system be further expanded and optimized with regard to environmental integrity, economic viability and social acceptability?" and (b) "What are the benefits of a separate FBWM as a component of the entire waste management system?" The specific objectives are:

a. To identify ways to improve the food and biodegradable waste management system
b. To investigate the technical feasibility of the continuous treatment of FBW using different waste treatment options.
c. To analyze various factors influencing the current FBWM practices.
d. To explore various policy scenarios for improving FBW Management

Extensive review of both primary and secondary data and in-depth review of literature, legal documents, and materials from the City office were undertaken to gain a more holistic view of the current waste problems, practices and proposed solutions.

System Dynamic and Multi Criteria Decision Approaches are employed to analyze the existing data and knowledge on FBW highlighting existing limitations and developments towards developing practical suggestions.

8.2 Summary of Findings and Conclusion

8.2.1 Ways to Improve the Food and Biodegradable Waste Management System

Multi-Criteria Decision Analysis (MCDA) was used to select the most suitable waste treatment option among four recommended waste treatment facilities (Anaerobic Digestion, Incineration, Compost and Landfill). The Analytical Hierarchy Process (AHP) using pairwise comparison showed that anaerobic digestion of FBW is the most suitable choice, based on the criteria in the sensitivity analysis. It is the first choice over incineration and composting, considering the recirculation of nutrients and weight volume reduction. This indicates that it is the best solution for the treatment of FBW. Since all resources from FBW can be fully recovered, anaerobic digestion and central composting with nutrients recovery are the possible combinations to be explored.

8.2.2 The Technical Feasibility of the continues Treatment of FBW

Benefit-cost analysis based on Analytic Hierarchy Process (AHP), a Multi-Criteria Decision Analysis (MCDA) approach is used in this analysis. For benefit analysis, the criteria used are value added, safety, efficiency and social benefits. Cost of energy, cost of operation & maintenance, environmental constraints and dis-amenity are used for the cost analysis. Anaerobic digestion has the highest overall benefit while composting has the least cost overall. The benefit-cost ratio result shows that, the most suitable treatment alternative is anaerobic digestion followed by composting and incineration with landfill as being the least favored ones. Sensitivity analysis shows no different result across four different scenarios. In general, three of all four alternatives are better than landfill. The study recommends that composting could be combined with anaerobic digestion to get the optimal FBW management option in Oita City.

Furthermore, the Geographic Information System-Based Multi Criteria Decision Analysis (GIS-MCDA) is used to assess land suitability (siting of anaerobic digestion plant) and its applicability to Oita city. Three constraints and seven factors maps were combined using Weighted Linear Combination (WLC) with AHP approach to produce the final result of three suitable sites. Through Cluster Analysis (CA), three suitable site options (Suitable, Moderately Suitable and Highly Suitable) were identified. The Highly suitable site has the following attributes: proximity to water bodies, forester areas, residential areas, tourism and cultural centers, roads, slope gradients and power lines. The result shows that an area of about 13.36 km2 from the entire case study area was the most suitable. The results provide guides or tips to assist the decision-makers in deciding the most suitable location for the FBW treatment facilities.

8.2.3 Factors Influencing the Current FBWM Practices

Causal loop diagram explains the dynamic interactions between all aspects and elements of the current MSW management system in Oita city. These dynamic interactions depict the importance of understanding FBW as an integral part of the MSW management system. These factors include: waste generation, sorted waste, cost of incineration, regulation, motivation to manage waste, environmental cost savings, treatment facilities, waste management budget, fund for waste management, and yield resources from waste.

The study shows that generated waste is currently sorted at source. The sorted waste is collected from the collection centers and sent to AD treatment and incineration plants for treatment. The rate of waste sorting is largely dependent on existing regulations.

Treatment of FBW in AD plant will certainly yield benefits from both AD and incineration plants. This will in turn increase the waste management budget. Motivation to manage waste is influenced through stronger enforcement of regulation. Environmental cost savings is the cost saved by not sending FBW to landfill and dumping it illegally. This could be seen as a benefit of proper sorting of waste at source. Waste management budget is the overall financial benefit gained throughout the MSW stream, which is influenced by revenue generated from resource recovered from both AD treatment and incineration plant. Illegal waste disposal is reduced when material recovery is included as part of the MSW stream. In turn, regulation and waste management policies are strengthened. The increase in illegal waste disposal will lead to the weakening and the demotivation to manage waste as a whole. As such, regulation plays a very significant role in the entire MSW system. The cost of incineration plays a significant role in the sustainability of the FBW treatment in the long run, because the cheaper the unit cost of incineration, the less chance for FBW to be treated in a separate waste treatment plant (i.e. AD plant).

8.2.4 Policy Scenarios for Improved FBW Management

The SD model is used to simulate policy measures under different policy scenarios. Maintaining the present practice or the status quo as a policy option involves higher costs as bigger volume of FBW is treated in incineration. Hopefully, the higher unit cost of waste incineration can encourage the municipal government to seek for other means of sustainable waste treatment. The second policy scenario with regulation means that the reinforcement of stronger regulation would apparently increase both the total waste management budget and environmental benefits. This signifies that strengthening regulation is a crucial part in effective FBW management. The third policy scenario involving separate treatment of FBW coupled with anaerobic treatment and regulation will make incineration cheaper and more efficient leading to a healthier environment and social acceptability.

