# Municipal Solid Waste Management in China with Focus on Waste Separation

Supervisor: Susanne Hartard

Author: Xiaolong ZOU

Student ID: 51209626

30 June 2011

# Declaration

My name is ZOU, Xiaolong, male, born on 29.06.1986. I hereby solemnly declare that this graduation thesis report for APU has been conducted by myself. All the references or contents from other sources have been properly acknowledged. I will take full responsibility for any plagiarism that occurs in the original content of this paper.

Date _____

Signature _____

## Acknowledgement

First and foremost, I want to dedicate this paper to both my father, who has always been a guiding star, giving me the driving force for becoming the man I am today, and my mother, without who's constant caring, nurturing and support, I would never make it this far on my own.

Moreover, I want to express my heartfelt gratitude to Professor Sussane Hartard, for being my supervisor of Master Thesis for APU and Fh Trier, from whom, I get a great deal of inspiration and help.

Last but not least, I want to express the utmost gratefulness to all the classmates and colleagues of IMAT program in Japan and Germany, for knowing them, spending time with them, and laughing with them like a family.

# Abstract

Municipal solid waste management has become a huge topic in many developing countries, especially the ones with huge populations, like China. MSW can be a gigantic trouble causer for the environment, ecological system and societies without proper management; meanwhile, it can also be a resource pool with tremendous potentials for source retrieving, energy recovering, if treated properly. This paper discuss generally about the current MSW status quo, political frameworks and management situations in China with focus on waste separations, both at-source and on-site separation. By introducing the advanced waste management schemes in industrialized countries like Germany and Japan, to determine what is the problems and recommendations for the waste management and separations in China.

**Keywords:** Municipal Solid Waste, Waste Management, Waste Separation, At-source Separation, On-site Separation,

# List of Figures and Chats

# List of Tables

# Acronyms

BMU: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

BMW: Biological Municipal Waste

GfK: German Society for Consumer Research

HW: Hazardous Waste

LFG: Landfill Gases

MA: Mechanic waste treatment plants

MBS: Mechanical-biological waste treatment plant with biological drying

MBT: Mechanical-biological Treatment

MFM: Material Flow Management

MPS: Mechanical physical drying

MSW: Municipal Solid Waste

NDRC: National Development and Reform Commission

OC: Organic Content

RMW: Residual Municipal Waste

RW: Recyclable Waste

OECD: The Organization for Economic Cooperation and Development

UNFCCC: the United Nation Framework Convention on Climate Change

CDM: Clean Development Mechanism

# Table of Contents

# 1. Introduction

Municipal Solid Waste (MSW) treatment has become a common but disturbing issue for developing countries, especially the ones with huge population foundation, like China, India, Indonesia etc. Currently in China, the most practiced way of MSW disposal is through landfills and incinerations. But most of the landfills are without emission or leachate controls, and for the incineration plants, only few are coupled with heat and electricity recovery facilities. These poor "end of pipe" approaches for waste management have lead to great loss of potential resources, huge consumption of energy and funds, together with profound ecological and environmental impacts. However, these cases can be totally reversed if the wastes are treated properly, as proofed in many industrialized countries like Germany and Japan. MSW could be a recourse pool for both material and energy retrieving. By conducting proper waste separations, the organic fractions are collected separately from the non-organics, and used as biomass input to produce energy carriers such as biogas, for electricity and heat generation; also to produce a rich variety of value-added byproducts like RDF, organic fertilizer and others. One major obstacle for the revalorization of MSW in China is the separations of organic wastes from the inorganics. Due to the lack waste classification and both at-source and on-site separation systems, most MSW in China is a mixture of everything, which causes the retrieve of values for organics of MSW both economically costly and technically difficult.

The necessities for the separations of MSW in China is acknowledged and accepted by more and more people, due to the alarmingly generation amount of waste, the environmental impacts from landfilling and incinerating those mixed wastes, as well as the increasing costs spent for treating them. This research aims to conduct a general analysis on the status quo of MSW management in China for urban cities[1]. By introducing and describing the waste source separation mechanism and technologies in Germany and Japan, and a general comparison between the MSW source separation mechanism in China and Germany, to discuss the potentials for

[1] MSW in this paper refers mainly to the residential wastes of urban area due to the system boundary set up for this paper, which is explained in chapter 1.1

improvement and propose recommendations for better systems of separation of MSW that can be applied in China.

## 1.1 Status Quo of Municipal Solid Waste Generation in China

China has become the world's 2nd biggest economic power since the year 2010, replacing Japan, after the United States. The fast economic development in China has lead to an averaged annual 8% of growth rate of GDP; however, many "by-products" have also tremendously affected China's environmental and ecological conditions, with municipal solid waste (MSW) being one of them.

### 1.1.1 GDP and Population with MSW Generation

The fast urbanization and population growth in China has lead to remarkable increase for MSW generation volumes. According to China Statistic Yearbook 2009, the average annual growth rate for MSW from 1979 to 2009 is approximately 7%[2] (refer to Figure 1). When compared to the OECD countries, the annual MSW generation rate combined is not more than 2% from 1980 to 2010(refer to Figure 2[3]). This huge contrast in numbers and volumes also reflects the severe situations faced in China in both the total generation volume and increase rates.

