LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Faculty of Energy Technology
Master's Degree Program in Environmental Energy

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WASTE MANAGEMENT IN COMMERCIAL ACTIVITY: STATE OF THE ART AND THE POTENTIAL INNOVATION IN THE URBAN AREAS OF HANOI, VIETNAM

Examiners: Professor Mika Horttanainen
Dr. Sc. (Tech.)

M. Sc. (Tech.) Lauri Anttila

ABSTRACT

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Keywords: Commercial waste, packaging materials, food waste, recycling rates, energy recovery.

As the rapid development of the society as well as the lifestyle, the generation of commercial waste is getting more complicated to control. The situation of packaging waste and food waste – the main fractions of commercial waste in different countries in Europe and Asia is analyzed in order to evaluate and suggest necessary improvements for the existing waste management system in the city of Hanoi, Vietnam.

From all waste generation sources of the city, a total amount of approximately 4000 tons of mixed waste is transported to the composting facility and the disposal site, which emits a huge amount of 1,6Mt of GHG emission to the environment. Recycling activity is taking place spontaneously by the informal pickers, leads to the difficulty in managing the whole system and uncertainty of the overall data. With a relative calculation, resulting in only approximately 0,17Mt CO2 equivalent emission, incinerator is suggested to be the solution of the problem with overloaded landfill and raising energy demand within the inhabitants.

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Linh Dong

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

C&I	Commercial and Industrial
CHP	Combined Heat and Power
EPR	Extended Producer Responsibility
EU	European Union
GHG	Greenhouse Gas
GNI/Capita	Gross National Income per Capita
HDPE	High Density Polyethylene
IWM	Integrated Waste Management
LDPE	Low Density Polyethylene
LHV	Lower Heating Value
MSW	Municipal Solid Waste
NCV	Net Calorific Value
OECD	Organization for Economic Co-operation and Development
PC	Polycarbonate
PET	Polyethylene Terephthalate
PLA	Poly-lactic acid
PP	Polypropylene
PS	Poly-styrene
PVC	Poly-vinyl chloride
RW	Recyclable Waste
Tonnes/capita/yr	Tonnes per Capita Annually
TPS	Thermoplastic starch
UK	United Kingdom
URENCO	Urban Environment Company
VOCs	Volatile Organic Compound
WTE	Waste To energy

1 INTRODUCTION

1.1 Introduction and stated problem

The management of global waste is a critical problem of the human kind and the situation has been getting worse in the modern world. One of the main factors of the waste generation comes from the commercial activities. As the consequence of modernization and urbanization, the consumption of goods has increased by geometric progression, especially in developing countries. This trend leads to the explosion of new supermarkets, open markets and shops to satisfy the high demand of the consumers. Some statistics from European Commission and World Bank show that approximately 401 kilograms of solid waste were generated per European capita in year 2012 and commercial waste made up about 35% in the total share. In Asia and Africa, the same measurements gave the results of commercial waste as one of the biggest fractions. Despite the effort of governments to prevent, reduce, re-use and recycle waste matter, changing consumption templates and the rapid growth of global population have led to one big question of how to best manage commercial waste concerning sustainable development.

1.2 Scope and goal of the thesis

This thesis gives a closer look at the current situation of the collection and management of commercial waste globally, as well as the properties of this waste category in different parts of the world such as Europe and important cities in Asia. Due to published information insufficiency, a number of assumptions were made based on the historical database as well as the trend of the society and governments concerning the waste management. Europe and Asia were chosen to be the main regions of the research according to the availability of the necessary information and references. The capital city of Vietnam - Hanoi was selected to be the specific case study of the thesis. The goal of this thesis is to collect the information about the current situation of commercial waste in order to evaluate the existing ways of management. Meanwhile, the writer gives some suggestion of the possible innovation within the limits of existing policies and legislation of each chosen region.

2 COMMERCIAL WASTE OVERVIEW

Within the scope of the thesis, commercial waste contains two main elements: food waste from the trading and the packaging materials. The major physical and chemical characteristics of the commercial waste components are presented as below.

Table 1. Typical physical characterization of commercial waste components (Chandrappa & Diganta Bhusan, 2012)

Waste material	Waste density (kg/m^3)	Moisture content (%)	LHV as received (MJ/kg)
Cardboard and corrugated paper box	30-80	4-10	14-16
Glass	90-260	1-4	-
Plastic	30-156	1-4	4,5 - 6
Wood	156-900	15-40	14,4-17,4
Food waste	120-480	50-80	4-10
Metal-ferrous	120-1200	2-6	-
Metal-Non Ferrous	60-240	2-4	-

The cultural and shopping habit difference in distinctive regions influence source of waste. In Europe, where supermarket chains are the main good providing places, there are mostly packed products. Therefore, packaging waste makes up a major fraction in the commercial waste share. Food waste is mainly with the wrapping layer such as plastic rack, corrugated box and liquid paper of expired products.

In difference, there are more types of unpacked fresh food in Asian supermarkets due to the cultivating conditions and availability. Besides, supermarkets are not the only food provider to the citizens. An additional commercial factor which is more common in Asia is the open-market. Here, majorly unpacked food types are sold with poorer reserving techniques than in grocery stores. Therefore, the food gets rotten faster and in a bigger amount.

The bigger fraction of commercial waste belongs to unpacked food waste. Base on the statistics from the nations, the data on the fraction of commercial waste is not clear in Asian countries due to the fact that it is not always considered a separate part of the waste stream. Thus, although the shares of packaging waste and food loss are provided, there is

not any certain about the origin of these compositions if they come from commerce activity. However, in some other European countries, the amount of commercial waste could be obtained as of approximately 40 million tons in the UK in 2004 (W. Dixon-Hardy & A. Curran, 2008) and 6,4 million tons (mixed with industrial waste) in Germany in 2007. (Helftewes, et al., 2012). The following sectors will give a detailed look about each fraction of the commercial waste.

2.1 Packaging waste

Packaging is a modern technique for protecting goods and maintaining the quality and quantity of the products as the standards. Furthermore, it limits the impacts of environmental factors to the goods from the process of goods producing until the consuming phase. Packages can be considered as the bridge between producers and consumers as they deliver the own image of the operation to the consumers to help the consumers easily identify and choose the right type of goods. The goods are packed in containers with net weight remains the possibility of the correspondent consumption, thus avoiding redundancy. Today, the basic materials of packages include, paper, paperboard, steel, glass, wood and plastics. (Bonadies, et al., 2001).

The first category of packaging is primary packaging. *Primary packaging or sales packaging* is utilized by the consumer, *as it is wrapping or* being *a container for the product as a sales unit*. (W. Dixon-Hardy & A. Curran, 2008). Package is used to pack rough and direct goods; its use is to protect goods such as moisture resistance, anti-vibration, separated from the other flavors. (Elke, 2012). The Figure 1 shows some examples of different types of products with primary package.

Figure 1. Examples of primary packaging

The secondary package category contains a number of primary packages; it provides a grouping function. It is useful in case primary package is traded in the form of more than a single unit. In many cases, there is more than one type of products in a secondary package. For example, in some promotion campaigns, different products are sold as a set of secondary package.(W. Dixon-Hardy & A. Curran, 2008). The Figure 2 provides a closer look at secondary packaging products.

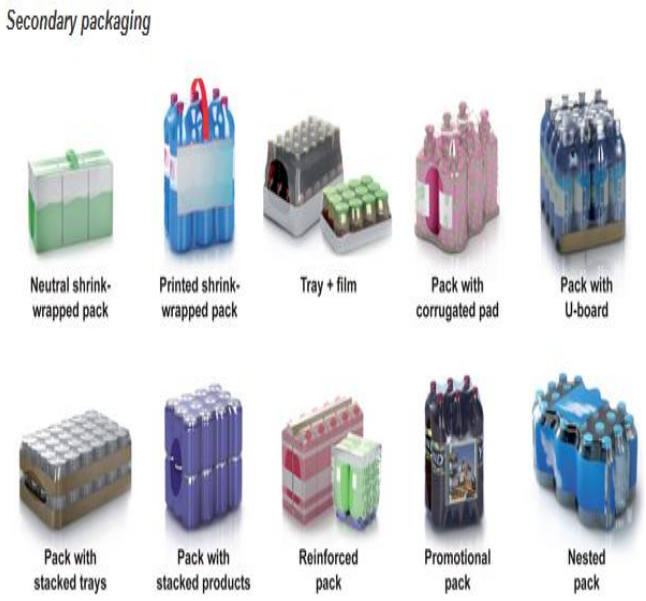

Figure 2. Examples of secondary packaging (Gebo Cermex, 2014)

The tertiary package is the shipping container, and typically contains a number of secondary packages. In the case of wholesale product provider, tertiary packages are used as it saves the turns of transportation as well as the energy consumption. (Elke, 2012) Normally, in supermarket chains or shopping malls, the main fraction of waste comes from these wrapping parcels and the group packages after being unpacked for retail trade.

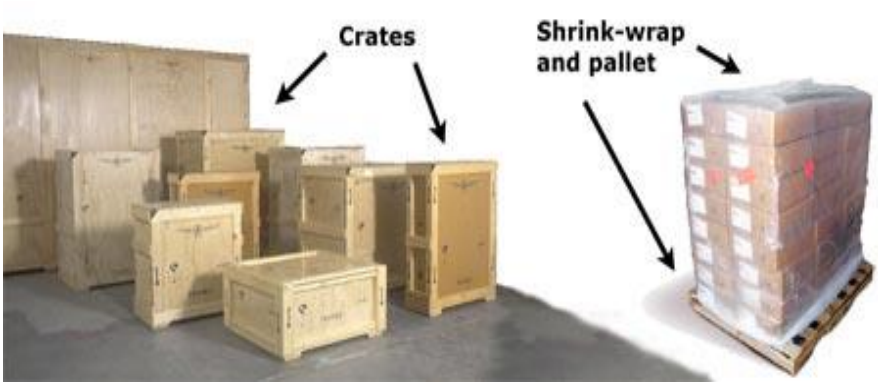

Figure 3. Example of tertiary packaging (Agalwar's Export and Import Inc., 2014)

2.1.1 Paper and cardboard

This is the widest utilized recyclable packaging material in the current time. Moreover, the flexible application of paper and cardboard due to their properties widen the share of this material in the total share of packaging elements. In the most cases, paper and cardboard are the secondary and tertiary packaging texture as described in the table below.

Table 2. Classification of paper and board packaging (Karli, et al., 2011)

Category	Paper density (g/m^2)	Structure	Applications
Kraft	10-120	One sheet	Bags; sacks; sheets; cartons; boxes; trays; labels
Boxboard (folding boxboard, carton board, paperboard)	120-800	Individual or multiple layered	Folding cartons; milk and juice cartons
Corrugated board	250-1500	Numerous layered with trench	Shipping boxes and cartons; pallets; edge protectors and braces; trays; separators
Molded paper packaging (spongy box)		Single layer	Egg cartons; take away food and drink boxes; buffer for electronic products
Liquid paperboard	300-400	Multiple layered with polymer or optical aluminum foil	Fresh milk boxes; soap and aseptic products; long-life liquid products such as milk or juice

The main source of paper and board waste from the researched commerce activity is from the tertiary level of packaging. The cultural and shopping habit difference in distinctive regions influences source of waste.

2.1.2 Plastic

The use of plastic materials has allowed a reduction in the weight of packaged products of almost 28% with respect to 10 years ago; as a consequence of this, the consumption of petroleum in transportation is decreased and thus plastic packaging has followed the project of “sustainable development”. Plastic is the major wrapping material in Western Europe, which makes up approximately 75,8% of the packaging materials in the market by 2002. (Bonadies, et al., 2001)

Renewable thermoplastic

The use of renewable thermoplastics, such as those derived from crops, in packaging applications is increasing. Types of renewable thermoplastics include: starch-based polymers, cellulose-based polymers and poly-lactic acid.

Starch-based polymers can be originated from potato, wheat or corn. They can be utilized in *injection molding and film applications*, resulting in popular products such as *cups, foamed trays, shopping bags, compost bags and film.* (Karli, et al., 2011)

Cellulose-based polymers are transparent and absorptive to water and oxygen. They are derived from different sources but mostly from trees and cottons. This material can be forced out and injected to molds to form products such as film layer to cover bakery products and fresh fruits, *twist wrap and glued bags*. (Ibid.)

Poly-lactic acid (PLA) is transparent and resistant to medium level heat and impact with the most popular applications such as bottles or food containers. The process of producing this type of renewable plastic is described as using *micro-organisms to convert corn starch (dextrose) into lactic acid via fermentation*. This material can be manufactured by *injection molding, sheet extrusion, blow-molding, thermoforming and film-forming*. (Ibid.)

There are alternatives for managing renewable thermoplastic such as composting, material recycling, final disposing and combusting. However, with the small quantities on the markets and the low level of separation with non-renewable thermoplastic from the discharge phase, this kind of packaging materials has a limit recovery rate. (Ibid.)