8.3 Suggestions and Recommendation

A more detailed and comprehensive investigation is needed in order to recommend more specific recommendations and plans due to the complexities of FBW management. Integration of FBW as a separate form of municipal solid waste is desired in order to tackle MSW challenges. In this regard, the proposed framework in this study is applied to the case of Oita city. The findings of this study can be applied to any city in Japan as this is based on the Waste Management Law in Japan. The benefit of this study can be seen from the perspectives of assessment methods for waste treatment planning and decision making, and a platform for testing and validating various policy measures and management strategies.

Using these frameworks on different case studies allows for comparison and the information collected during the process can serve as valid basis and as valuable contributions to the improvement of the MSW management system. This way, decision makers will have the right information to base their judgments, and in turn prevent risk, save time and money. Furthermore, these frameworks can be modified and expanded by adding new policy instruments, criteria, variables, and elements.

The increasing FBW generation may be influenced by waste management policies and regulations. Feedback of such policies and regulations could be included in the long term waste management planning program .Since waste treatment facilities can be highly related to the type of waste included in the waste system, an evaluation of the entire waste management system is in order. These policies and regulations should provide support and promote the market demand and supply of byproducts from waste treatment facility in order to encourage material recovery. Moreover, public-private partnership investments through different arrangements may perhaps be considered to offer another source of revenue for waste management facilities and consequently facilitate and ease the burden of the municipal government. Ultimately, success and efficiency of any waste management program depends on the involvement of the community. In addition, the community's involvement in the entire process, their education, awareness and advocacy are crucial too.

REFERENCES

Abba, A.H., Noor, Z.Z., Yusuf, R.O., Din, M.F.M.D., Hassan, M.A.A., 2013. Assessing environmental impacts of municipal solid waste of Johor by analytical hierarchy process. Resources, Conservation and Recycling 73, 188–196.

Al-Harbi, K.M.A.-S., 2001. Application of the AHP in project management. International Journal of Project Management 19, 19–27.

Al-Jarrah, O., Abu-Qdais, H., 2006. Municipal solid waste landfill siting using intelligent system. Waste Management, 26(3), 299–306.

Antizar-Ladislao, B., Turrion-Gomez, J.L., 2010. Decentralized Energy from Waste Systems. Energies 3, 194–205.

Appels, L., Lauwers, J., Degrève, J., Helsen, L., Lievens, B., Willems, K., Van Impe, J., Dewil, R., 2011. Anaerobic digestion in global bio-energy production: Potential and research challenges. Renewable and Sustainable Energy Reviews 15, 4295–4301.

Aragonés-Beltrán, P., Pastor-Ferrando, J. P., García-García, F., Pascual-Agulló, A., 2010. An Analytic Network Process approach for siting a municipal solid waste plant in the Metropolitan Area of Valencia (Spain). Journal of Environmental Management, 91(5), 1071–1086.

Assamoi B. and Lawryshyn Y., 2012. The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. Waste Management., 32 (5), 1019–1030

Astrup, T.F., Tonini, D., Turconi, R., Boldrin, A., 2015. Life cycle assessment of thermal Waste-to-Energy technologies: Review and recommendations. Waste Management, Special Thematic Issue: Waste-to-Energy Processes and Technologies 37, 104–115.

Babalola M.A., 2011. A Strategic Environmental Decision Analysis to Identify a Suitable Option for Food and Biodegradable Waste Management in Japan: A Case Study of Oita City. Master Thesis, Graduate School of Asia Pacific Studies, Ritsumeikan Asia Pacific University, Beppu Oita, Japan.

Bernstad, A., la Cour Jansen, J., 2012. Review of comparative LCAs of food waste management systems – Current status and potential improvements. Waste Management 32, 2439–2455.

Bouloiz, H., Garbolino, E., Tkiouat, M., Guarnieri, F., 2013. A system dynamics model for behavioral analysis of safety conditions in a chemical storage unit. Safety Science 58, 32–40.

Braber, K., 1995. Anaerobic digestion of municipal solid waste: A modern waste disposal option on the verge of breakthrough. Biomass and Bioenergy, 9(1-5), 365–376.

Bryman A., Bell E., 2011. Business Research Methods Oxford University Press Inc., New York 3rd ed.

Burns A., 1999 Collaborative action research for English language teachers. Cambridge University Press, Cambridge, U.K

Carmone Jr., F.J., Kara, A., Zanakis, S.H., 1997. A Monte Carlo investigation of incomplete pairwise comparison matrices in AHP. European Journal of Operational Research 102, 538–553.

Chaerul, M., Tanaka, M., Shekdar, A.V., 2008. A system dynamics approach for hospital waste management. Waste Management 28, 442–449.

Chang, N.-B., Chang, Y.-H., Chen, H.-W., 2009. Fair fund distribution for a municipal incinerator using GIS-based fuzzy analytic hierarchy process. Journal of Environmental Management 90, 441–454.

Chen, L., Lisha, Z., Na, L., Ming, Z., 2012. Modelling and Simulation of Power Grid Engineering Project based on System Dynamics on the Background of Smart Grid. Systems Engineering Procedia, Information Engineering and Complexity Science - Part I 3, 92–99.

Chen, Z., Ngo, H.H., Guo, W., 2012. A critical review on sustainability assessment of recycled water schemes. Science of The Total Environment 426, 13–31.