Then comes the question of whether the increase of GDP will definitely lead to the corresponding growth of MSW generation. It might make sense to day, the more domestic products produced, leads to higher consumptions, which followed by higher wastes generation. Figure 3 shows the waste generation per capita and GDP per capita in 2002, we can see that China has rather low GDP and also a low waste generation by then, with less than 5,000 US dollar per year and around 0.8 kg/person/day of waste generation. However, if we take carefully examine the figures between the U.S. and Japan, they share about the same level of GDP but American people have almost

[2] Table based on the figures from China Statistic Yearbook various years
[3] From 2010 and onwards are projection figures, and the base number is set for 100 in 1980 for the calculation of growth. Refer to http://www.eea.europa.eu/data-and-maps/figures/oecd-country-municipal-waste-generation-1980-2030

twice of amount of waste generation than Japanese people. This proves that the economic development might not necessary lead to increase of waste generation.

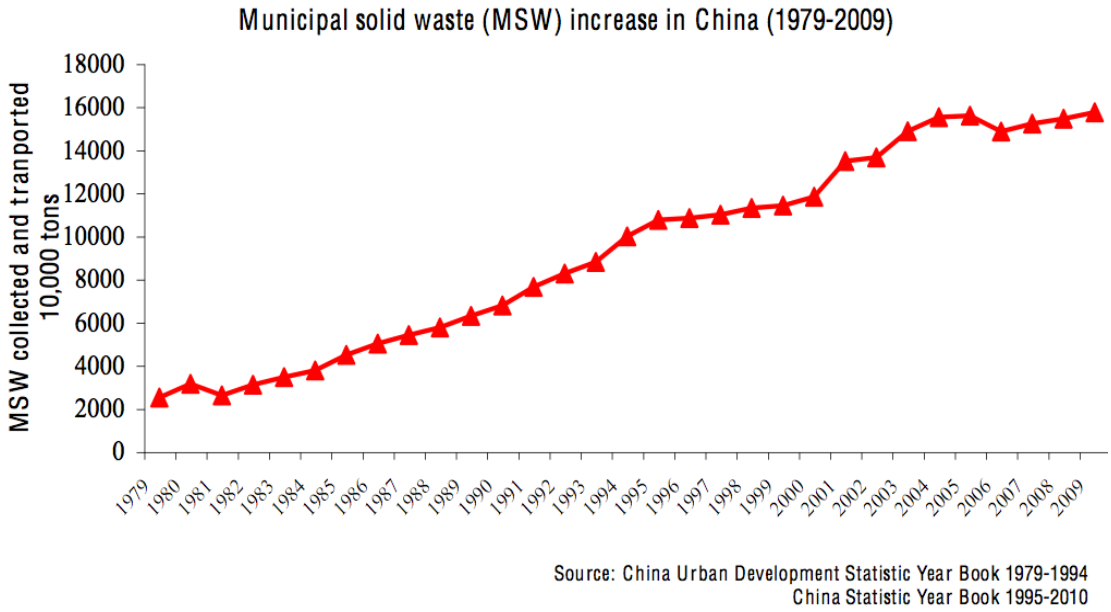
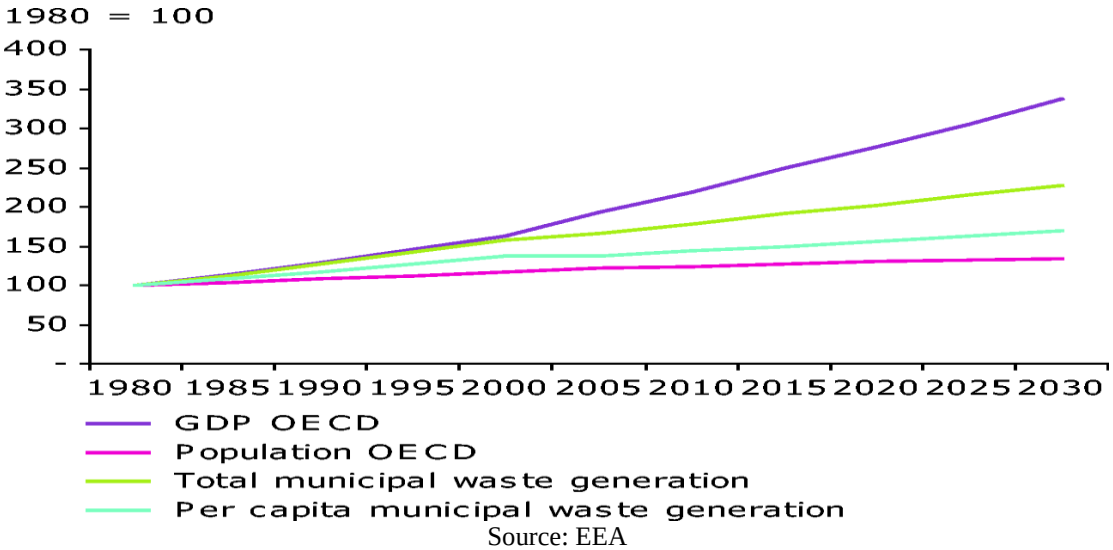
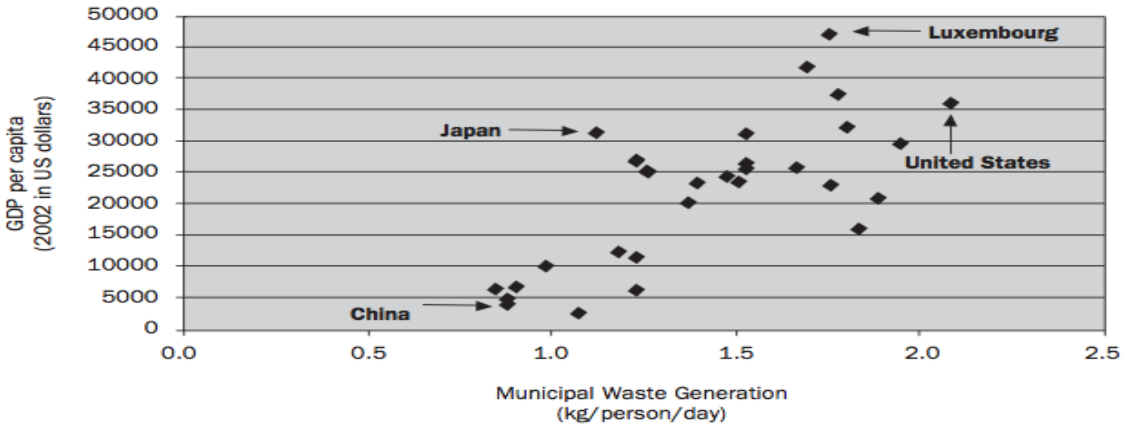