Non-renewable thermoplastic

The raw materials used to produce non-renewable thermoplastics are mostly obtained from petrochemicals (hydrocarbons), *either natural gas or crude oil extracted from the earth*. Other raw materials are obtained from a *variety of sources*, such as chlorine in Polyvinyl Chloride, originated from rock salt. (Karli, et al., 2011).

Table 3. [Modified] Classification of non-renewable thermoplastic (Karli, et al., 2011)

Polymer	Applications	Resin ID code	Density (g/cm^3)
Polyethylene Terephthalate (PET)	Soda and water bottles, medicine containers		1,38-1,40
High Density Polyethylene (HDPE)	Detergent containers, shampoo and motor oil boxes		0,96
Polyvinyl Chloride (PVC)	Shower curtain, plastic pipes		1,35-1,40
Low Density Polyethylene (LDPE)	Wrapping film, bags for food and clothing, produce bags and liners, coatings,		0,92
Polypropylene (PP)	Takeaway food containers, dairy dip containers, paint tubs, margarine and yoghurt tubs, cosmetic jars		0,9
Polystyrene (PS)	Bottles for tablets and capsules and thermoformed trays		1,06
Polycarbonate (PC)	Microwave-proof containers, ovenware, food storage containers and water containers		1,20-1,22

The wrapping layers which cover the container of product are mainly produced from either LDPE or PVC which have an average potential of recycling. After the usage stage, several scenarios could happen to the non-renewable fossil-derived thermoplastics waste such as being littered, recycled, disposed to landfill, or combusted for energy recovery.

There are three main technologies to recover non-renewable plastic such as: mechanical recycling, feedstock recycling and energy recovery/generation. Each of these methods has different requirements of local infrastructure to ensure the performance of the process. For example, in mechanical recycling, plastics are grinded, cleaned, compounded and finally pelletized, or *molded directly into a new product*. This recycling technique is wide-spread in mostly developed countries. In feedstock recycling, plastic waste is transformed back to the raw material stage to change its chemical characteristics and form a new product or join other chemical processes. (Karli, et al., 2011)

2.1.3 Wood, metal and glass

Pallets are the most popular type of transfer packaging used in supermarkets in many countries in Europe such as the UK and Germany. On the way from the origins to the sales, the products are put on the pallets and simply attached by pile up one with another. For example, fresh food categories such as vegetables, fruits, and flowers are transported to the supermarkets in the form of huge wooden pallet piles. (W. Dixon-Hardy & A. Curran, 2008).

According to EUROSTAT data, the tonnage of wood packaging placed on the market in EU-15 fell by 5.5% between 2003 and 2011, an average annual reduction of 1.1%. While the same data of metal packaging placed on the market in EU-15 fell by 10.9% between 1998 and 2011, making an average annual reduction of 0.9%. (EUROPEN - The European Organization for Packaging and the Environment, 2011). Finally, the amount of glass packaging supplied to the market in EU-15 fell by 5.7% between 1998 and 2011, with an average annual decrease of 0.4%. However, the same source of statistics within the period 1998 – 2011 recorded a raise of plastic packaging provided to the market by 32.3% (approximately 2.2% annually). For paper and cardboard, this value was 14.2% of increasing demand with about 1.1% raise per year.

2.1.4 Other biodegradable wrapping materials

In the rural regions of Asian continent, the utilization of cheap and available wrapping materials such as leaves is quite common. Banana or plantain leaves are often used for wrapping certain types of food (e.g. steamed dough and confectionery). Corn husk is used to wrap corn paste or unrefined block sugar, and cooked foods of all types are wrapped in leaves (e.g. vine leaves, bamboo leaves).

Biodegradable packaging is an excellent solution for the problem of how to pack products that are consumed soon after purchase as they are cheap and readily available. They do not however protect the food against moisture, oxygen, odors or micro-organisms, and are therefore not suitable for long-term storage. Normally, after being utilized, approximately 60% by weight of this type of biodegradable wrapping materials is dumped on the side of

the food stalls and collected together with all other kinds of waste. This packaging waste fraction should be separated to be transferred straight to the composting facility.

2.2 Food waste

There are a variety of factors that affect the amount of food waste through the retail activity such as:

- Excess stock causes by the return systems and the order cancellation at the last minute. It is a common contract between the food suppliers and the retails that the unsold food could be taken back to the producer. This leads to a consequence that safe and still-in-good-condition food might be discarded in a huge amount depends on the magnitude of the retail. Inaccurate ordering and forecasting of demand also affects the wholesale/retail sector. (European Commission, 2010). Based on different surveys, approximately 40% of the food in the grocery store in the US is never utilized.

- Transportation between the factories and the shops can result in both packaging and storage problems. Low quality packaging leads to the *damage to food products* and later the abandonment of the products. It can be recorded that food is eliminated from the shelf unharmed only because of a poor appearance. Another factor during the delivery route of the goods is that the improper changes in temperature and preserving conditions can destroy or shorten the shelf life of food products. Improvements of the packaging performance as well as a better temperature control of the delivery transportation are expected in order to reduce the amount of food loss. (European Commission, 2010)

- In the field of food service such as restaurants, food stalls or other hospitality industries, food waste could be the consequence of the following reasons. Firstly, the consumers finish their food at an average rate of 92% if they take the food themselves, according to a 2005 study at Cornell University. A solution for this problem is to serve only a set portion dishes, however, it should be made based on a carefully research on the actual size of the portion. (European Commission, 2010). Another way to control is to let the customers serve themselves but calculate the price based on the weight of the food. This way, the customers will have an inner motivation to eat up their food without leaving good food discarded.

3 THE COMMERCIAL WASTE MANAGEMENT LEGISLATION IN CHOSEN REGIONS

On 12 June 1991, Germany put into force Packaging Ordinance and became the first nation to adopt a binding legislation on recycling and recovery of commercial waste. *Under this regulation*, the producer of the product is taking the extended responsibility for post-consumer products, which has been conventionally taken by *municipalities and taxpayers.*

On 20 December 1994, the European Parliament introduced a directive (94/62/EC) in order to *harmonize* the package and packaging measures of each country and to *provide a high level of environmental protection* and to protect the designed *functioning of the internal market*. This is the first international commitment on packaging waste which was the result of a 2-year negotiation among the stakeholders such as European Parliament, European Organization of Packaging and other relating parties. (Bonadies, et al., 2001)

In the first version of the Directive (published in 1994) stated that, by the end of 2001, all countries should have at minimum level of 50% recovered (with a maximum of 65%) and 25% recycled (with a maximum of 45%) of the total packaging waste. More detailed, the lowest recycling rate for each material fraction was 15%.

The Directive and the targets set for all member states were updated in 2004 (Directive 2004/12/EC). According to this version (currently in force), by the end of 2008, the member states should have recovered a minimum of 60% by weight of packaging waste, whereas the recycling targets for each material were 60% by weight for glass, paper and board, 50% by weight for metals, 22.5% by weight for plastics and 15% by weight for wood (the overall target for recycling was 55%, with a maximum of 80%).

Among the European Member States, there were the exceptions to the deadlines of the Directive for Greece, Ireland and Portugal (mainly due to their specific geographical features, *such as the large number of small islands or the presence of rural and mountain areas*). For these three countries the 2001 targets should be obtained by the end of 2005, while the 2008 targets should be reached by the end of 2011. (Ferreira da Cruz, et al., 2013). Since the publication of Directive 94/62/EC, all the member states have been

seriously taking into account by investing a considerable amount of money in the infrastructure of recycling facilities and sorting equipment.

According to the German Commercial Waste Ordinance (Nature Conservation and Nuclear Safety , 2002), *the fractions paper and cardboard, glass, plastics, metals and biodegradables need to be separated in order to ensure a high-quality recovery*. In case these materials are sending to the pre-treatment plant before any further action, a combined classification of them (except for bio-waste fraction) is allowed.

In Asia, the legislation on commercial waste has not been tighten enough so that packaging waste is still a big problem due to the poor source separation and recycling. Following is the short summary of the current waste management legislation in chosen Asian countries.

In Japan, in 1996, the Packaging Recycling Law came into force which encourages the contribution of recycling action. In addition, by 2015, the waste recycling rate in this country is expected to increases 24% or 12 Mt. In Taiwan, the prohibition of plastic bag free discard is valid since 2003 which reduce the overload of landfills. (Atsushi , et al., 2005).

In Republic of Korea, there is the controlled limit of packaging disposal as well as the legislation of compulsory recycling items (paper pack, metal cans, glass bottles and plastic) are put into force. In India, Taiwan and Korea, the governments have promulgated the prohibition of using thin plastic bag. Such strong and direct policy shows that many countries/regions have dealt with a huge trouble with *disposable packaging in their waste management systems.* (Atsushi , et al., 2005)

In the Appendix II and III, more details about the legislation and policy concerning recycle materials are provided.

4 WASTE MANAGEMENT OF COMMERCIAL ACTIVITY

The following figure is the traditional Hierarchy of Waste management which shows the priority of the treatment methods for integrated waste. However, this approach is rather simple and less accurate for all the cases. Furthermore, it might not point out the best

management alternative for every scenario, especially when more than one treatment facility is combined.

In an integrated waste management (IWM) system, the hierarchy cannot predict, for example, whether composting combined with incineration of the residues would be preferable to materials recycling plus landfilling of residues. An overall evaluation of the system is missing from the functions of the approach. (Mc Dougall, et al., 2008)

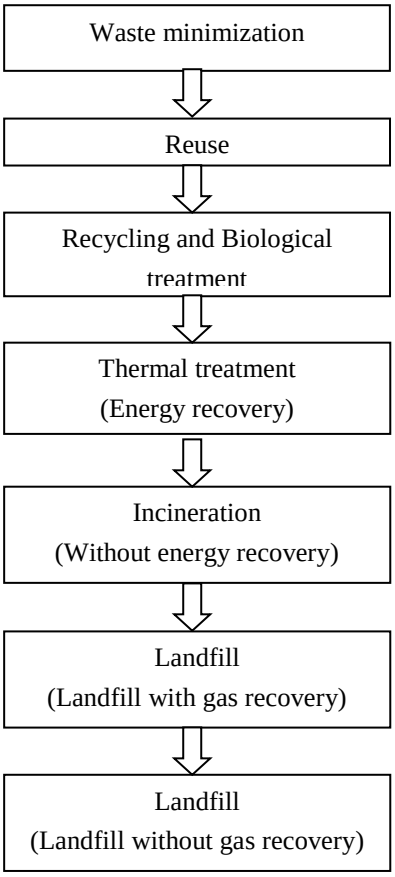

Figure 4. [Modified] The traditional priority order of commercial waste treatment (Mc Dougall, et al., 2008)

The modern approach of waste management as described below could be the improved version of the traditional method. The efficiency of the treatment scenarios is based on the typical characteristics of the location and on the magnitude of the market for recovered products from the facilities. The following figure presents this advanced approach.

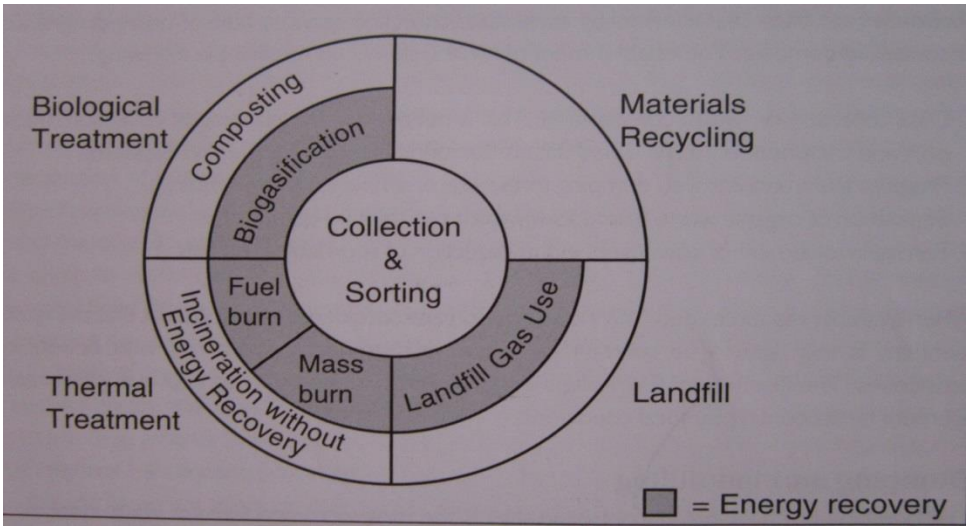

Figure 5. The modern approach of waste management (Mc Dougall, et al., 2008)

4.1 Recycling effort

Statistics from (European Union, 2011) show the recycling ratio of the packaging waste in chosen European countries in the years 2005-2011. It is visible that recycled plastic packaging waste fraction is still at average rate even though this type of wrapping material requires a more serious concern from the governments.