Chiueh, P.-T., Lo, S.-L., Chang, C.-L., 2008. A GIS-based system for allocating municipal solid waste incinerator compensatory fund. Waste Management, Pay as you throw: a tool fo urban waste management 28, 2690–2701.

Chung, S.S., Poon, C.S., 1996. Evaluating waste management alternatives by the multiple criteria approach. Resources, Conservation and Recycling 17, 189–210.

Coelho, H.M.G., Lange, L.C., Coelho, L.M.G., 2012. Proposal of an environmental performance index to assess solid waste treatment technologies. Waste Management 32, 1473–1481.

Creswell J. W., 2014. Research design : qualitative, quantitative, and mixed methods approaches. SAGE Publications Inc., Thousand Oaks, Calif 4th ed., international student ed

Creswell J. W., Plano Clark V. L., 2011. Designing and conducting mixed methods research. SAGE Thousand Oaks, Calif, 2nd ed.

Dace, E., Bazbauers, G., Berzina, A., Davidsen, P.I., 2014. System dynamics model for analyzing effects of eco-design policy on packaging waste management system. Resources, Conservation and Recycling 87, 175–190.

De Feo, G., De Gisi, S., 2010. Using an innovative criteria weighting tool for stakeholders involvement to rank MSW facility sites with the AHP. Waste Management 30, 2370–2382.

Demesouka, O.E., Vavatsikos, A.P., Anagnostopoulos, K.P., 2013. Suitability analysis for siting MSW landfills and its multicriteria spatial decision support system: Method, implementation and case study. Waste Management 33, 1190–1206.

Dijkgraaf, E., Vollebergh, H.R.J., 2004. Burn or bury? A social cost comparison of final waste disposal methods. Ecological Economics 50, 233–247.

Dodgson, J.S., Spackman, M., Pearman, A., Phillips, L.D., 2009. Multi-criteria analysis: a manual [WWW Document]. URL http://eprints.lse.ac.uk/12761/ (accessed 8.23.11).

Dong, J., Chi, Y., Zou, D., Fu, C., Huang, Q., Ni, M., 2014. Energy–environment–economy assessment of waste management systems from a life cycle perspective: Model development and case study. Applied Energy 114, 400–408.

Drobne, S., Lisec, A., 2009. Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. Informatica, 33 (4), 459.

Dyson, B., Chang, N.-B., 2005. Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling. Waste Management 25, 669–679.

Eastman J. R., 2009. IDRISI Taiga-Guide to GIS and Image Processing, Clark Labs., Clark University, Worcester, MA.

Ekmekçioğlu, M., Kaya, T., & Kahraman, C., 2010. Fuzzy multicriteria disposal method and site selection for municipal solid waste. Waste Management, 30(8-9), 1729–1736.

European Union 1999. Landfill of Waste Directive 1999/31/EC, 26 April 1999 OJ L 182, 16.7.1999, p. 1 Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1999L0031:20081211:EN:PDF

Ford A., 2010. Modeling the environment. Island Press. Washington 2nd Ed.

Franchetti, M., 2013. Economic and environmental analysis of four different configurations of anaerobic digestion for food waste to energy conversion using LCA for: A food service provider case study. Journal of Environmental Management 123, 42–48.

Garfì, M., Tondelli, S., Bonoli, A., 2009. Multi-criteria decision analysis for waste management in Saharawi refugee camps. Waste Management 29, 2729–2739.

Gbanie, S.P., Tengbe, P.B., Momoh, J.S., Medo, J., Kabba, V.T.S., 2013. Modelling landfill location using Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA): Case study Bo, Southern Sierra Leone. Applied Geography, Special Issue: Constraints and Opportunities in Urban Development in Sub-Saharan Africa. Applied Geography 36, 3–12.

Geneletti, D., 2010. Combining stakeholder analysis and spatial multicriteria evaluation to select and rank inert landfill sites. Waste Management 30, 328–337.

Generowicz, A., Kulczycka, J., Kowalski, Z., Banach, M., 2011. Assessment of waste management technology using BATNEEC options, technology quality method and multi-criteria analysis. Journal of Environmental Management 92, 1314–1320.

Geng, Y., Tsuyoshi, F., Chen, X., 2010. Evaluation of innovative municipal solid waste management through urban symbiosis: a case study of Kawasaki. Journal of Cleaner Production 18, 993–1000.

Gentil, E.C., Gallo, D., Christensen, T.H., 2011. Environmental evaluation of municipal waste prevention. Waste Management 31, 2371–2379.

Gerring J., 2007. Case study research: principles and practices. Cambridge University Press, Cambridge, U.K.

Goh, Y.M., Love, P.E.D., 2012. Methodological application of system dynamics for evaluating traffic safety policy. Safety Science 50, 1594–1605. doi:10.1016/j.ssci.2012.03.002

Gohari, A., Eslamian, S., Mirchi, A., Abedi-Koupaei, J., Massah Bavani, A., Madani, K., 2013. Water transfer as a solution to water shortage: A fix that can Backfire. Journal of Hydrology 491, 23–39.

Gorsevski, P.V., Donevska, K.R., Mitrovski, C.D., Frizado, J.P., 2012. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average. Waste Management 32, 287–296.