Figure 1 China's MSW Generation from 1979 to 2009




Source: EEA

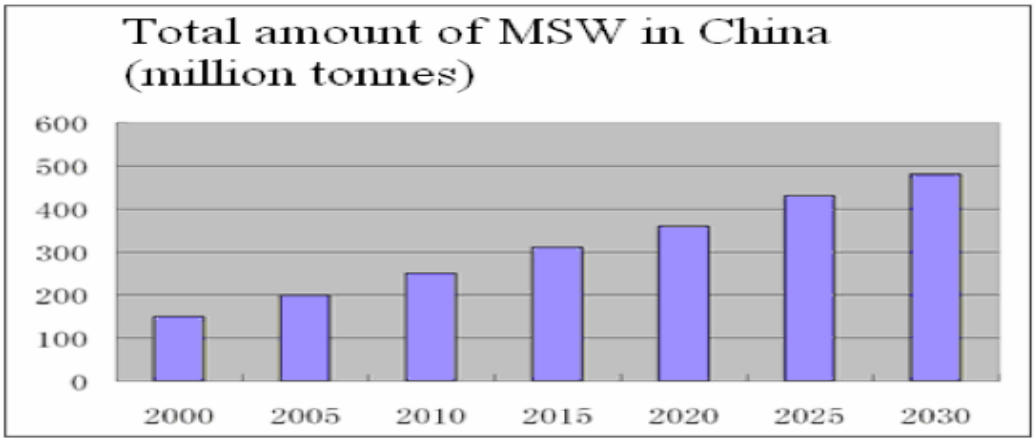
Figure 2 MSW Generation in OECD Countries




Source: OECD

Figure 3 OECD Countries Municipal Waste Generation Compared to GDP

According to a report from PTL Group[4] that, "China's domestic waste generation volume had overtaken the U.S. in the year 2004. If the status quo remains unchanged, by the year 2030 China's annual waste generation (solid) will grow over two folds of the total volume compared to the year 2004, from around 190million to 480 million tons." Figure 4 from the World Bank predicts the waste generation situation in China from 2000 to 2030, based on the already obtained data.




**Source: Word Bank, MSW Management in China, 2005**

Figure 4 Total Amount of MSW in China 2030 (projection from 2010-2030)

Another more direct factor for MSW generation in China is of course the population growth. Due to the fast urbanization, the cities have been the major cradles for waste generations. It is projected by the Word Bank that by 2030, the urban population will

[4] PTL Group Publication, 2010,*Waste Management in China*. http://www.ptl-group.com/index.php/en/china-blog/528-waste-management-in-china

reach 900 million in China with an average waste generation of 1.2 kg/person/day (refer to figure 5).

It is inevitable that there only will be more MSW generated with population growth in China. There were two other projections made, based on separately scenarios of low waste generation and high waste generation (refer to figure 6). With the population base, the lowest waste generation waste per capital is expected to be 1.20 kg/per/day, and the highest 1.8 kg/per/day by the year 2030.