Statistics from (EUROPEN - The European Organization for Packaging and the Environment, 2011) show the results of the progress of pursuing the EU packaging and packaging waste recycling target within Member States until 2011. As could be seen from the below chart, most of the Member States have reached the 55% recycling target by the set year, except Denmark due to a new calculation method of the nation.

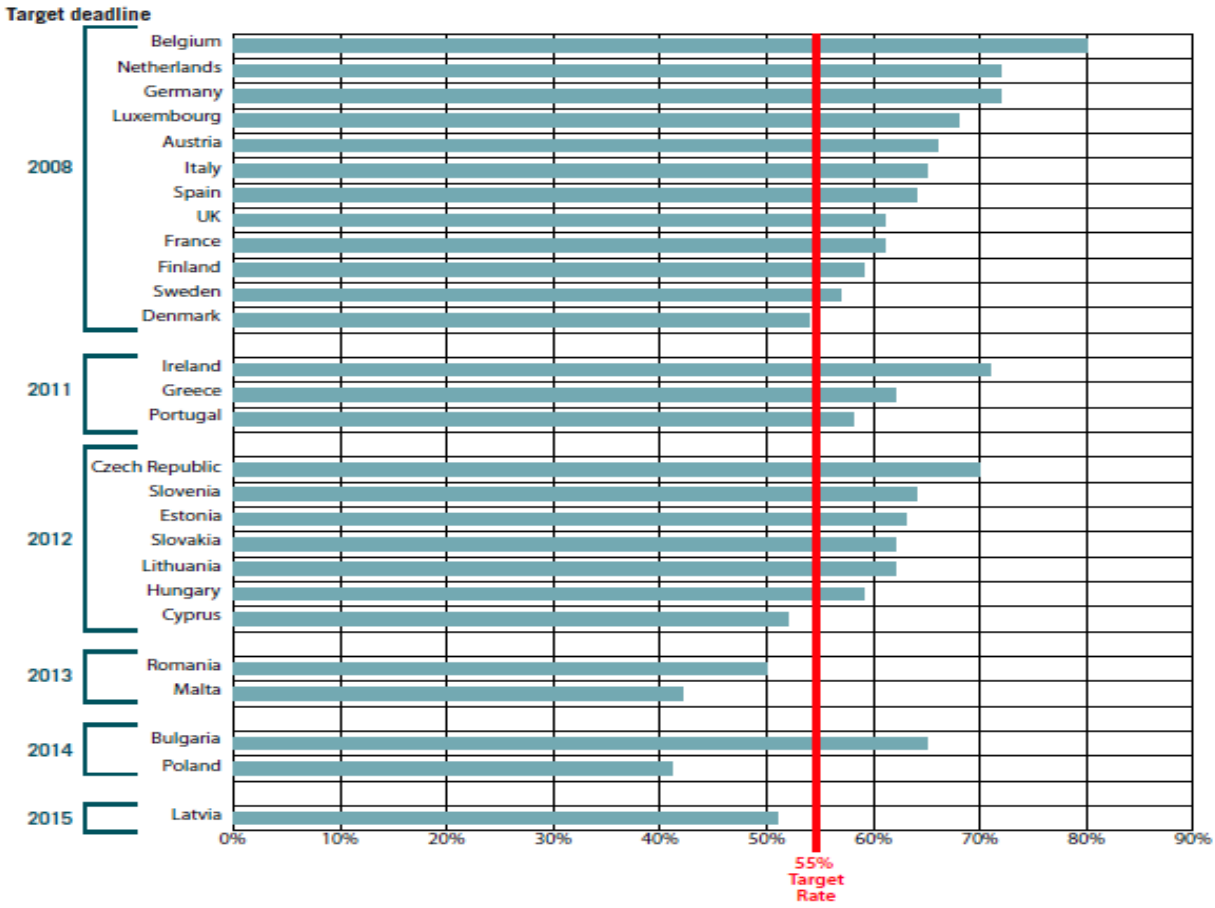

Figure 6. Member States's performance toward the EU recycling target (EUROPEN - The European Organization for Packaging and the Environment, 2011)

In Asia, nowadays, most of the countries/regions recognize the *importance of recycling*. In these nations, there are normally two main trends of collecting the recyclable materials. The junk buyers, who are not working for the waste service companies come to the dump sites (the shops' trash bins and the landfills) and collect the wrapping trash such as plastic bottles, metal cans and paper and cardboard. Later they sell these materials to the junk shops which in turn provide materials for the packaging production.

The second trend of collecting recycling materials is controlled by the formal waste collecting service before transferring waste to any further treatment facilities. (Atsushi , et al., 2005) Nevertheless, very few countries or regions hold data on recycling rates for each type of material, except for Hong Kong, the Republic of Korea, Turkey, and Japan. The recycling rates for typical materials from MSW in these countries are shown in figure (Atsushi , et al., 2005)

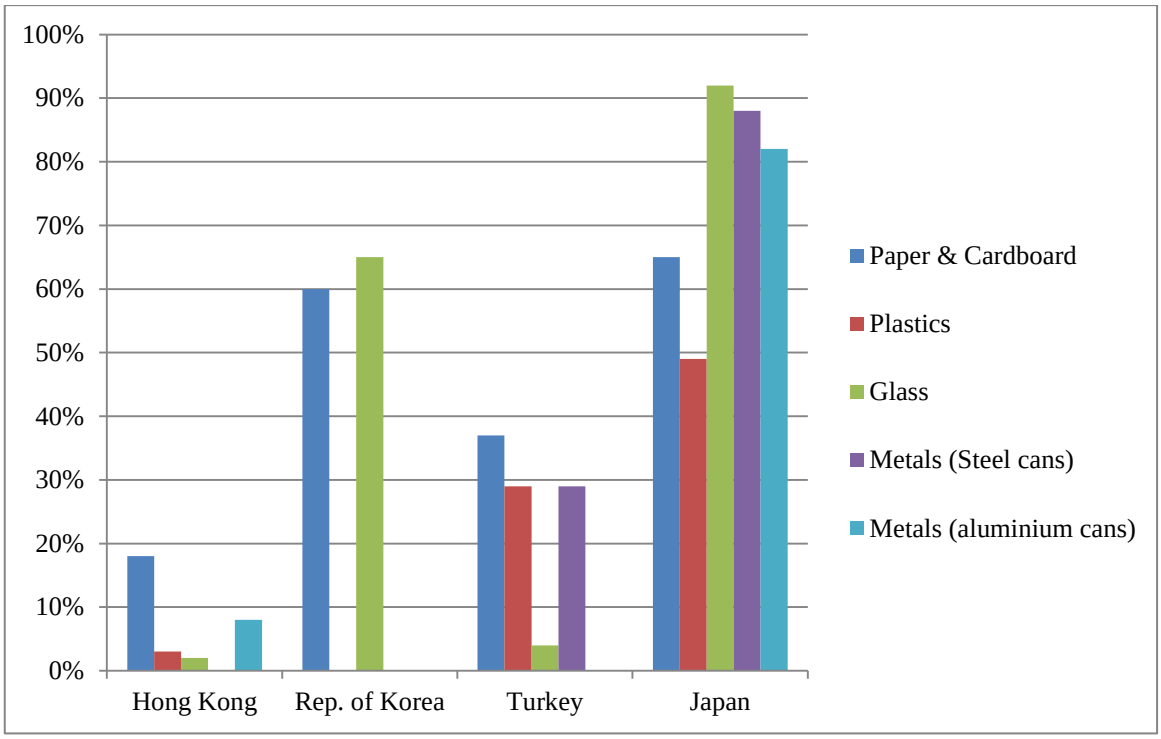

Figure 7. Recycling rates in chosen Asian countries (Atsushi , et al., 2005)

Available statistics for some chosen European countries reflect the effort of the governments on the common trend of increasing the plastic recycling rates. Only some small falls of the plastic recycling percentage are recorded in countries such as Belgium and Poland.

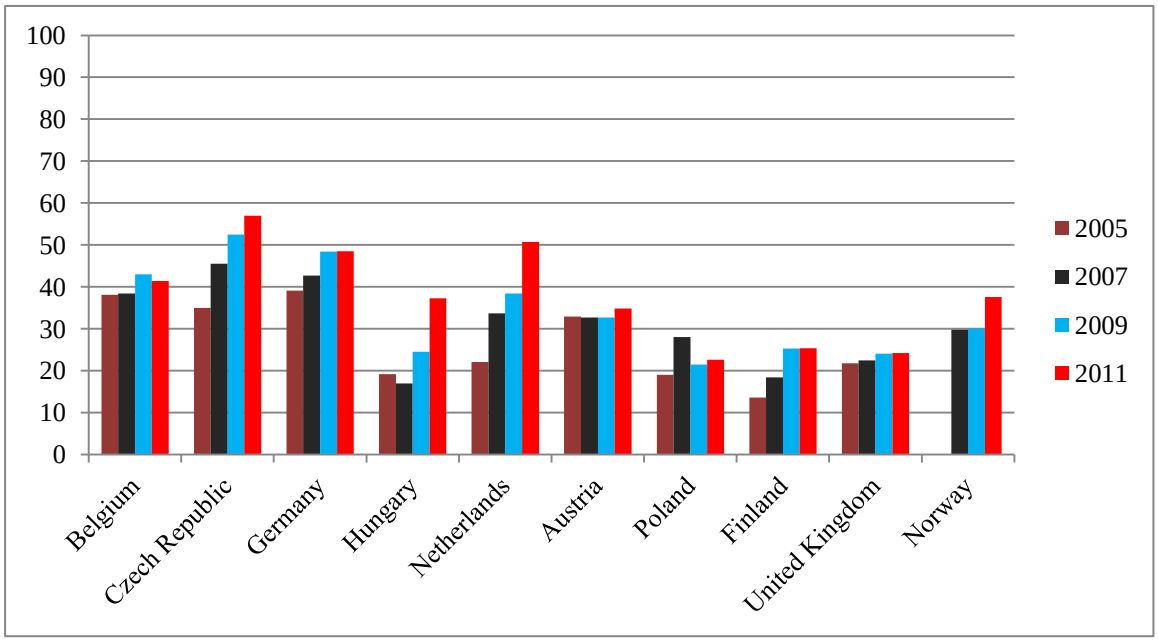

Figure 8. Recycling rates of plastic packaging waste in Europe (Eurostat, 2011)

The recycling rates of paper and cardboard as wrapping material in the period of 2005 – 2011 is summarized in the following chart. Paper and cardboard has been recycled increasingly in the recent years in Nordic countries such as Finland, Norway and Sweden. However, there is a slightly decrease in the recycling rate of this packaging material in other European countries such as Germany, Netherlands and Czech Republic.

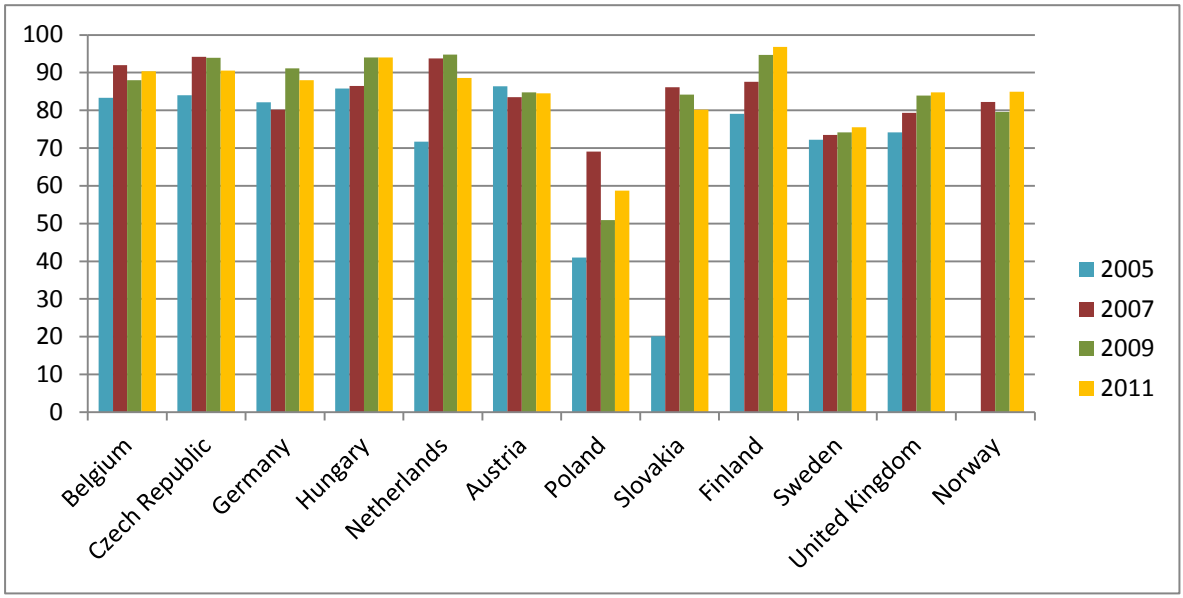

Figure 9. Recycling rates of paper and cardboard waste in Europe (Eurostat, 2011)

A study carried out by (Croasdell, 2011) provided an overall report about the actual amount of steel packaging and aluminum beverage cans put onto the EU-27 market in 2011, which is 3,5 million tons and 400 thousand tons respectively. Approximately 2,6 million tons of steel packaging (73,6%) and 277 thousand tons of aluminum beverage can (68%) were recycled.