Groot, J., Bing, X., Bos-Brouwers, H., Bloemhof-Ruwaard, J., 2014. A comprehensive waste collection cost model applied to post-consumer plastic packaging waste. Resources, Conservation and Recycling, SI:Packaging Waste Recycling 85, 79–87.

Guo, Z., Sheffield, J., 2008. A paradigmatic and methodological examination of knowledge management research: 2000 to 2004. Decision Support Systems 44, 673–688.

Hanan, D., Burnley, S., Cooke, D., 2013. A multi-criteria decision analysis assessment of waste paper management options. Waste Management 33, 566–573.

Herath Gamini and Prato Tony, 2006. Role of multi-criteria decision making in natural resource management in using multi-criteria decision analysis in natural resource management Eds by Herath Gamini and Prato Tony. London, Ashgate Publishing Ltd.

Hodges R. J., Buzby J.C., and Bennett B. 2011. FORESIGHT PROJECT ON GLOBAL FOOD AND FARMING FUTURES: Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. Journal of Agricultural Science, 149, 37-45

Hokkanen, J., Salminen, P., 1997. Choosing a solid waste management system using multicriteria decision analysis. European Journal of Operational Research 98, 19–36.

Horio, M., Shigeto, S., Shiga, M., 2009. Evaluation of energy recovery and CO2 reduction potential in Japan through integrated waste and utility management. Waste Management 29, 2195–2202.

Hosseini Koupaie, E., Barrantes Leiva, M., Eskicioglu, C., Dutil, C., 2014. Mesophilic batch anaerobic co-digestion of fruit-juice industrial waste and municipal waste sludge: Process and cost-benefit analysis. Bioresource Technology 152, 66–73.

Hosseini Koupaie, E., Barrantes Leiva, M., Eskicioglu, C., Dutil, C., 2014. Mesophilic batch anaerobic co-digestion of fruit-juice industrial waste and municipal waste sludge: Process and cost-benefit analysis. Bioresource Technology 152, 66–73.

Hsu, C.-W., 2012. Using a system dynamics model to assess the effects of capital subsidies and feed-in tariffs on solar PV installations. Applied Energy, Clean Energy for Future Generations 100, 205–217.

Iacovidou, E., Vlachopoulou, M., Mallapaty, S., Ohandja, D.G., Gronow, J., Voulvoulis, N., 2013. Anaerobic digestion in municipal solid waste management: Part of an integrated, holistic and sustainable solution. Waste Management 33, 1035–1036.

Ishizaka, A., Labib, A., 2011. Review of the main developments in the analytic hierarchy process. Expert Systems with Applications 38, 14336–14345.

ISWA- the International Solid Waste Association, 2013. Food Waste As a Global Issue- From the perspective of municipal solid waste management. Key Issue Paper, ISWA Publications

Izumi Kouichi, Okishio Yu-ki, Nagao Norio, Niwa Chiaki, Yamamoto Shuichi, and Toda Tatsuki, 2010. Effects of particle size on anaerobic digestion of food waste. International Biodeterioration & Biodegradation, 64(7), 601-608

Japan statistical year book, Statistics Bureau, 2011. Ministry of Internal affairs and communication http://www.stat.go.jp/english/data/nenkan/backdata/index.htm (Assess 16/08/14)

Karagiannidis, A., Papageorgiou, A., Perkoulidis, G., Sanida, G., Samaras, P., 2010. A multi-criteria assessment of scenarios on thermal processing of infectious hospital wastes: A case study for Central Macedonia. Waste Management 30, 251–262.

Karavezyris, V., Timpe, K.-P., Marzi, R., 2002. Application of system dynamics and fuzzy logic to forecasting of municipal solid waste. Mathematics and Computers in Simulation, Intelligent Forecasting, Fault Diagnosis, Scheduling, and Control 60, 149–158.

Kemal Korucu, M., Erdagi, B., 2012. A criticism of applications with multi-criteria decision analysis that are used for the site selection for the disposal of municipal solid wastes. Waste Management 32, 2315–2323.

Kevin T. P. and Lewis A. O., 1997. An introduction to global environmental issues 2nd Ed London; New York: Rutledge.

Khalid, A., Arshad, M., Anjum, M., Mahmood, T., Dawson, L., 2011. The anaerobic digestion of solid organic waste. Waste Management, 31(8), 1737–1744.

Khalili, N.R., Duecker, S., 2013. Application of multi-criteria decision analysis in design of sustainable environmental management system framework. Journal of Cleaner Production 47, 188–198.

Khan, S., Faisal, M.N., 2008. An analytic network process model for municipal solid waste disposal options. Waste Management 28, 1500–1508.

Khoo, H.H., Lim, T.Z., Tan, R.B.H., 2010. Food waste conversion options in Singapore: Environmental impacts based on an LCA perspective. Science of The Total Environment 408, 1367–1373.

Kim, M.-H., Kim, J.-W., 2010. Comparison through a LCA evaluation analysis of food waste disposal options from the perspective of global warming and resource recovery. Science of The Total Environment 408, 3998–4006.

Kim, M.-H., Song, Y.-E., Song, H.-B., Kim, J.-W., Hwang, S.-J., 2011. Evaluation of food waste disposal options by LCC analysis from the perspective of global warming: Jungnang case, South Korea. Waste Management 31, 2112–2120.