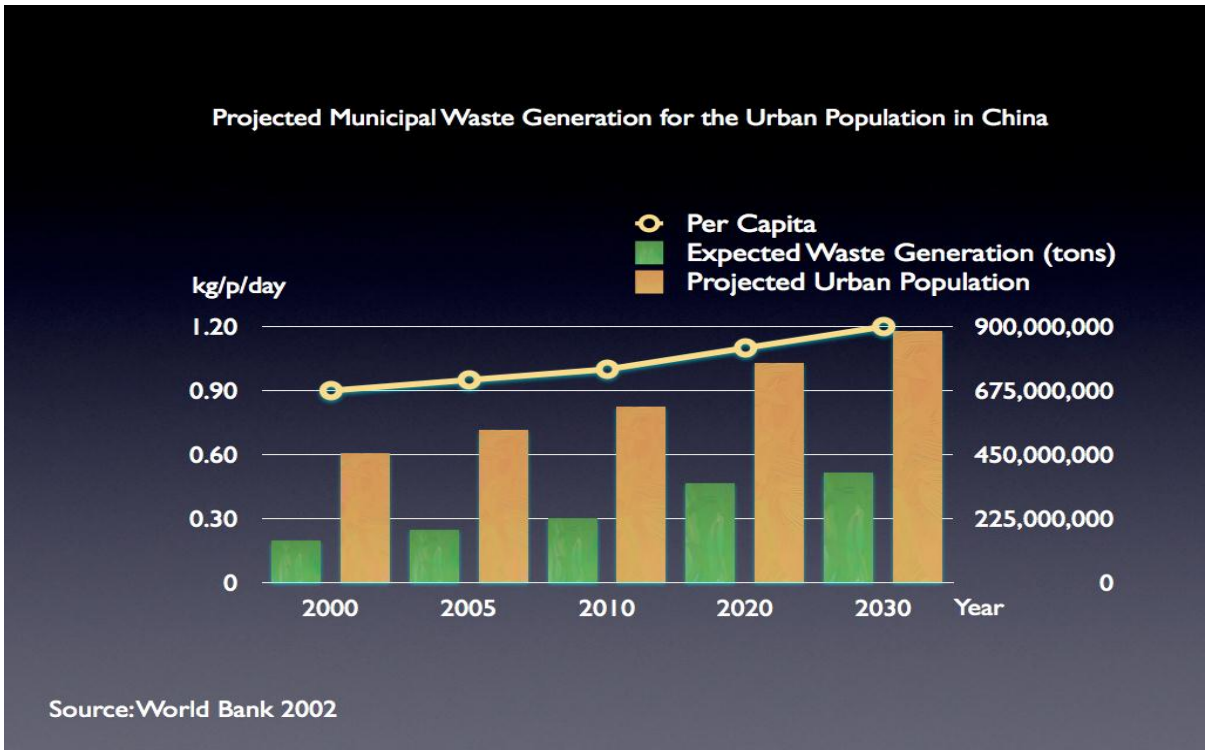



Figure 5 Projected Municipal Waste Generation for the Urban Population in China

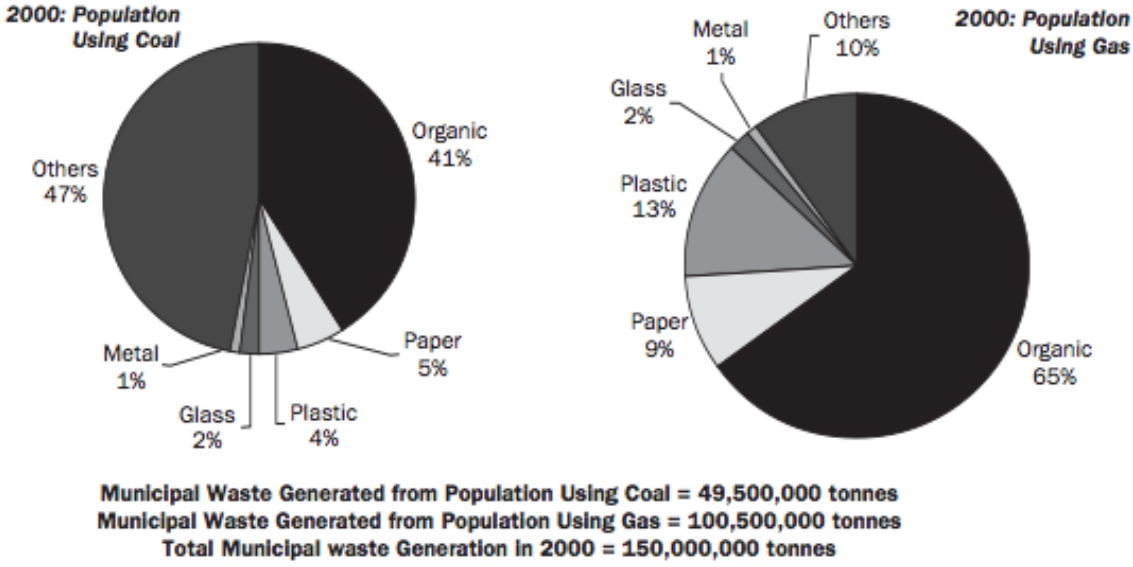
| Year | Projected Urban Population (thousands)[1] | Low Waste Generation Rate (kg/p/day) | Low Waste Generation MSW Generation (tonnes) | Expected Waste Generation Rate (kg/p/day) | Expected Waste Generation MSW Generation (tonnes) | High Waste Generation Rate (kg/p/day) | High Waste Generation MSW Generation (tonnes) |
|---|---|---|---|---|---|---|---|
| 2000 | 456,340 | 0.90 | 149,907,690 | 0.90 | 149,907,690 | 0.90 | 149,907,690 |
| 2005 | 535,958 | 0.95 | 185,843,437 | 1.00 | 195,624,670 | 1.10 | 215,187,137 |
| 2010 | 617,348 | 1.00 | 225,332,020 | 1.10 | 247,865,222 | 1.30 | 292,931,626 |
| 2015 | 698,077 | 1.05 | 267,538,101 | 1.20 | 305,757,726 | 1.50 | 382,197,158 |
| 2020 | 771,861 | 1.10 | 309,902,192 | 1.30 | 366,248,045 | 1.60 | 450,766,824 |
| 2025 | 834,295 | 1.15 | 350,195,326 | 1.40 | 426,324,745 | 1.70 | 517,680,048 |
| 2030 | 883,421 | 1.20 | 386,938,398 | 1.50 | 483,672,998 | 1.80 | 580,407,597 |