Wood recycling rates are likely the most sensitive data of many countries. The reason is that there are contrary definitions on “reused wood” and “recycled wood”. (EUROPEN - The European Organization for Packaging and the Environment, 2011) Comparing to other recycling materials such as glass and metal, which can *easily be melted down* and reproduced, whilst *wood is hard to recycle* because it is not possible to reform wood. This material is also deteriorates by time, according to the environment and preserving conditions. Thus, the percentage of recycled wood or reused wood is hard to attain any increase. On the other hand, metal and glass do not degrade as fast as wood does since they are more resistant under the environmental changes. (W. Dixon-Hardy & A. Curran, 2008)

4.2 Composting

In the period since 1970, recorded a new wave of biological treatment of waste brings about the investment in research and development on composting technology. The reason for this developing trend is the tighten legislation on waste management and the rapidly raising landfill tax. (Schuchardt, 2005). Composting brings the opportunity for the bio-based waste fractions to be treated separately and properly instead of being disposed to the landfill and causing a huge problem with the landfill gas generation. The commercial waste fractions which can be composted are any organic waste and degradable packaging materials.

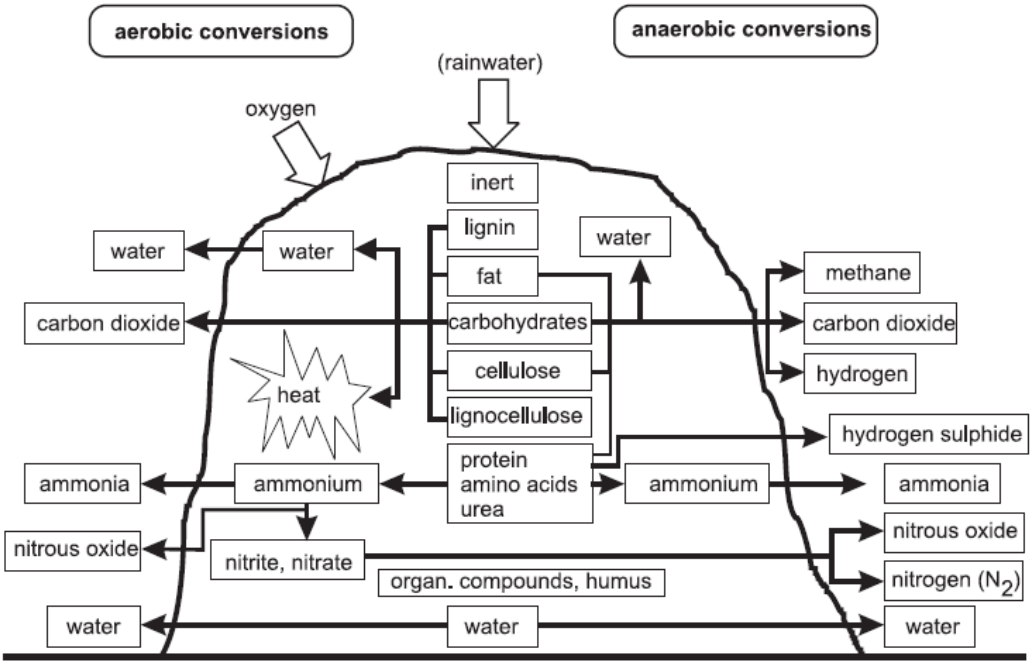

Figure 10. The processes inside a compost heap (Schuchardt, 2005)

The general requirement for the composting site is the far distance to the nearest habitat to avoid any odor or noise pollution to the citizen. The separation of mixed waste from the districts could be taken into account by the source classification, by the manual sorting of the workers at the waste conveyor or by designed machine. This stage plays an important role to the quality of the composting product.

4.3 Thermal treatment

The composition of the waste has an important role in the decision of operating the thermal facility. Waste from commercial (with exception like fish/meat/vegetable/fruit market) and industrial activities have a much higher LHV than domestic waste. The following commercial waste fractions could be treated by thermal techniques: recycling materials maintaining in the mixed waste such as paper and cardboard, wood, textiles and even bio-waste.

The idea of burning waste with or without energy conversion comes from the fact that the CO_2 emission from the combustion of bio-based waste is not taken into account of the total exhausted air.

4.3.1 Incinerator

Incineration of waste (with energy recovery) can erase the burden of the disposal sites by treating capacity up to 90% of the waste in volume, especially with the mixed waste streams with the big share of commercial waste fractions such as paper, plastics and garden waste. In most of northern Europe countries, wooden broken pallets are often combusted rather than repaired or reformed because the water content of this waste type is not high, thus the incineration effectiveness is much increasing. (EUROPEN - The European Organization for Packaging and the Environment, 2011)

One characteristic of the waste incineration process is that the mixed waste feedstock is generally not prepared properly such as separation and water distraction. This problem leads to one requirement for the combustion in order to obtain a high performance of the facility. The oxygen had to be provided sufficiently to oxidize fully the waste. Moreover, the temperature of the furnace has to be at 850°C at minimum so that waste could be converted totally into carbon dioxide and water. Normally, incineration without energy generation is *not a preferred option due to costs and pollution*. (Hoornweg & Bhada-Tata, 2012)

The following figure introduces a simple model of a waste to energy plant with the proper air emission and bottom ash control.

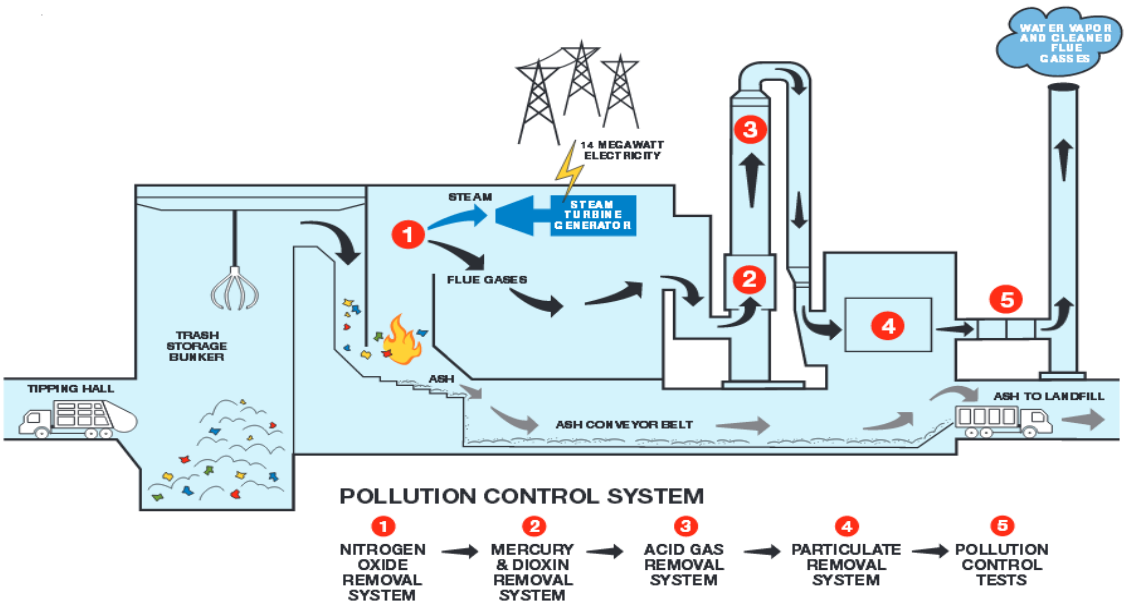

Figure 11. Simplified model of incineration process with energy generation (U.S. Environmental Protection Agency, 2014)

4.3.2 Gasification

Gasification is the thermal conversion of any kind of organic waste in a heat chamber with just a small amount of air/oxygen to produce syngas – the mixture of hydrogen, carbon dioxide, carbon monoxide and some other substances. The amount of oxygen required is just enough to ensure the heat level that is necessary for the process to happen. At the second heating stage, the generated syngas is utilized to generate heat or/and electricity. (Stantec, 2011)

The categories of gasification technologies used for waste treatment consist of three primary types such as fixed bed, fluidized bed and high temperature gasification. Among the three popular technologies, the high temperature gasification is utilized at the largest magnitude. The figure below presents the simplified model of the mentioned facility.

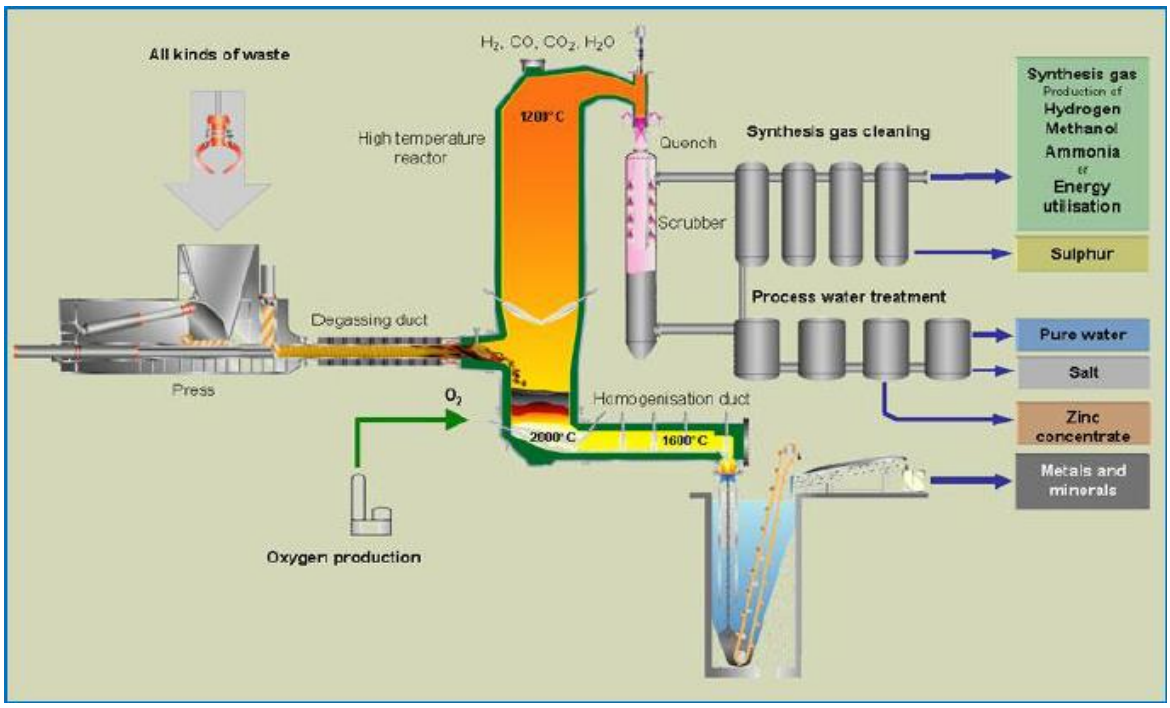

Figure 12. Gasification of mixed waste (Stantec, 2011)

Firstly, the mixture of waste goes through a degassing duct, there the water content of the waste will be reduced by the drying phase. Then, the waste flow is injected into a gasification chamber/reactor where it is heated under certain conditions. At this stage, occurs the transformation of the solid fuel to syngas. Oxygen is fed into the chamber so that temperature of more than 2000°C can be obtained. (Ibid.)

4.3.3 Pyrolysis of waste

Differently from incineration technology, *pyrolysis is the thermal degradation of a substance in the absence of oxygen*. This process requires an external heat source to maintain the temperature required. Generally, the temperature range of the pyrolysis process of mixed waste is between 300°C to 850°C. (Stantec, 2011)

Recently, in Taiwan, one advanced technique of plastic waste treatment using pyrolysis process has been researched and developed. The product of the treatment is fuel oil which can be used in *boiler for heating or diesel engine for electricity*. (ITRI - Industrial Technology Research Institute, n.d.) The following figure describes simply the process of waste plastic pyrolysis to obtain fuel oil.