Kim, M.-H., Song, Y.-E., Song, H.-B., Kim, J.-W., Hwang, S.-J., 2011. Evaluation of food waste disposal options by LCC analysis from the perspective of global warming: Jungnang case, South Korea. Waste Management 31, 2112–2120.

Kollikkathara, N., Feng, H., Stern, E., 2009. A purview of waste management evolution: Special emphasis on USA. Waste Management 29, 974–985.

Kollikkathara, N., Feng, H., Yu, D., 2010. A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues. Waste Management, Special Thematic Section: Sanitary Landfilling 30, 2194–2203.

Kontos, T. D., Komilis, D. P., Halvadakis, C. P., 2005. Siting MSW landfills with a spatial multiple criteria analysis methodology. Waste Management, 25(8), 818–832.

Lebersorger, S., Schneider, F., 2011. Discussion on the methodology for determining food waste in household waste composition studies. Waste Management 31, 1924–1933.

Malczewski, J., 1999. Spatial Multicriteria Decision Analysis in Jean-Claude Thill (Ed) Spatial Multicriteria Decision Making and Analysis: A Geographic Information Sciences Approach. Ashgate Publishing Ltd London, pp.11- 48

Malczewski, J., 2000. On the Use of Weighted Linear Combination Method in GIS: Common and Best Practice Approaches. Transactions in GIS, 4(1), 5–22.

Malczewski, J., 2006. GIS-based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science, 20(7), 703–726.

Managi, S., Hibiki, A., Shimane, T., 2014. Efficiency or technology adoption: A case study in waste-treatment technology. Resource and Energy Economics 36, 586–600.

Matsumoto Naoko, Sano Daisuke, and Elder Mark, 2009. Biofuel initiatives in Japan: Strategies, policies, and future potential. Applied Energy, 86(1), S69-S76.

Matsumoto, N., Sano, D., Elder, M., 2009. Biofuel initiatives in Japan: Strategies, policies, and future potential. Applied Energy, Bio-fuels in Asia 86, Supplement 1, S69–S76.

McKenna, S., Richardson, J., Manroop, L., 2011. Alternative paradigms and the study and practice of performance management and evaluation. Human Resource Management Review, New Developments in Performance Management 21, 148–157.

McKernan J., 1996. Curriculum action research: a handbook of methods and resources for the reflective practitioner. Routledge Kogan Page, London 2nd ed

McTaggart R., ED 1997 Participatory action research: international contexts and consequences. State University of New York Press, Albany

Ministry of Agriculture, Forestry and Fisheries (MAFF), 2007. 2007 Report Outline of Survey Results on Food Recycling as Renewable Resources. http://www.maff.go.jp/e/maffud/2007/pdf/no684.pdf (Assess 03/12/14)

Ministry of Agriculture, Forestry and Fisheries (MAFF), 2008. Annual Report on Food, Agriculture and Rural Areas in Japan FY 2007. http://www.maff.go.jp/e/annual_report/2007/pdf/e_all.pdf (Assess 03/12/13)

Ministry of Economy, Trade and Industry (METI), 2012. Feed-in-tariff scheme in Japan. http://www.meti.go.jp/english/policy/energy_environment/renewable/pdf/summary201207.pdf (Assess 20/26/14)

Ministry of Environment (MOE), 2012. Solid Waste Management and Recycling Technology of Japan: Toward a Sustainable Society https://www.env.go.jp/en/recycle/smcs/attach/swmrt.pdf (Assess 20/26/14)

Ministry of the Environment (MOE), 2002. Regulations of Waste Management and Public Cleansing Law: Ordinance No. 35 of Ministry of Health and Welfare of 1971 (Latest Amendment by Ordinance No. 1 of Ministry of Environment of 2002)

Ministry of the Environment, 2010. Establishing A Sound Material-Cycle Society: Milestone toward a sound material-cycle society through changes in business and life styles. Biomass Nippon Strategy. http://www.env.go.jp/en/recycle/smcs/a-rep/2010gs_full.pdf (Assess 20/09/13)

Moeinaddini, M., Khorasani, N., Danehkar, A., Darvishsefat, A. A., zienalyan, M., 2010. Siting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj). Waste Management, 30(5), 912–920.

Morecroft J., 2007. Strategic Modeling And Business Dynamics: A Feedback Systems Approach. John Wiley, Chichester.

Moriarty, Kristi, 2013. Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana. The National Renewable Energy Laboratory (NREL) http://www.nrel.gov/docs/fy13osti/57082.pdf (Assess 16/02/26)

Morisaki I., 2011. Pattern of Food Losses in Households: A Case Study in Oita-Prefecture, Japan, Master Thesis, Graduate School of Asia Pacific Studies, Ritsumeikan Asia Pacific University, Beppu Oita, Japan.

Morris, J., 2010. Bury or Burn North America MSW? LCAs Provide Answers for Climate Impacts & Carbon Neutral Power Potential. Environ. Sci. Technol. 44, 7944–7949.

Nathanson, J. A., 2008. Basic Environmental Technology: Water Supply, Waste Management, and Water Pollution Control. Saddle River, N.J.: Pearson Prentice Hall

Nijkamp P. & Rietveld P., Voogd H., 1990. Multicriteria evaluation in physical planning. Amsterdam, Netherlands. Elsevier Science Pub.