Source: World Bank 2002

Figure 6 Three Projections of Waste Generation for Urban Population in China

### 1.1.2 Composition and Management of MSW in China

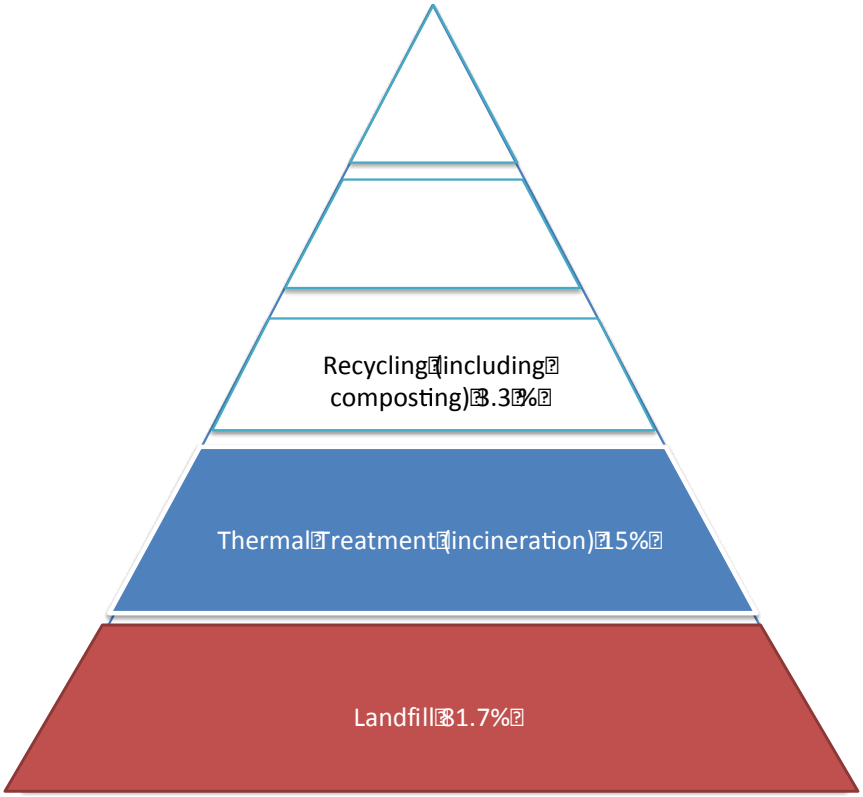
The contents of household waste (HW) or residential waste (RW) vary in different regions with different economic developments. Generally speaking, fuels that are used affect the MSW composition, specially the organic contents (Christian et al. 2005).




Source: (Christian et al. 2005)

Figure 7 General MSW Compositions in Urban Areas in China

The most problematic part lies not only in the tremendous amount of wastes generated, but more in the treatment ratio and treatment outcome of those wastes. Due to the limitations of the MSW treatment capacity, by the year 2009, only 66.8% of wastes are treated in China, leaving almost 1/3 of the total waste volume either not properly disposed or untreated (Lybæk R B et al., 2010). Among the treated waste however, more than 4/5 is landfilled, around 15% is incinerated, only 3.3% of the treated wastes are recycled, including composting treatment (Ibid). The flowing chart shows China's the waste hierarchy:




Source: Ibid

Chart 1 China's Waste Treatment Hierarchy

According to European Environmental Agency (EEA[5]), in 2006 the landfill rate of German's untreated waste is only 1%[6], and by the year 2020, Germany aims to shut down all the landfills. This indeed formed a huge contrast to the different situations between China and Germany in terms of waste management approaches. What are the key reasons for Germany's advancement in waste management worth profoundly analyzing and studying, especially for countries like China.

What is needed to specifically point out is that, in China, most of the waste data is classified into three categories, namely, municipal, industrial and hazardous waste (refer to table 4). In some cases, construction and demolition waste is also included and can dramatically skew the generation rate, thusly; in this paper construction wastes are not included into MSW category (Lin Jiaoqiao et al., 2007).

Table 1 General Waste Classification Categories in China

[5] http://www.eea.europa.eu/
[6] http://earth911.com/news/2009/07/13/trash-planet-germany/

| **Municipal Waste (MSW)** | **Industrial Waste** | **Hazardous Waste** |
|---|---|---|
| Residential, institutional, commercial, street cleaning, non-processing waste from industries, etc. | Process waste from industries, e.g. scrap metal, slag, mine tailings and alike by-products | Medical waste, small-scale generation of hazardous substances from households, institutions, radioactive wastes etc. |

To be more specific, the following is the in-depth classification of the wastes in China, for interested personals as references (Christian et al. 2005).