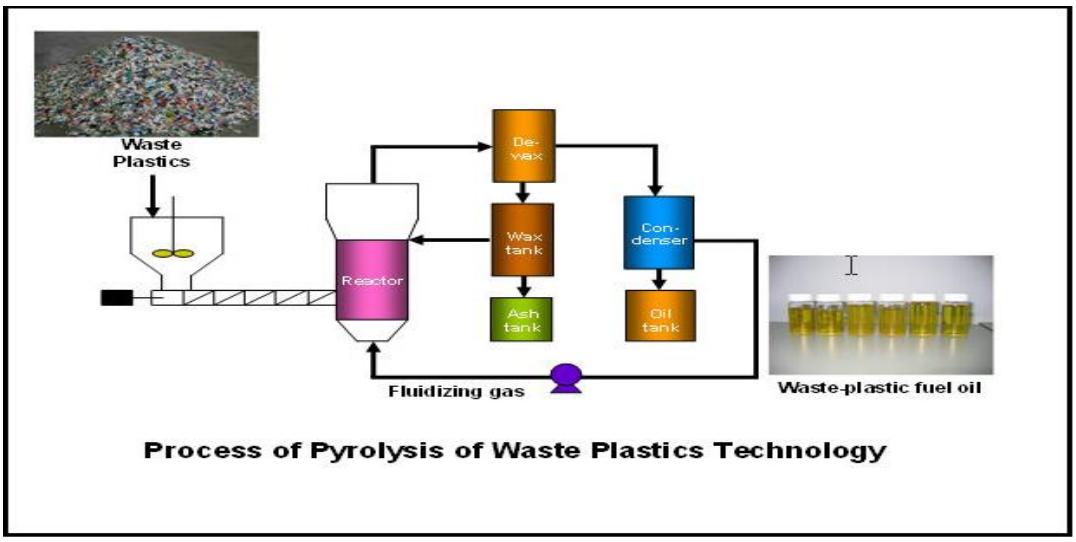

Figure 13. Fuel oil produced from waste plastic using pyrolysis technique (ITRI - Industrial Technology Research Institute, n.d.)

4.4 Dumping and Landfilling

Although recycling and composting of waste have been spread widely among European Member States in the past years, however, statistics points out that a number of countries is still sending their waste to the disposal sites. More actions need to take into account to reach the compulsory target of having 50% of waste recycled by 2020. (Euractiv, 2013)

The Figure 15 below provided the amount in million tons of waste to go to different waste treatment facilities. Approximately 45,5% of EU-27 total waste in 2010 was transferred directly to the disposal sites which mainly are landfills and a small share of water bodies discharges and mining sites. (European Commission, 2013)

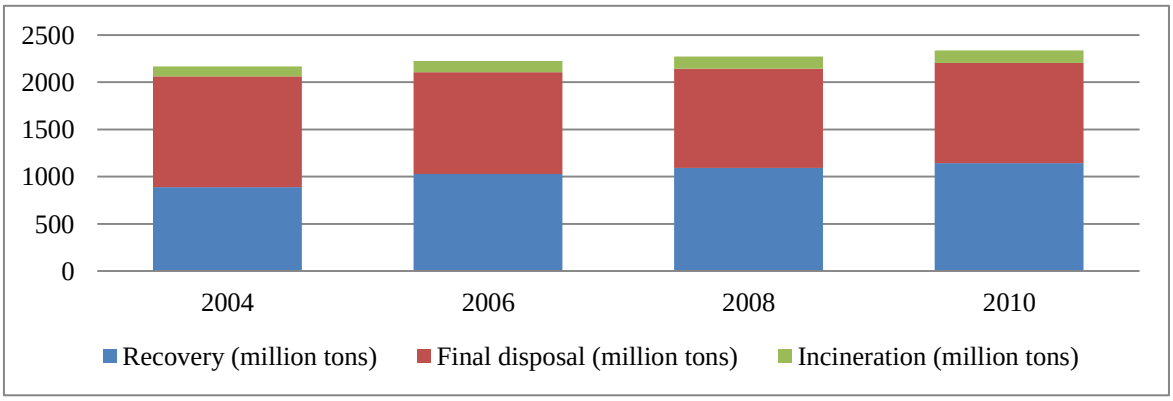

Figure 14. Waste treatment stream in EU-27 through the years(European Commission, 2013)

A raising action of the European governments is to enforce the landfill taxes in order to redirect the waste stream away from the dump sites. Landfill tax was first introduced in Denmark and the Netherland, resulting in considerably low rates of all-type waste going to landfills.

A tax level of approximately or greater than €30 per ton of waste is applied in most of the city within EU-27. In a more powerful action, a number of countries has already increased their tax level to the range between 50€ and 70€. (European Topic Centre on Sustainable Consumption and Production, 2012)

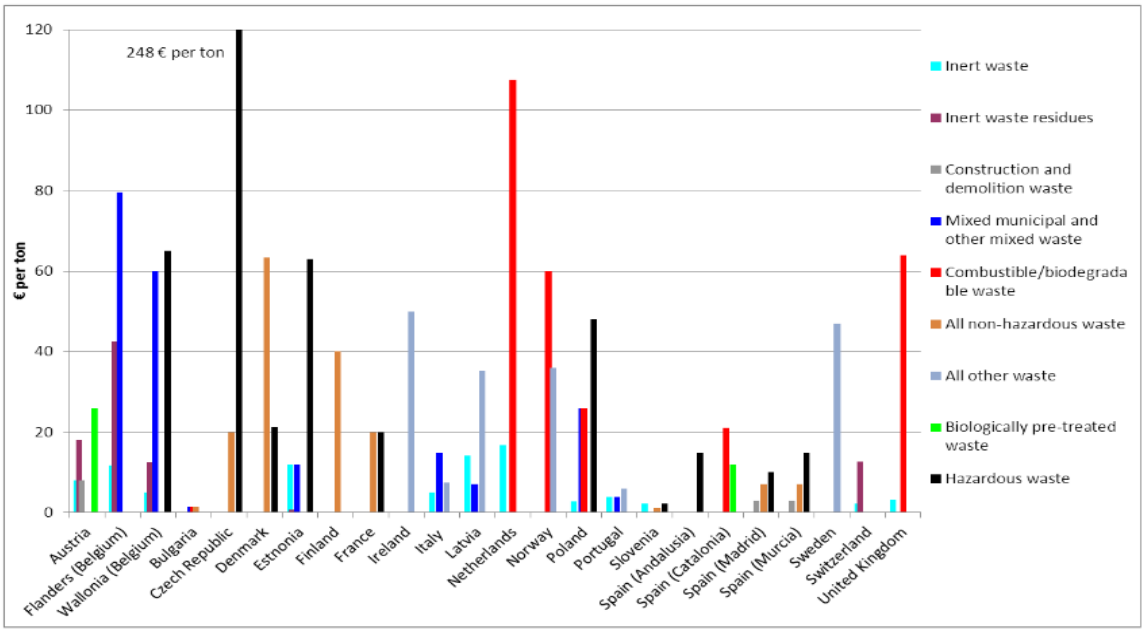

Figure 15. Comparison of landfill tax on different waste fraction in Europe (European Topic Centre on Sustainable Consumption and Production, 2012)

In Asia, landfill is still the dominant method for waste disposal without proper management and updated technologies. A typical analysis was made about the trend of waste disposal in the leading Asian countries/regions to evaluate the waste management system as the whole. The following figure shows the situation of waste stream in China in 2000 with landfilling accounts for about 96.9%, composting 1.3%, and incineration 1.8% of the generated waste. This sad situation is predicted not to *change significantly* in the coming years because the source separation and recycling of materials are not put in practice in majority of the cities and standardized incineration of waste is yet an unaffordable option. (Idris, et al., 2004)

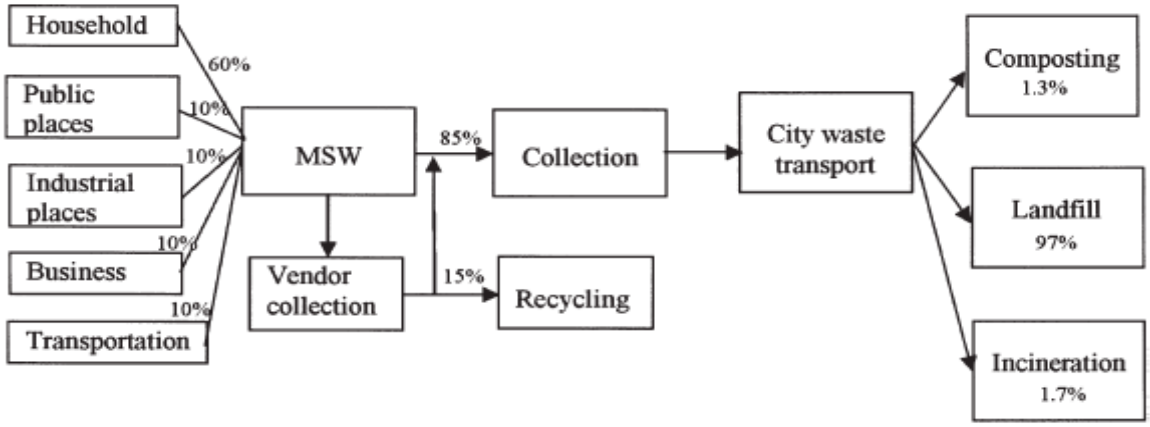

Figure 16. Waste treatment stream in China in 2000 (Idris, et al., 2004)

In Taiwan, about 40% of waste is transferred to the landfills with the existence of improper dumping and non-sanitary landfills. About 15.56% of the waste flow to incinerators and landfills is recycled. However, there is not reliable data on how much of these recycled materials is put back to the markets, as the result of the data missing of the recycling process. At the present, 19 incineration plants are operating, and by 2002, they have combusted approximately *4.32 million tons (54.2%) of MSW and 1.28 million tons (2%) of general industrial waste*. Similar data was recorded in Republic of Korea despite of the government effort on introducing new legislation on waste management, recycling materials and landfilling. (Ibid.)

The situation in Malaysia is not so much promising when 25% of landfills *in municipal councils* and 59% in *district councils* are open dumps. The lack of cover material applications and odor control from the decomposition bring the threat to the living environment of the surrounding regions of the landfills. (Idris, et al., 2004)

4.5 Waste treatment cost

The following table shows the summary of the waste management cost in different countries which have the variable ranges of income. (Hoornweg & Bhada-Tata, 2012). As can be seen, the higher income the country has, the much higher cost the management is.

Table 4. Summary of waste treatment cost in countries with different income levels (Hoornweg & Bhada-Tata, 2012)

	Low Income Countries	Lower Mid Inc Countries	Upper Mid Inc Countries	High Income Countries
Income (GNI/capita)	<$876	$876-3,465	$3,466-10,725	>$10,725
Waste Generation (tonnes/capita/yr)	0.22	0.29	0.42	0.78
Collection Efficiency (percent collected)	43%	68%	85%	98%
Cost of Collection and Disposal (US$/tonne)				
Collection[2]	20-50	30-75	40-90	85-250
Sanitary Landfill	10-30	15-40	25-65	40-100
Open Dumping	2-8	3-10	NA	NA
Composting[3]	5-30	10-40	20-75	35-90
Waste -to-Energy Incineration[4]	NA	40-100	60-150	70-200
Anaerobic Digestion[5]	NA	20-80	50-100	65-150

Collection costs normally make up the biggest share of all waste management costs in those countries/regions *where landfill is a major disposal method, including the Republic of Korea*. In India, laborers make up a portion of 90 percent of total waste management costs, mostly in collection phase. Differently, in Japan, a dominant portion of budget is invested in incineration facilities, and this cost was recorded to be doubled between 1987 and 1993. (Atsushi , et al., 2005)

5 METHODOLOGY OF THE CASE STUDY

The case study was carried out based on the collected information concerning the commercial activity in Hanoi from both personal surveys and interviews and the scientific literature references of the field.

Due to the unavailability of separated data on commercial waste from the domestic solid waste flow, the calculation on the GHG emission of the mixed waste fractions will be assumed to represent the situation of the commercial waste in Hanoi. This assumption was made base on the fact that bio-waste and packaging waste – the two major composition of commercial waste make up the biggest share in the waste generation of Hanoi. The following assumptions are made in order to simplify the calculation process.

The GHG emission potential of the current system and the scenarios will be calculated based on the emission factor of each commercial waste factor while being combusted (as presented in Table 5), composted or disposed. (Jochen, 2014)

At the composting facility, each ton of bio-waste can produce 510 kg of composting product (Virtavuori, 2009) meanwhile emitting 4,060kg CH_4 emission, 0,055kg N_2O emission and 0,157kg NH_3 emission, giving a total emission factor of 118kg CO_2 equivalents. (Nguyen, 2012).