Oita City, 2012. The Current Situation of Waste Handling in Oita City http://www.city.oita.lg.jp/www/contents/1241147724156/files/gomi.pdf (Assess 18/08/13)

Oita Municipal Government, 2014. Oita Zero waste Strategy: The Status and plans of biomass resource utilization Oita prefecture.

Okuda, I., Thomson, V.E., 2007. Regionalization of Municipal Solid Waste Management in Japan: Balancing the Proximity Principle with Economic Efficiency. Environmental Management 40, 12–19.

Ozeair Abessi, M. S., 2009. Site Selection of a Hazardous Waste Landfill Using GIS (ozeair Abessi) http://gatech.academia.edu/ozeairAbessi/Papers/1409844/Site_Selection_of_a_Hazardous_Waste_Landfill_Using_GIS (Assess 20/10/11)

Parkin P., 2009. Managing change in healthcare: using action research. SAGE Publications Inc.,

Petty, N.J., Thomson, O.P., Stew, G., 2012a. Ready for a paradigm shift? Part 1: Introducing the philosophy of qualitative research. Manual Therapy 17, 267–274.

Petty, N.J., Thomson, O.P., Stew, G., 2012b. Ready for a paradigm shift? Part 2: Introducing qualitative research methodologies and methods. Manual Therapy 17, 378–384.

Piewthongngam, K., Vijitnopparat, P., Pathumnakul, S., Chumpatong, S., Duangjinda, M., 2014. System dynamics modelling of an integrated pig production supply chain. Biosystems Engineering 127, 24–40.

Rao C.S. 1991. Environmental Pollution Control Engineering. New York, Wiley

Rehl, T., Müller, J., 2013. CO2 abatement costs of greenhouse gas (GHG) mitigation by different biogas conversion pathways. Journal of Environmental Management 114, 13–25.

Saaty T. L., 1980. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation, McGraw-Hill International Book Co, New York; London.

Saaty, T. L., &Vargas, L. G., 2001. Models, Methods, Concepts & Applications of The Analytic Hierarchy Process, Kluwer Academic Publishers, Boston.

Saaty, T.L., Sagir, M., 2009. An essay on rank preservation and reversal. Mathematical and Computer Modelling 49, 1230–1243.

Sakai, S., Sawell, S. E., Chandler, A. J., Eighmy, T. T., Kosson, D. S., Vehlow, J., van der Sloot, H. A., Hartlen, J., Hjelmar, O., 1996. World terends in municipal solid waste management. Waste Management, 16(5–6), 341–350.

Sakai, S., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M.V., Wejchert, J., Schmid-Unterseh, T., Douvan, A.R., Hathaway, R., Hylander, L.D., Fischer, C., Oh, G.J., Jinhui, L., Chi, N.K., 2011. International comparative study of 3R and waste management policy developments. J Mater Cycles Waste Manag 13, 86–102. doi:10.1007/s10163-011-0009-x

Salman Mahini, A., Gholamalifard, M., 2006. Siting MSW landfills with a weighted linear combination (WLC) methodology in a GIS environment. International Journal Environment Science & technology, 3 (4), 435-445

Santibañez-Aguilar, J.E., Ponce-Ortega, J.M., Betzabe González-Campos, J., Serna-González, M., El-Halwagi, M.M., 2013. Optimal planning for the sustainable utilization of municipal solid waste. Waste Management 33, 2607–2622.

Schübeler P., Wehrle K. and Christen J., 1996. Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries. (Working Paper No. 9) UNDP/UNCHS (Habitat)/World Bank/SDC Collaborative Programme on Municipal Solid Waste management in Low-Income Countries. Urban Management and Infrastructure. Switzerland, SKAT

Seadon, J.K., 2006. Integrated waste management – Looking beyond the solid waste horizon. Waste Management 26, 1327–1336.

Şener, Ş., Şener, E., Nas, B., Karagüzel, R., 2010. Combining AHP with GIS for landfill site selection: A case study in the Lake Beyşehir catchment area (Konya, Turkey). Waste Management, Special Thematic Section: Sanitary Landfilling 30, 2037–2046.

Sharifi, M., Hadidi, M., Vessali, E., Mosstafakhani, P., Taheri, K., Shahoie, S., Khodamoradpour, M., 2009. Integrating multi-criteria decision analysis for a GIS-based hazardous waste landfill sitting in Kurdistan Province, western Iran. Waste Management, 29(10), 2740–2758.

Showa Denko 2013. Shaping CSR: Showa Denko CSR Report 2013. SHOWA DENKO Group http://www.sdk.co.jp/assets/files/english/csr/library/report/pdf/csr_f2013_e_all.pdf (Assess 10/08/14)

Starr, K., Gabarrell, X., Villalba, G., Talens Peiro, L., Lombardi, L., 2014. Potential CO2 savings through biomethane generation from municipal waste biogas. Biomass and Bioenergy 62, 8–16.

Starr, K., Gabarrell, X., Villalba, G., Talens Peiro, L., Lombardi, L., 2014. Potential CO2 savings through biomethane generation from municipal waste biogas. Biomass and Bioenergy 62, 8–16.

Sterman J. D., 2000. Business Dynamics: Systems Thinking And Modeling For A Complex World. Irwin/McGraw-Hill, Boston

Stuart, T., 2009. Waste: Uncovering the Global Food Scandal. London: Penguin Books.