Table 2 Classifications and Description of Waste Type in China

| Source | Typical Waste Generators | Types of Solid Wastes |
|---|---|---|
| Residential | Single and multifamily dwellings | Food waste, paper, cardboard, plastic, textiles, leather, yard, waste, wood, glass, metal, ash, special, waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires) and household hazardous waste |
| Industrial | Light and heavy manufacturing fabrication, construction sites, power and chemical plants | Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous wastes, ash, special waste |
| Commercial | Stores, hotels, restaurants, markets, office buildings | Paper, cardboard, plastic, wood, food waste, glass, metal, special waste, hazardous waste |
| Institutional | School, hospitals, prisons, government centers | Same as commercial |
| Construction and Demolition | New construction sites, road repair, renovation sites, demolition of buildings | Wood, steel, concrete, dirt, etc. |
| Municipal Services | Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants | Street sweepings, landscape and tree trimmings; general waste from parks, beaches and other recreational areas, sludge from water and wastewater treatment plants |

| | | |
|---|---|---|
| Process | Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing | Industrial process waste, scrap materials, off-specification products, slag, tailings |

Source: the World Bank[7]

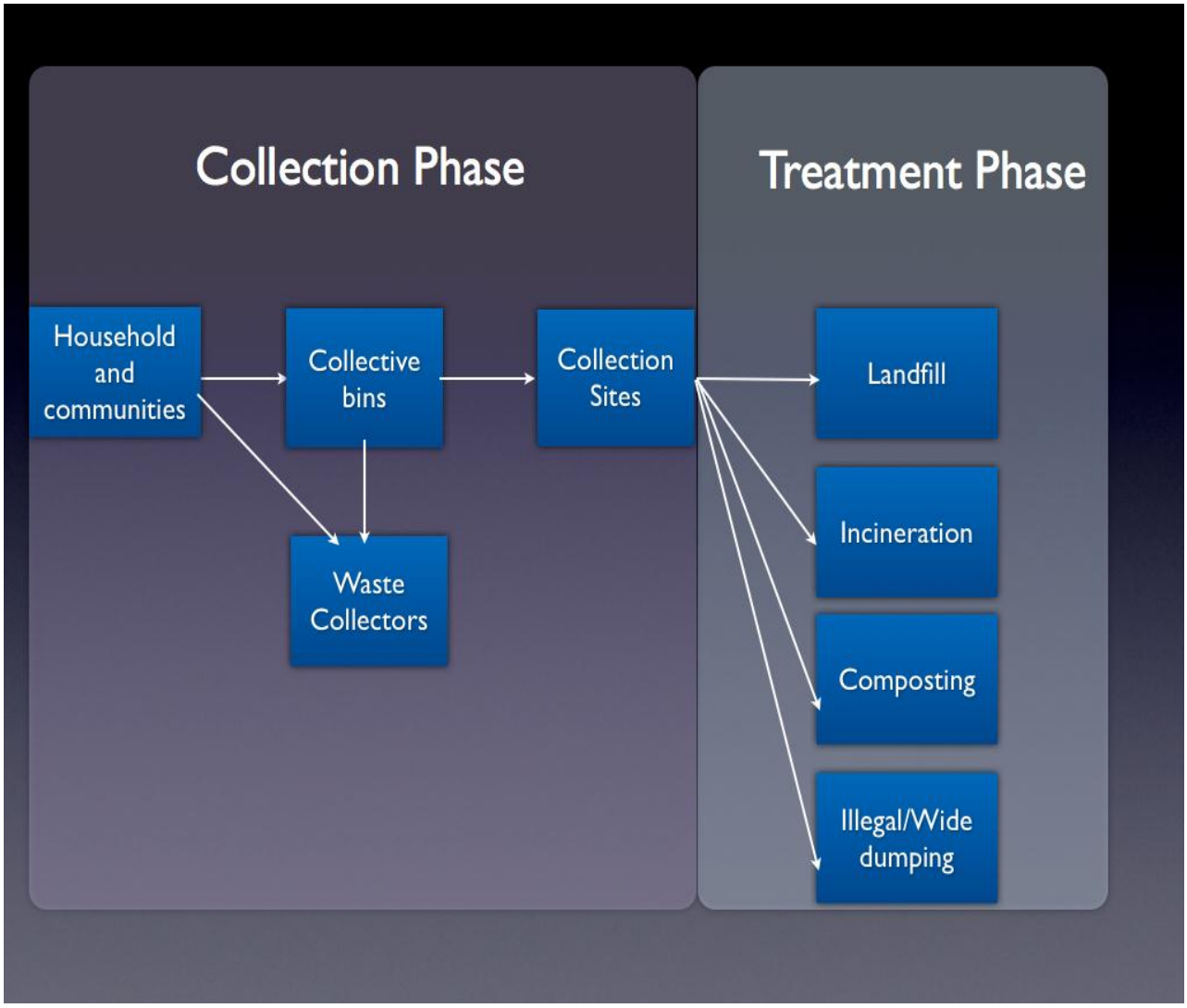
Compared to Table1 and 2, we can observe some ambiguity terms that belongs to more than one categories, such as ash, food waste etc. Thusly, for the purpose of accurate conduction of the scientific research in this paper, **the MSW mentioned in this paper mainly refer to Residential Wastes or Household Waste excluding the hazardous waste from household.**

## 1.2 MSW Separation Situation in China

Up to now in China, there is not yet a comprehensive and complete MSW at-source separation scheme established. Even in the capital city of China-Beijing, where most of the pioneer eco-projects are held, the at-source separation ratio was approximately 15%(Yi et al., 2007). There have been, however, a number of pioneer projects about at-source separations in many provincial capital cities that have shown positive results of at-source separation of SMW, which will be discussed later in this chapter.