Table 5. Emission factors of commercial waste fractions in thermal treatment (Intergovernmental Panel on Climate Change, 2006) (Jochen, 2014)

Fuel	**Percentage by weight (%)**	**Lower heating value as received (MJ/kg)**	**Emission factor for stationary combustion (kg of greenhouse gas per MJ on a Net Calorific Basis)**		
			CO_2	**CH_4**	**N_2O**
Bio-waste	53,81	4,65	0	$0{,}03 \times 10^{-3}$	$0{,}004 \times 10^{-3}$
Paper & Cardboard	6,53	16,75	0	$0{,}03 \times 10^{-3}$	$0{,}004 \times 10^{-3}$
Plastic	13,57	4,5	$91{,}7 \times 10^{-3}$	$0{,}03 \times 10^{-3}$	$0{,}04 \times 10^{-3}$
Wood	2,51	15	0	$0{,}03 \times 10^{-3}$	$0{,}04 \times 10^{-3}$
Textile	5,82	11	$91{,}7 \times 10^{-3}$	$0{,}03 \times 10^{-3}$	$0{,}004 \times 10^{-3}$

The landfill produces a certain amount of annual CH_4 emission which can be obtained by the following equation (Intergovernmental Panel on Climate Change, n.d.)

$$Methane\ emission \left(\frac{Gg}{yr}\right) = MSW_T \times MSW_F \times MC_F \times DOC \times DOC_F \times F \times \frac{16}{12} - R \times (1 - OX)$$

Where:

MSW_T = total MSW generated (Gt/yr) = 2000 Gg/yr

MSW_F = fraction of MSW disposed to solid waste disposal sites = 71,5 (%)

MC_F	=	methane correction factor (fraction = 0,6)
DOC	=	degradable organic carbon (fraction)
DOC_F	=	fraction DOC dissimilated (default is 0,7)
F	=	fraction of CH4 in landfill gas (default is 0,5)
R	=	recovered CH4 (Gg/yr) (currently equals zero)
OX	=	oxidation factor (fraction - default is 0)

The value of DOC could be calculated by the formula (Intergovernmental Panel on Climate Change, n.d.)

$$\textit{Percent DOC (by weight)} = 0.4\,(A) + 0.17\,(B) + 0.15\,(C) + 0.30\,(D)$$

Where:

A = per cent MSW that is paper and textiles

B = per cent MSW that is garden waste, park waste or other non-food organic putrescibles

C = per cent MSW that is food waste

D = per cent MSW that is wood or straw

6 COMMERCIAL WASTE MANAGEMENT CASE STUDY: HANOI, VIETNAM

6.1 The legislation system concerning commercial waste management in Vietnam

The elemental legislation for environmental management in Vietnam is the Environmental Protection Law (amended in 2005), which takes precedence over other laws concerning waste management. The waste management system was established under the Decree on Solid Waste Management (2007), *covers the overall waste management policy and prioritizes recycling, reutilization, and treatment and recovery, to prevent land used for landfills*. The collection, transport, and treatment of waste are subject to fees of 40,000 VND/t for MSW (Sakai, et al., 2011)

The government of Vietnam has set the target to the year 2025 of the 40% reduction of the nylon bags utilized at supermarkets and commercial centers compared to the 2010 level. (Environment, 2009). Moreover, a goal of controlling 100% landfills that cause serious environment pollution listed in the Decision 64/2003/QD-TTg dated 22 April 2003 by the Prime Minister has been mentioned in the National action.

6.2 The current situation of commercial waste in Hanoi

The rapid urbanization, population growth and the upgraded living condition are the main reasons for the considerably increase of waste including commercial waste in Hanoi. (Thao, 2005). To be the capital of Vietnam with over 6.5 million citizens after the area expansion in 2008, the city of Hanoi produces the most waste in the Northern Vietnam with average ratio of 0.61 kg/cap/d and second most in the whole nation.

In the past years, urban districts areas have been experiencing a fast urbanization. Statistics show that, in 2009, Hanoi has 70 open-markets and *hundreds of restaurants and commercial centers* in total. The amount of waste is increasing daily, however, the legislation framework, the infrastructure as well as the awareness of the citizens (who were living in rural region of extended Hanoi) are obsolete *causing many environmental burdens* for citizens and the local authorities. (Ngo, et al., 2012)

Based on the Vietnamese Standard (TCVN 6705-2009 - Non-hazardous solid waste - Classification), commercial waste is not considered as an individual waste type but included in domestic solid waste together with waste generated from households and services activity. This classification model leads to the difficulty on collecting data about the generation and composition of commercial waste exclusively. (Nguyen, 2014)

The whole system of both formal and informal waste managing sectors in Hanoi is described as the figure below. (Kosuke, 2012) (Kosuke & Masahiro, 2013)

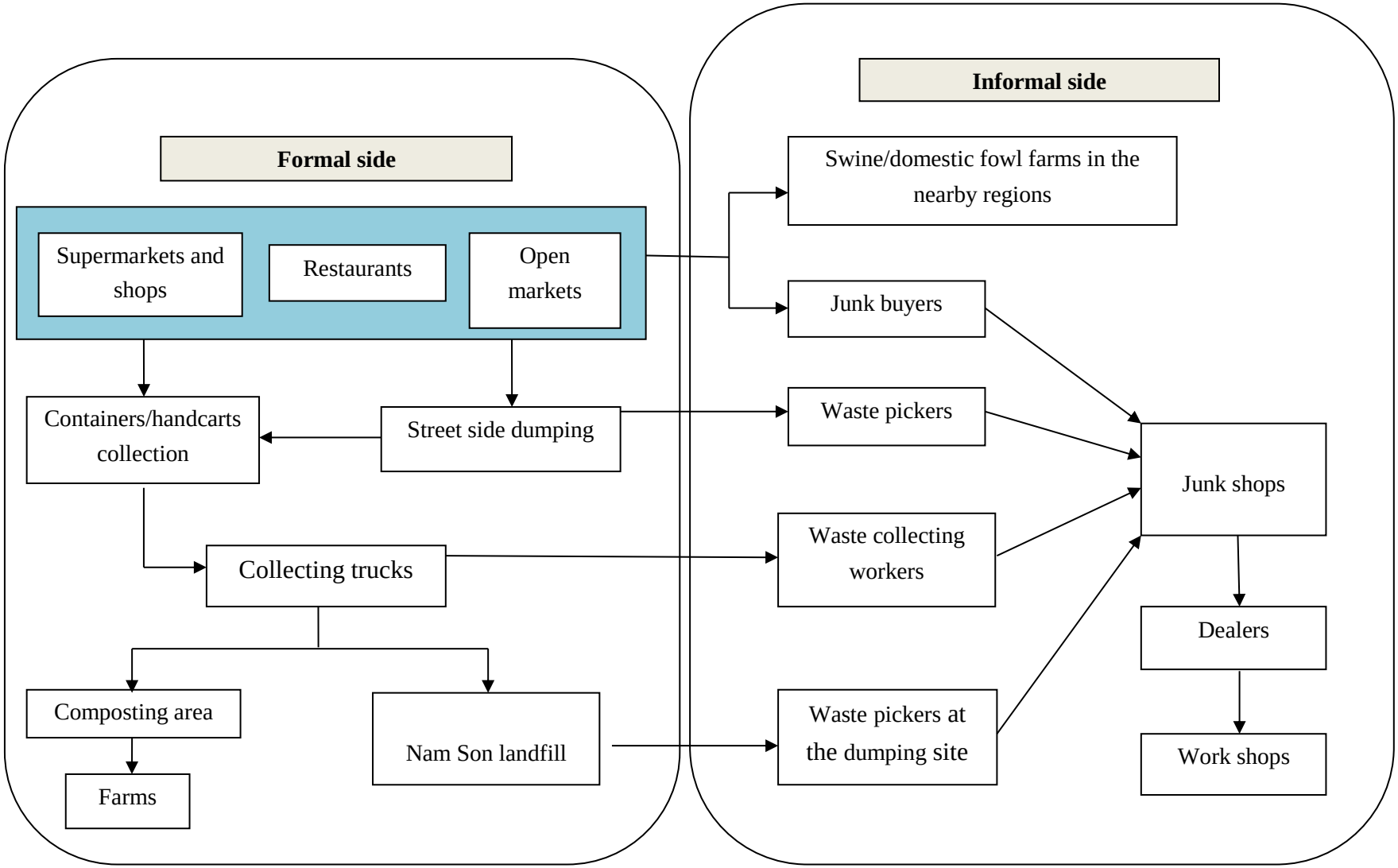

Figure 17. [Modified] Commercial waste flow in Hanoi (Kosuke, 2012), (Kosuke & Masahiro, 2013)

There are more concerns about the waste management in Hanoi such as:

- Season – The composition of the waste is rather affected by the seasonally different consumption. In the warm months, there is a higher demand of fruit and vegetable. Furthermore, a considerable amount of street food and drink stalls operates at their peak capacity as Vietnamese people prefer to go out more during this time of the year. Thus, the amount of organic waste both with and without wrapping layer is raising suddenly. (Thao, 2005)

- Cultural activities – The Cultural festivals such as the Vietnamese New Year or Woman's Day result in more organic waste produced due to the amount of orange trees and flowers bought for the occasions.

- Hanoi was expanded from the original area of the city in 2008 into a triple size, which has brought the heavier burden for the city in the waste management. The integrated areas were countryside and rural area so that the characteristic of the waste fractions are of more complex.

- Hanoi is an attractive destination with a significant increase of tourists in the recent years. This has led to the consequences of more service facilities as well as commercial infrastructure of the city. The amount of waste together with the complication of waste collection process has raised an important problem in the managing system. The fractions of waste in supermarkets, shopping center, open-markets and restaurants are described in the following chart.

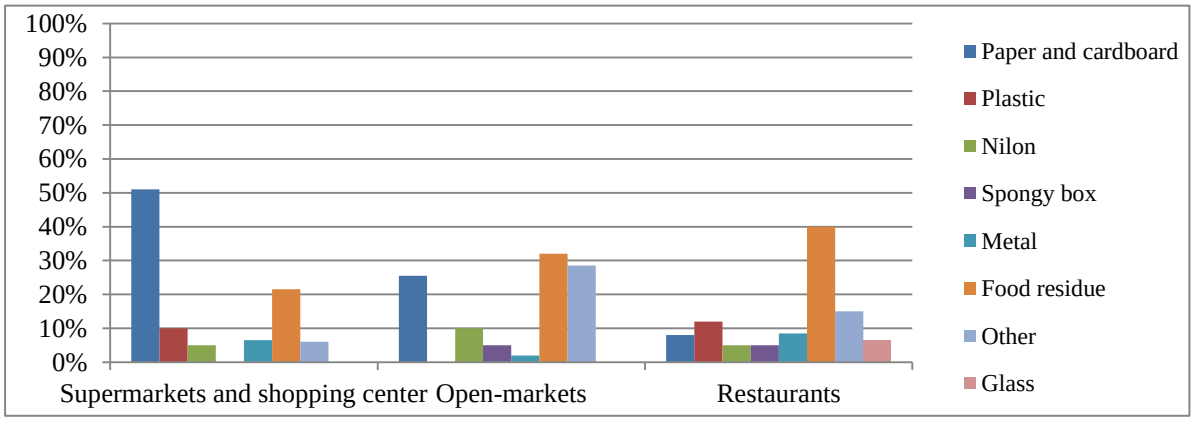

Figure 18. Commercial waste fractions in Hanoi (Ngo, et al., 2012)

The classification of waste in super markets is fairly easier to carry out because the composition of waste is much simple compared to the mixed solid waste from the districts. Furthermore, in big size supermarkets, waste collectors are employed by private waste service, thus they are well-trained about the source separation of waste.

On the other hand, practices show the complicated progress of waste management in open markets in Vietnam due to the typical features of this trading form. The major fractions of waste from open markets are plastic bags and organic waste which do not have high calorific value if combusted. Organic waste fraction is generally transported to farms to be feedstock for animals or to the composting sites as only high quality, non-meat food can be used for this purpose. Noticeably, disposed food which is still wrapped in packaging materials is the main hardship for the classification stage before any further treatment.

Researches show that waste separation in restaurant system in Hanoi also facing complicated trouble. While some big restaurants have strict regulations for waste source separation, other street food stalls in small and medium size discard waste *freely on the street without any separation*. (Ngo, et al., 2012)

A study of (Tomonori , et al., 2008) compared the difference in waste composition between waste flows from Hanoi districts including and excluding markets as the table below. As presented in the table MW1 is the municipal waste generation in the regions excluding big markets and MW2 is the municipal waste generated in regions with big markets.

Table 6. Comparison of waste fractions from different sources (Tomonori , et al., 2008)

	MW1		MW2	
	(kg)	(%)	(kg)	(%)
Garbage, grass, leaves	36.5	39.4	49.6	56.3
Paper	5.8	6.2	4.4	4.9
Leather, rubber	0.3	0.3	0.0	0
Plastics	7.8	8.4	7.8	8.8
Textiles	2.0	2.2	2.6	2.9
Wood	0.5	0.5	0.8	0.9
Glass	0.8	0.9	0.1	0.1
Bone, shell	0.4	0.4	0.3	0.3
Metals	0.3	0.3	0.0	0
Ceramics	0.3	0.3	1.7	1.9
Bricks, others	38.2	41.2	21.0	23.8
Total	92.6	100	88.2	100

Based on the table, there are several subjective assumptions were made by the writer. The first assessment is that waste fractions such as organic waste, plastic, textiles, wood can represent the characteristics of commercial waste as they make up a bigger portion when counting the waste flows from business entities.