Sumathi, V. R., Natesan, U., Sarkar, C., 2008. GIS-based approach for optimized siting of municipal solid waste landfill. Waste Management, 28(11), 2146–2160.

Suryani, E., Chou, S.-Y., Hartono, R., Chen, C.-H., 2010. Demand scenario analysis and planned capacity expansion: A system dynamics framework. Simulation Modelling Practice and Theory 18, 732–751.

Tabata T., 2013. Waste-to-energy incineration plants as greenhouse gas reducers: A case study of seven Japanese metropolises. Waste Management and Research 31(11) 1110-1117.

Takata, M., Fukushima, K., Kino-Kimata, N., Nagao, N., Niwa, C., Toda, T., 2012. The effects of recycling loops in food waste management in Japan: Based on the environmental and economic evaluation of food recycling. Science of The Total Environment 432, 309–317.

Takatsuki, H., 2013. Waste problems and our lifestyle. Waste Management 33, 2145–2146.

Tavares, G., Zsigraiová, Z., Semiao, V., 2011. Multi-criteria GIS-based siting of an incineration plant for municipal solid waste. Waste Management 31, 1960–1972.

United Nations Environment Programme, (UNEP) 2013. The Japanese Industrial Waste Experience: Lessons for rapidly industrializing countries. http://www.unep.org/ietc/Portals/136/Publications/Waste%20Management/UNEP%20DTIE_Japanese%20waste_english_web.pdf (Assess 20/10/14)

United Nations Environment Programme, 2005 Solid waste management (volume 1). http://www.unep.or.jp/ietc/publications/spc/solid_waste_management/Vol_I/Binder1.pdf (Assess 20/10/14)

Vaidya, O.S., Kumar, S., 2006. Analytic hierarchy process: An overview of applications. European Journal of Operational Research 169, 1–29.

Villanueva, A., Wenzel, H., 2007. Paper waste – Recycling, incineration or landfilling? A review of existing life cycle assessments. Waste Management, Life Cycle Assessment in Waste Management 27, S29–S46.

Wang, G., Qin, L., Li, G., Chen, L., 2009. Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. Journal of Environmental Management, 90(8), 2414–2421.

William, H., 2008. Integrated analytic hierarchy process and its applications – A literature review. European Journal of Operational Research 186, 211–228.

Wong, L.-F., Fujita, T., Xu, K., 2008. Evaluation of regional bioenergy recovery by local methane fermentation thermal recycling systems. Waste Management 28, 2259–2270.

Ye, G., Yuan, H., Shen, L., Wang, H., 2012. Simulating effects of management measures on the improvement of the environmental performance of construction waste management. Resources, Conservation and Recycling 62, 56–63.

Yeh, C.-H., J. Willis, R., Deng, H., Pan, H., 1999. Task oriented weighting in multi-criteria analysis. European Journal of Operational Research 119, 130–146.

Yin R. K., 2003. Case study research: design and methods. SAGE Publications Inc., Thousand Oaks, Calif. 4th ed

Yin R. K., 2012. Applications of case study research. SAGE Publications Inc., Thousand Oaks 3rd ed

Yoshida, H., Shimamura, K., Aizawa, H., 2007. 3R strategies for the establishment of an international sound material-cycle society. J Mater Cycles Waste Manag 9, 101–111.

Yuan, H., 2012. A model for evaluating the social performance of construction waste management. Waste Management 32, 1218–1228.

Yuan, H., Chini, A.R., Lu, Y., Shen, L., 2012. A dynamic model for assessing the effects of management strategies on the reduction of construction and demolition waste. Waste Management 32, 521–531.

Yuan, H., Wang, J., 2014. A system dynamics model for determining the waste disposal charging fee in construction. European Journal of Operational Research 237, 988–996.

Yuan, H.P., Shen, L.Y., Hao, J.J.L., Lu, W.S., 2011. A model for cost–benefit analysis of construction and demolition waste management throughout the waste chain. Resources, Conservation and Recycling, Environmental Supply Chain Management 55, 604–612.

Zhao, W., Ren, H., Rotter, V.S., 2011. A system dynamics model for evaluating the alternative of type in construction and demolition waste recycling center – The case of Chongqing, China. Resources, Conservation and Recycling 55, 933–944.

APPENDIX A:
EQUATIONS AND CONSTANTS USED IN THE SYSTEM DYNAMICS MODEL

AD Plant Treatment (t) = AD Plant Treatment (t - dt) + (Waste Treated in AD Plant - Resources Gained From AD) * dt

INIT AD Plant Treatment = 0

INFLOWS:

Waste Treated in AD Plant = Collected Waste*Rate of Treatment

OUTFLOWS:

Resources Gained From AD = AD Plant Treatment

Amount of FBW Incinerated (t) = Amount of FBW Incinerated (t - dt) + (Decreasing Rate - Increasing Rate) * dt

INIT Amount of FBW Incinerated = 1

INFLOWS:

Decreasing Rate = GRAPH (1-Motivation to Manage Waste)

(1.00, 0.01), (1.40, 0.02), (1.80, 0.03), (2.20, 0.04), (2.60, 0.04), (3.00, 0.05), (3.40, 0.06), (3.80, 0.07), (4.20, 0.08), (4.60, 0.09), (5.00, 0.1)

OUTFLOWS:

Increasing Rate = GRAPH (Unit Cost of Incineration)