One special feature about China is the waste collector systems. The wastes generated in each household contain recycling material such as papers, plastics, metals etc. The waste collectors usually go door to door in each neighborhood, serving as traders, buy in cheap price of those comparatively good quality recyclables and sell later on to the related manufactures as raw input material. The following chart briefly depicts the general treatment mechanism of the MSW in China (without quantified reference).

[7] Urban Development Working Papers East Asia Infrastructure Department World Bank, Working Paper No. 9




Source: Own

Chart 2 MSW Treatment General Mechanism in China

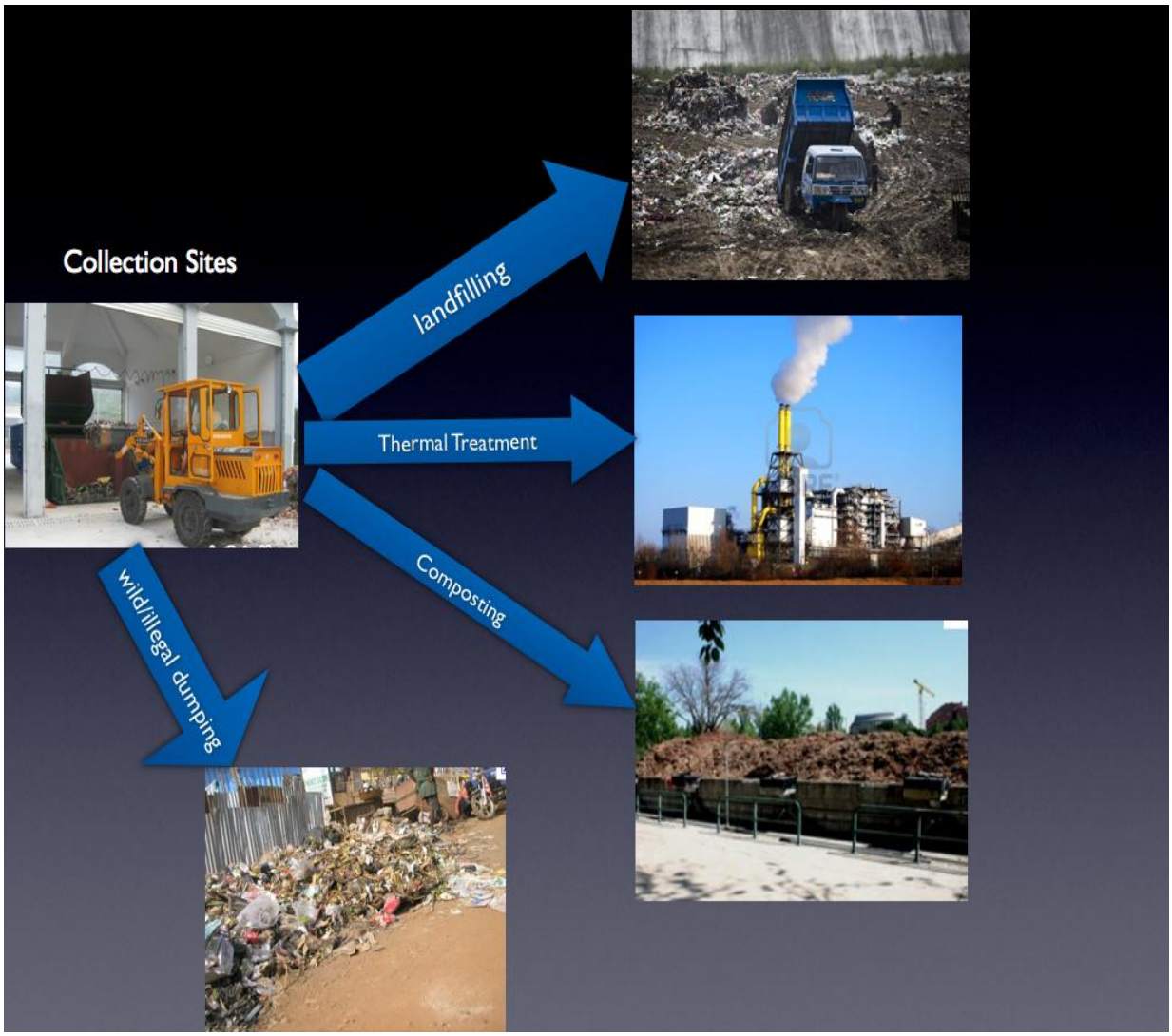
### 1.2.1 Collection Phase

In normal households of Chinese cities, there is no bin for separating the garbage. Due to the purchasing from door-to-door waste collectors of the materials such as plastic bottles, metal bins, used books or package papers etc., these wastes with direct recycling values are extracted from the mixed waste of normal households. However, the food residuals and other household wastes are mixed up and dumped into collective bins situated in neighborhoods, communities or streets. The following charts illustrate how this works in China.