It can be concluded roughly that these waste type are the main commercial waste in the urban regions of Hanoi. However, the divergence of these commercial waste percentage in the two cases is not considerably much, leads to the second consumption that the cycling activity at supermarkets and other commercial centers is taking place rather effectively. Other prediction is that the commercial waste make up a smaller share compare to the household waste. It can be estimated that commercial waste makes up 15-20% of the total waste generation of Hanoi. The assumption about the active collection service for the whole solid waste generation in general and commercial waste in particular would be demonstrated in the following sector.

6.3 Waste collection services

In the urban regions of Hanoi, waste generated is collected by the only service of the Urban Environment Company (URENCO) who has the exclusive contract with the local People's Committee of Hanoi. The task of URENCO is to collects, transports and disposes of municipal solid waste including commercial waste.

One research results in the data of the waste collection rate in Hanoi from 2000 to 2003, with the average percentage increased from 65 to 71% (World bank, MONRE and CIDA, 2004). In one study of (Thao, 2005) it was estimated that 98% of the waste will be collected properly in Hanoi by 2006. However, the author could not assume exactly because of the expansion of the city up to triple size in 2008. This factor affects considerably to the increased amount of waste generated as well as the waste collecting rates of the city.

In the city of Hanoi, approximately 66% of revenue for managing MSW is sponsored by the Hanoi city People's Committee, 10% is from household waste collection fees and the maintaining 10% comes from fees collected from business entities. (Kosuke & Masahiro,

2013). In the same study, a summary of collection fee together with the citizen satisfaction were created at a certain amount of chosen commercial entities and offices.

Table 7. Average waste collection fee of surveyed commercial entities in Hanoi (Kosuke & Masahiro, 2013)

Business type	Number of survey samples	Average collection fee	Percentage of satisfaction on the service
Shops	80	14.8€/month	93.8%
Restaurants	40	46€/month	90%
Hotels	40	55€/month	87.5%
Offices	40	15.5€/month	82.5%

6.4 Existing treatment methods for solid waste in Hanoi

6.4.1 Composting of organic waste

Encompassing Hanoi there are some composting facilities such as: Cau Dien composting plant, Kieu Ki dump site, Gialam district and Green Sun Co.Ltd, Duong Lieu, Hoai Duc, Ha Tay. However, Cau Dien composting factory is the most effective operating one with the designed capacity of 140 tons of mixed waste per day. (The European Union's Asia-Link Programme, 2009).

The Appendix I describes the composting process flow at the facility. Firstly, recyclable materials are sorted manually by the workers at the conveyor and automatically by magnetic separator. The inert substances after the separation are transported back to the landfill for further treatment. The bio-based waste is pre-treated (chopped in to pieces) before going to the fermentation unit. Then, the products are transferred to the maturing yard where the fermentation process is complete. The next stage is the refining which consists of the second elimination of extraneous matters, dust collection and adding nitrogen, potassium and phosphorus to the mixture. Finally, comes the packing phase of the composting product. (Luong, 2011)

It is expected at the construction stage that by processing 50 000 tons of MSW per year, the factory could reach the productivity of approximately 13 260 tons of composting

product. Nevertheless, due to the lack of source separation and the complicated composition of waste, the practical annual yield of the facility is only 8000 tons of fertilizer from 22000 tons of mixed waste. The fractions of waste to be treated at the composting factory are shown as in the Figure 16 below (Hanoi National Economics University, 2009)

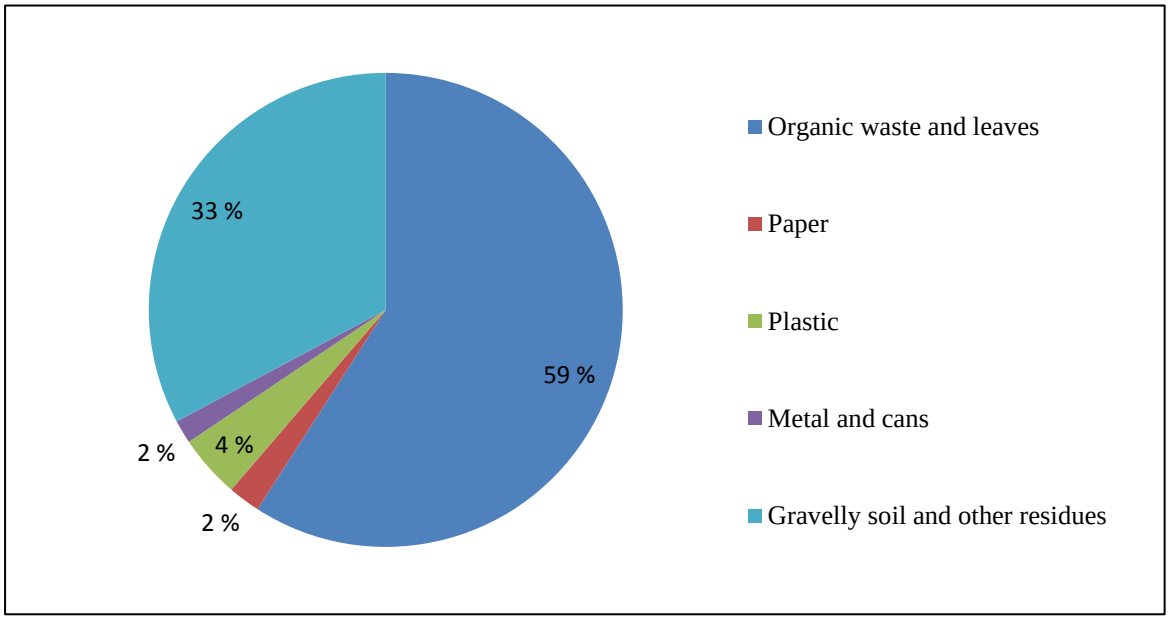

Figure 19. Composition of the waste flow at Cau Dien composting plant (Hanoi National Economics University, 2009) (The European Union's Asia-Link Programme, 2009)

The composting production market is limited due to high operation costs, low tipping fee of the State and low selling price of compost. Besides, farmers still prefer using chemical rather than organic fertilizers. Enterprises have not yet received incentives such as support for sorting waste at-source, consumption, advertising products, subsidizing product price in production of compost. Composting quality is not currently at the good level due to the technology shortage and standard control of the product. (Ministry of Natural Resources and Environment - Vietnam, 2014)

6.4.2 Recycling of wrapping and containing materials

Junk buyers recycled 25.5% by weight of containers and packaging waste. (Dong, et al., 2012). Firstly, junk buyers visit recyclable waste sources such as small to medium size restaurants and retail shops to collect the recycling materials by paying the owners some

tips. The price of recovered materials is normally low and changing due to the demand from the material manufacturers.

Secondly, MSW collection workers from Hanoi URENCO recover recyclable waste that has been disposed onsite together with other waste fractions simply by the handcarts. Thirdly, waste pickers collect recyclable waste at landfill the fraction of packaging materials is still high due to the lack of source separation. At the composting facility, recycling materials are sorted manually out of the mixed waste stream. Only organic waste remains and transported to further composting phases.

The governmental institution has not been able to control the informal recycling villages due to the spontaneity of the operation. Packaging materials (of three main groups: waste paper, waste metal and waste plastic) from the junk shops are traded to approximately 80 - 90 handicraft villages and workshops to be reused or reformed. *Recycling villages are the handicraft villages* where collected objects are reproduced simply by hand or with rudimentary techniques. (The European Union's Asia-Link Programme, 2009)

6.4.3 Landfilling

Landfill is a dominant form of solid waste disposal in Vietnam currently. Statistics show the number of landfills in the whole country is 91 including 17 sanitary dumping sites only. In Hanoi, Nam Son landfill is the only existing disposal site of waste for the whole region. (Nguyen, et al., n.d.) The landfill is located 55 km from the city center of Hanoi with the magnitude of 150 hectares. Daily, a quantity of approximately 4000 tons of mixed waste is delivered by trucks to the dumping sites. (Luong, 2011). The fractions of waste going to the landfill are considered to be the same as the data from Figure 16 above.

6.4.4 Waste-to-energy

The energy consumption and the price of energy are increasing in the past decade in Vietnam. With the current electricity generated from coal fired power plants and hydroelectricity plants, the national target toward sustainable development might not be obtained. The scenario of commercial waste combustion combined with energy production will erase the major burden of the landfills, the environment and the government.

At the present, there are some utilized small scale incinerators in the urban regions of Hanoi. Nevertheless, most of these thermal treatment facilities are of poor technology and without air pollution control unit. The only standardized waste-to-energy system which uses mixed waste as the feedstock is under construction and expected to first operate by June, 2014. The location of the rotary kiln and stoker incinerator is on the site of the only landfill of Hanoi, which could reduce the stress for the overloaded disposal area.

The initial design of the rotary kiln stoker is to combust approximately 75 tons of mixed waste per day that normally go to disposal site in Hanoi and at the same time generate 1,96 MW of electricity. The air emission control unit was constructed to ensure that Dioxin emission from the incineration will be lower than the *designated medical waste restriction of 2.3ng-TEQ/m^{3}N* (Hitachi Zosen Corporation, 2012). With the target of resolving energy shortage and problematically environmental issues in Vietnam and reducing burdens of the landfill, the first operation of the facility is highly expected. (NEDO, 2012)

There is the fact that the main composting facility of Hanoi city is struggling with the fertilizer market break-down and the low performance of the production compare to designed capacity (60%). Another combusting technology called Aono is introduced in order to deal with the daily huge organic waste stream and at the same time produce energy. The following figure describes the fundamental of the thermal treatment facility.

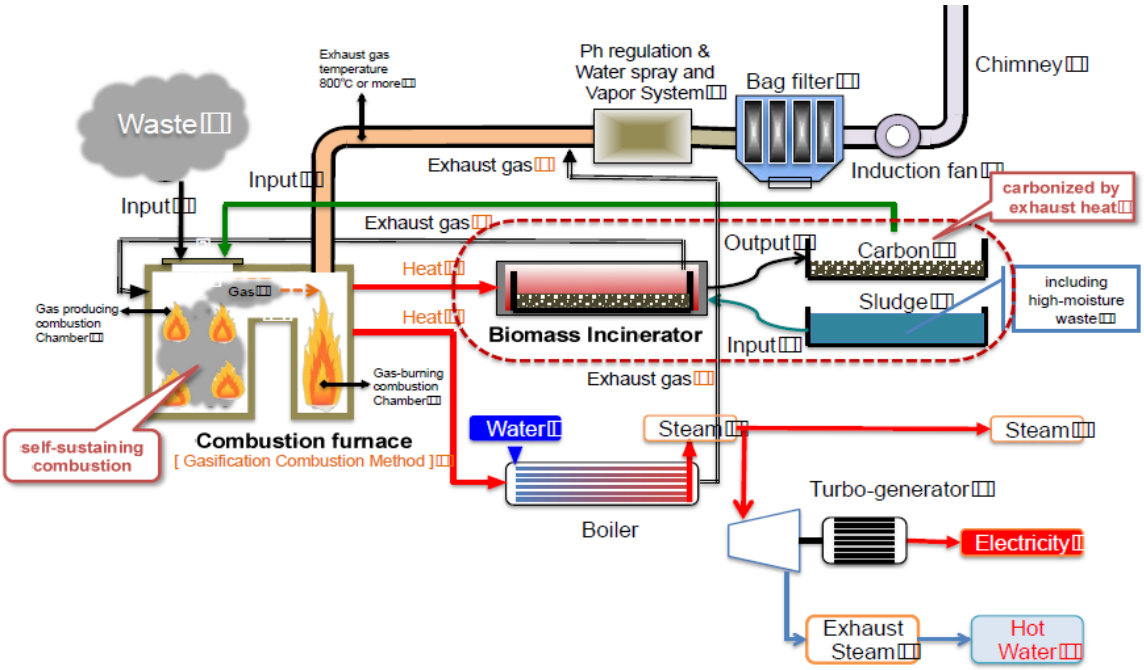

Figure 20. AONO organic waste incineration system (NEDO, 2013)

Aono's biomass incineration system utilizes organic wastes as the major feedstock in order to produce energy from the recovered heat of the combustion. The combusting facility consists of different units of *incinerator, exhaust heat boiler, carbonization chamber and flue gas cooling unit.*

The significant feature of the incineration furnace is the 2-phase gasification combustion. Waste is fed into the first chamber to be gasified then led to the second furnace to be incinerated. This technology ensures the standard thermal treatment for the waste fraction which has a low heating value. The temperature of the chamber satisfies the environmental criteria of WHO (800℃) and Vietnam (1,050℃) for waste management without any requirements of additional burning fuel. (NEDO, 2013)

With the waste type which contains a high fraction of water content, the carbonization chamber is an advanced unit to support the complete combustion in the incineration. Discharged gas is treated properly with the water spray and bag filter system to control the air emission before entering the atmosphere. Heat from the combustion is recovered by a water circulation boiler to generate electricity and heat. (NEDO, 2013)

6.5 Calculating the GHG emission of different scenarios

Currently, the region's MSW is processed at multiple facilities. Approximately ¼ of the recycling materials (plastic, glass and metal, paper and cardboard) is collected by the junk buyers. Part of bio-waste is treated at the composting facility while solid waste residues are taken to the landfill for disposal. To reduce the burden of the landfill and nature resources, instead of fossil fuel, mixed waste could be incinerated in a small thermal power plant situated onsite of the landfill.