(0.00, 0.01), (90.0, 0.02), (180, 0.02), (270, 0.03), (360, 0.04), (450, 0.05), (540, 0.06), (630, 0.07), (720, 0.08), (810, 0.09), (900, 0.1)

Collected Waste (t) = Collected Waste (t - dt) + (Waste Collection - Waste Treated in AD Plant - Incineration Rate) * dt

INIT Collected Waste = 0

INFLOWS:

Waste Collection = Sorted Waste*Rate of Collection

OUTFLOWS:

Waste Treated in AD Plant = Collected Waste*Rate of Treatment

Incineration Rate = Collected Waste*Amount of FBW Incinerated

Incineration (t) = Incineration (t - dt) + (Incineration Rate - Resource Gained from INC) * dt

INIT Incineration = 0

INFLOWS:

Incineration Rate = Collected Waste*Amount of FBW Incinerated

OUTFLOWS:

Resource Gained from INC = Incineration

Regulation (t) = Regulation (t - dt) + (Regulation Strengthening) * dt

INIT Regulation = 1

INFLOWS:

Regulation Strengthening = GRAPH (1-Amount of FBW Incinerated*Regulation)

(0.00, 0.005), (0.1, 0.01), (0.2, 0.015), (0.3, 0.025), (0.4, 0.045), (0.5, 0.065), (0.6, 0.085), (0.7, 0.105), (0.8, 0.12), (0.9, 0.145), (1, 0.165)

Resources Yield From AD (t) = Resources Yield From AD (t - dt) + (Resources Gained From AD) * dt

INIT Resources Yield From AD = 0

INFLOWS:

Resources Gained From AD = AD Plant Treatment

Resources Yield From INC (t) = Resources Yield From INC (t - dt) + (Resource Gained from INC) * dt

INIT Resources Yield From INC = 0

INFLOWS:

Resource Gained from INC = Incineration

Sorted Waste (t) = Sorted Waste (t - dt) + (Waste Sorting - Waste Collection) * dt

INIT Sorted Waste = 0

INFLOWS:

Waste Sorting = Waste Generation*Sorting Rate

OUTFLOWS:

Waste Collection = Sorted Waste*Rate of Collection

Waste Generation (t) = Waste Generation (t - dt) + (Burnable Waste - Waste Sorting) * dt

INIT Waste Generation = 0

INFLOWS:

Burnable Waste = Generated Waste*Rate of Waste Generation

OUTFLOWS:

Waste Sorting = Waste Generation*Sorting Rate

Ammonia = Syngas*0.64*Unit Price of Ammonia

Biogas Power Generation = Resources Yield from AD*MWh per Ton Biogas*Unit price of Power Biogas

CO2 = Syngas*2.07*Unit Price of CO2

Cost of Collecting &Transportation = Collected Waste*Unit Cost of Collecting & Transportation

Cost of Incineration = Incineration*Unit Cost of Incineration

Cost of O&M AD Plant = AD Plant Treatment*Unit Cost of O&M AD

Cost of O&M Incineration = Incineration*47

Environmental Cost Savings = Unit Cost of ECS*Incineration

Fertilizer = (Resources Yield From AD*Unit Price Fertilizer)*0.75

Fund Needed for Waste Management = Cost of Collecting & Transportation + Cost of Incineration + Cost of O&M AD Plant + Cost of O&M Incineration

Generated Waste = 132151.81

GWP Cost Saving = Ammonia+CO2

MWh per Ton Biogas = 0.6

MWh per Ton Incineration = 0.52

Power Generation = Resources Yield From INC*MWh per Ton Incineration

Rate of Collection = 0.99

Rate of Treatment = IF Amount of FBW Incinerated<0.1THEN 0.83 ELSE IF Amount of FBW Incinerated<0.2 THEN 0.72 ELSE IF Amount of FBW Incinerated<0.3 THEN 0.61 ELSE IF Amount of FBW Incinerated<0.4 THEN 0.50 ELSE IF Amount of FBW Incinerated<0.5 THEN 0.40 ELSE IF Amount of FBW Incinerated<0.7 THEN 0.30 ELSE 0.83

Rate of Waste Generation = 1.47

Revenue from AD Plant = Biogas Power Generation + Fertilizer

Revenue from Incineration = Power Generation*Unit price of Power waste

Sorting Rate = Amount of FBW Incinerated*Motivation to Manage Waste

Syngas = Resources Yield From INC

Total Environmental Benefit = Environmental Cost Savings + GWP Cost Saving

Total Waste Budget = Total Revenue-Fund Needed for Waste Management

Total Revenue = Environmental Cost Savings + GWP Cost Saving + Revenue from AD Plant + Revenue from Incineration

Unit Cost of Collecting & Transportation = 100

Unit Cost of Incineration = 100

Unit Cost of O&M AD = 48

Unit cost of ECS = 63.1

Unit Price Fertilizer = 100

Unit Price of Ammonia = 150

Unit Price of CO2 = 27.594

Unit price of Power Biogas = .40

Unit price of Power waste = 0.17

Motivation to Manage Waste = GRAPH (Regulation)

(0.00, 0.00), (1.00, 0.12), (2.00, 0.205), (3.00, 0.31), (4.00, 0.395), (5.00, 0.48), (6.00, 0.54), (7.00, 0.64), (8.00, 0.725), (9.00, 0.82), (10.0, 0.955)