At this incinerator plant, heat generated from the combustion process could be utilized to generate energy. Two different scenarios in addition to the existing situation were created and compared to the existing situation in order to find out the best treatment method for the commercial waste from the studied region. Table 6 below describes the scenarios for the solid waste management for the region.

Table 8. Commercial waste treatment scenarios for Hanoi city

Scenarios	Composting	Stationary combustion	Recycling facility	Landfill
Case 0 (Baseline)	Bio-waste	-	Plastic materials Paper and cardboard Metal & Glass	Mixed waste Composting residues
Case 1	Bio-waste	Mixed waste	Plastic materials Paper and cardboard Metal Glass	Combustion residues Composting residues
Case 2	-	Bio-waste Mixed waste	Plastic materials Paper and cardboard Metal & Glass	Combustion residues

The GHG emission of each scenario was calculated in order to make a comparison and find out the best commercial waste management alternative for Hanoi under the GHG potential point of view.

Using the data from Figure 16 and the equation introduced in the methodology of the study, the value of DOC was calculated to be 15%. With an average amount of 5500 tons of collected waste per day, after being manually recycled/bought from the informal sector of 25.5%, approximately 4097.5 tons of mixed waste are going straight to the disposal site (71.5% by weight) and composting facility (3% by weight) in Hanoi. The total amount of CH_4 emission from the landfill annually is roughly 60 Gg/yr = 0.06Mt/yr

Table 9. Total GHG emission of each waste management scenario

Scenarios	Total amount (Mt CO2 equiv./yr)
Case 0 (Baseline)	1,6
Case 1	0,26
Case 2	0,17

Calculation shows that the current scenario has the most GHG emission which reflects the same discussion of the previous chapters. The first scenario is the optimal option which collects most of the recyclable materials; sends the bio-waste to the composting facility and incinerates the rest of the waste.

6.6 Assessment and suggestions for the improvement of the commercial waste management system

The current management system for the urban regions of Hanoi is not yet an optimal choice toward the national target as well as the common climate change goal. Firstly, the waste collecting activity is not synchronous as it is handled by both formal and informal sector. This leads to the difficulties of the policy makers due to the inconsistent data of collected waste fractions. The price of recycled materials at the junk shops is rather low that subsidies from the government are expected in order to promote the recycling packaging waste approach.

Source separation is not a trend among the citizens, which leads to more difficulties for the collecting services when gathering the waste from trash bins. It is expected that the classification of recycling materials should be taken into account at the source such as supermarkets or retails. It results in a more effective overall performance and increases the recycling rates of commercial waste.

The classification of solid waste based on the national standard does not consider commercial waste as one separate waste type which limits the database transparent about the waste fractions as well as the effects of improving commercial waste management scheme to the whole solid waste system in Hanoi.

As landfill is still the major solution for municipal solid waste (including commercial waste) in many countries, it should be put under a special concern of the governments. The major disposal sites are still open dumps, *and are managed poorly either by the local authorities or by other landfill operators*. (Idris, et al., 2004). Furthermore, waste classification is not popular and uniform in most of the Asian countries including Vietnam, thus the fraction of mixed waste is still high. These problems will cause both negative impacts on the environment and the secure of the society. (Idris, et al., 2004)

The calculation of the GHG emission of total waste (including commercial waste fractions) management alternatives in Hanoi shows the weakness as well as set the caution on the current waste treatment system of Hanoi. Annually, an approximately amount of 1,5 Mt CO2 equiv. is emitted to the atmosphere from the landfill without any action of control or capture.

At the same time, numbers claim the benefit of a waste-fired incinerator to reduce significantly burden of the government toward the national Climate Change target as well as providing a sustainable source of energy to the citizens. Nevertheless, it is highly recommended that the staff should be well-trained about the technology in order to manage the air emission from the combustion if this unit is designed within the incineration facility.

7 CONCLUSION

In the past decade, rapid economic growth and uncontrolled urbanization in different parts of the world have led to the serious problems with solid waste management system, including commercial waste treatment. The paper work has analyzed the current global situation of commercial waste which contains of the two major fractions: packaging materials and food waste.

It can be concluded that in developed countries where commercial waste legislation system is tighten, the recycling rates of the packaging wastes as well as the control of food waste are at high performance. However, in the developing countries, the data on commercial waste management is uncertain due to the existence of the informal sector in waste management. The legislation on commercial waste was put into force, but not really spreading the power over the society.

The source separation of waste has been put under more caution, resulting in the effectiveness of the collecting phrase. Thus, the share of mixed waste is getting lower in these countries, resulting in the burden reduction of technology development on waste treatment. In most of Asian countries, landfills are still the main waste management

method, causing a huge trouble with the living environment and the serious reduction of the land use.

Incineration of waste is still the trend in European countries which solves the landfill problem as well as provides considerable source of energy for the communities. Some leading Asian countries/regions such as Japan and Taiwan have handled well the waste stream by combusting a major fraction of mixed waste besides the recycling activities. The practical results of waste management of these countries might be the motivation for other Asian countries to change the direction of waste treatment.

The case study of the commercial waste management in Hanoi, Vietnam analyzed the current situation of the city by evaluating the treatment facilities such as recycling sector, composting site and landfill. Incineration plants for mixed waste as well as bio-waste only are suggested to be the solution for the coming years. The effectiveness of the composting site improvement, incinerators operation and informal recycling sector control is shown through a simplified calculation chapter on GHG emission potential of given scenarios. Number proves that the current waste management system has the highest CO_2 emission to the atmosphere, concurrently raises the action of the government on waste control including commercial waste.

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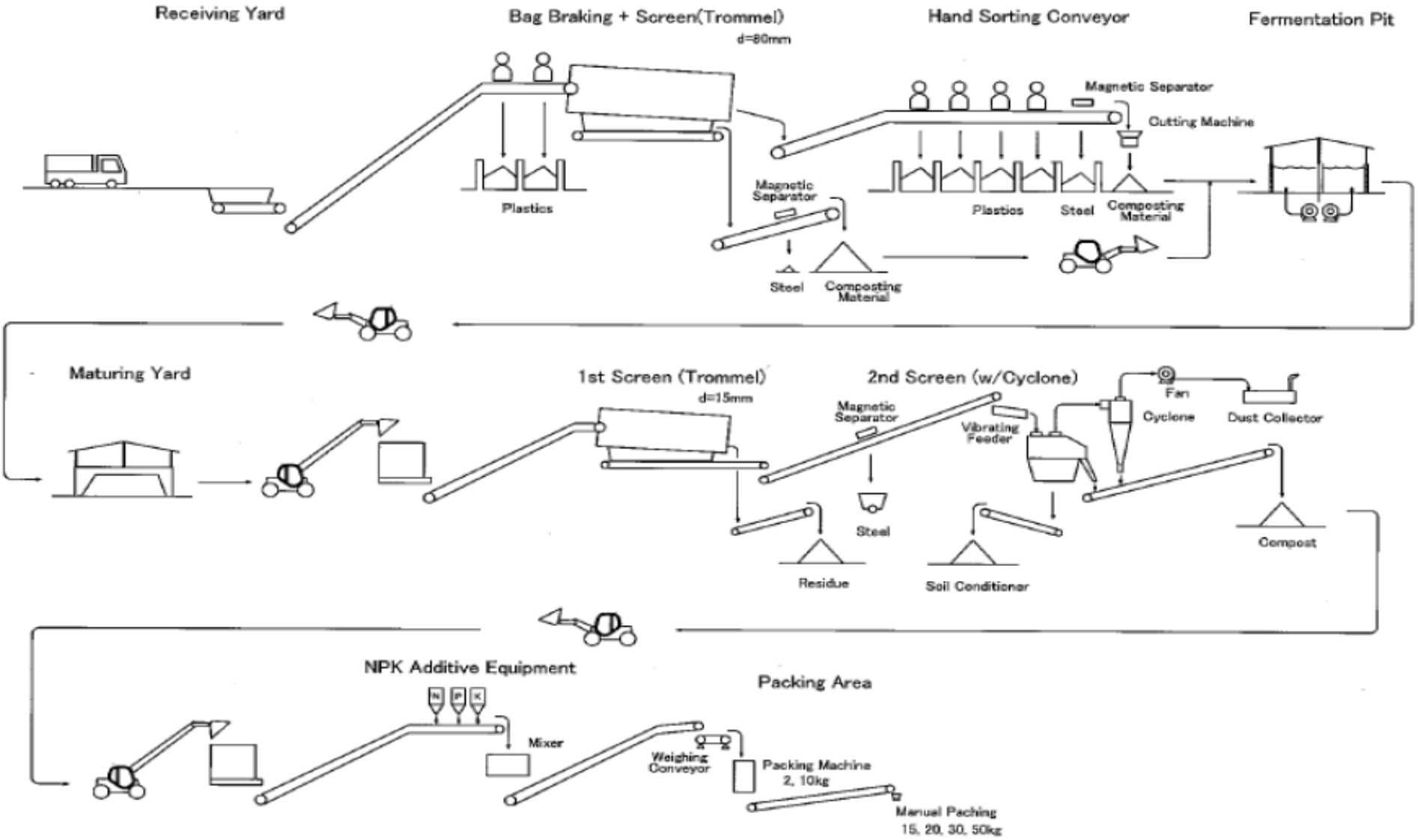
APPENDIX I. Composting process flow of the bio-waste fraction in Hanoi (Luong, 2011)



APPENDIX II. Legislation and policy on recycle waste management in Asia (Atsushi , et al., 2005)

	Philippines	Taiwan	Thailand	Turkey	Japan
Legislation	RA9003 Ecological Solid Waste Management Act (2001)	Waste Disposal Act (1974, amended 2001) Resource Recycling and Reuse Act (2002)	Enhancement and Conservation of National Environmental Quality Act, B.E.2535 (1992)	Solid Waste Control Regulation (1991)	Basic Law for Establishing a Sound Material Cycle Society (2000) Waste Management Law (1970, 2000 amended) Law for the Promotion of Utilization of Recycled Resources (2000 amended)
Basic goals or standards	RA9003 sets targets for solid waste avoidance and volume reduction.	Avoidance or reduction, recycling, and disposal.	MSW generation per capita, non-collection rate, recycling rate, etc. are set as standard for 2005 to 2010.	Preventing damage to the environment during solid waste generation, transportation, and disposal. Waste minimization, proper disposal and more recycling/recovery.	Productivity per resources use, recycling rate, and final disposal volume are main standards under the Basic Plan for a Recycling-based Society. Individual recycling laws each set target recycling rates .

APPENDIX III. Legislation and policy on recycle waste management in Asia (continued.) (Atsushi , et al., 2005)

	China	Hong Kong	India	Indonesia	Republic of Korea	Malaysia
Legislation	• Law on the Prevention and Control of Solid Waste Pollution to the Environment (1996). • Temporary Provisions on Some Issues in Implementing Comprehensive Utilization of Resources (1985, 1996 amended). • The tenth Five-year Plan for Renewable Resources Recovery and Reuse (2001).	• Waste Disposal Ordinance (1980, amended 2004).	• Municipal Solid Waste Regulation (Management and Handling) (2000).	• Act no. 23/1997 on Environmental Management.	• Waste Management Law (1986, amended 1999). • Resources Conservation and Recycling Promotion Law (1992, amended 2003). • National Comprehensive Waste Management Plan (1993).	• Environmental Quality Act (1974, amended 2001). • Environmental Quality (Scheduled Wastes) Regulations (1989).
Basic goals or standards	Waste reduction and minimization of solid waste output, and comprehensive utilization of resources.	Unclear.	Minimization of the burden of landfills is addressed in the Regulation.	Indonesian Agenda 21 (management of waste and emissions, including management of hazardous waste, management of solid and liquid waste, and management of radioactive waste).	The goal "firm establishment of a sustainable and resource circulating socio-economic foundation" is given in the National Comprehensive Waste Management Plan.	Waste minimization is prescribed the in Environmental Quality Regulations (only for hazardous waste).