Chart 3 MSW Collection Demonstrations in China

### 1.2.2 Treatment Phase

When the MSW is collected and transported to the collection sites, there are mainly four means for treatment and disposal, namely, landfilling, thermal treatments, composting, and wild/illegal dumping. And most landfills are not yet equipped with landfill gas (LFG) control devices, and the leachate also has caused serious environmental problems such as soil, underground water body pollution. Thermal treatment mainly refers to incineration without heat or electricity recovery, and due to the lack of filtering system, the exhausts like $SO_x$ $CO_x$ and Dioxin etc. posed great threat to the air quality and people the health. The following chart illustrates the general approaches for MSW treatment in China (no quantitative indicators).




Source: Google Image

Chart 4 MSW Treatment Schemes in China[8]

What is needed to point out is that, despite of similar nature, there is a fundamental difference between waste collector and scavenger, the former one is a profession that has been practiced for decades, while the later one mainly get the valuables from waste sites for survival. These waste collectors have conducted the initial separation for directly tradable recyclables from the households. And major data for contents analyzing in this paper is collected normally from the bins, unless pointed out otherwise.

[8] Images taken from Goolge Image

## 1.3 Political Framework and Social Factors for MSW Management in China

There are several major factors that have lead to the current situation in terms of waste management have been concluded, according to an Internet survey done jointly by the Minyi China and Sohu.com[9]. In this survey, the interviewees think that at-source separation has been given less attention by the government (62.1%) and lack of input for infrastructures are the major reason (61.4%); other major factors are people's lack of separation habits (63%) and complicated separation standards (54.3%)[10]. However, only 18.2% of the interviewees confirmed their keeping separating the wastes as time goes on while more than 78.7% know the overall benefits of waste at-source separation. These figures indirectly reflect despite of people's willingness to participant, what matters more is the force to keep them constantly practicing the notion.

From a legislative point of view, there is not yet a specific national legal policy that gives standardized regulations for wastes separations, only general directions of waste management. In the year 2000, Guanzhou was appointed as one of the pioneer cities for waste at-source separation, but due to lack of participation, public campaign of awareness, poor infrastructures, the separation bins were no longer set in the city by 2009[11]. And only in 2010, Beijing municipality government decides to come up with a detailed regulation for urban waste management if the notion is voted passes the municipality council. The following table enlists the major regulations and legal frameworks up until 2005(Christian et al. 2005), most of which are overlapping general concepts, some don't clarify the responsible agency, or have ambiguity in definitions etc.

Table 3 Summaries of National Chinese Laws and Regulations on MSW

| **Laws and Regulations (English)** | **Brief Description** | **Issuer** | **Effective Time** |
|---|---|---|---|

[9] Minyi China and Sohu.com are two well-known internet service based companies.
[10] Each factor has been voted individually with 100%, not all together 100%. Data results collected from http://zqb.cyol.com/html/2011-04/19/nw.D110000zgqnb_20110419_1-07.htm
[11] http://news.sohu.com/20110407/n280169679.shtml

| | | | |
|---|---|---|---|
| Law on Prevention and Control of Environmental Pollution Caused by Solid Waste of PRC | Fist law to regulate management of MSW. | The Standing Committee of the National People's Congress | April 1, 1996 |
| Law for Promotion of Cleaner Production of PRC | From each step of the production, the manufactures should take measurements to reduce pollution | The Standing Committee of the National People's Congress | Jan. 1, 2003 |
| Law for Environment Impact Assessment of PRC | Emphasize the importance of preventing environmental pollution from source; any new construction must obtain EIA approval before breaking ground. | The Standing Committee of the National People's Congress | Sep.1, 2003 |
| City Appearance and Environmental Sanitary Management Ordinance | Principle guidelines on city appearance (outdoor advertisement & horticulture) and environmental sanitary (MSW & public latrines) management; Local government would work out practical measurements | The State Council | Aug.1, 1992 |
| Regulations Regarding Municipal | Regulations regarding the management of collecting, transferring | The Ministry of Construction of PRC | Sep.1, 1993 |

| | | | |
|---|---|---|---|
| Residential Solid Waste | and treating residential solid waste | | |
| Technical Policies on the Disposal of Domestic Waste and the Prevention of Pollution | Guidance and standards of the technologies applied in the MSW treatment | The Ministry of Construction of PRC | June, 2000 |
| Comments on Promoting the Industrialization of Municipal Waste Water Treatment and Municipal Solid Waste Treatment | An important signal for attracting private and foreign investment into municipal wastewater and solid waste industry | State Development & Planning Committee, The Ministry of Construction, and State Environmental Protection Administration | Sep., 2002 |

Source: InterChina[12]

Due to the vast coverage of territory and uneven developments of regions, the regulatory and legal frameworks usually adapt to local situations based on the national polities, but as mentioned previously, the lack of specific instruction and awareness from the people have become major obstacles for waste at-source separation of MSW management in China.

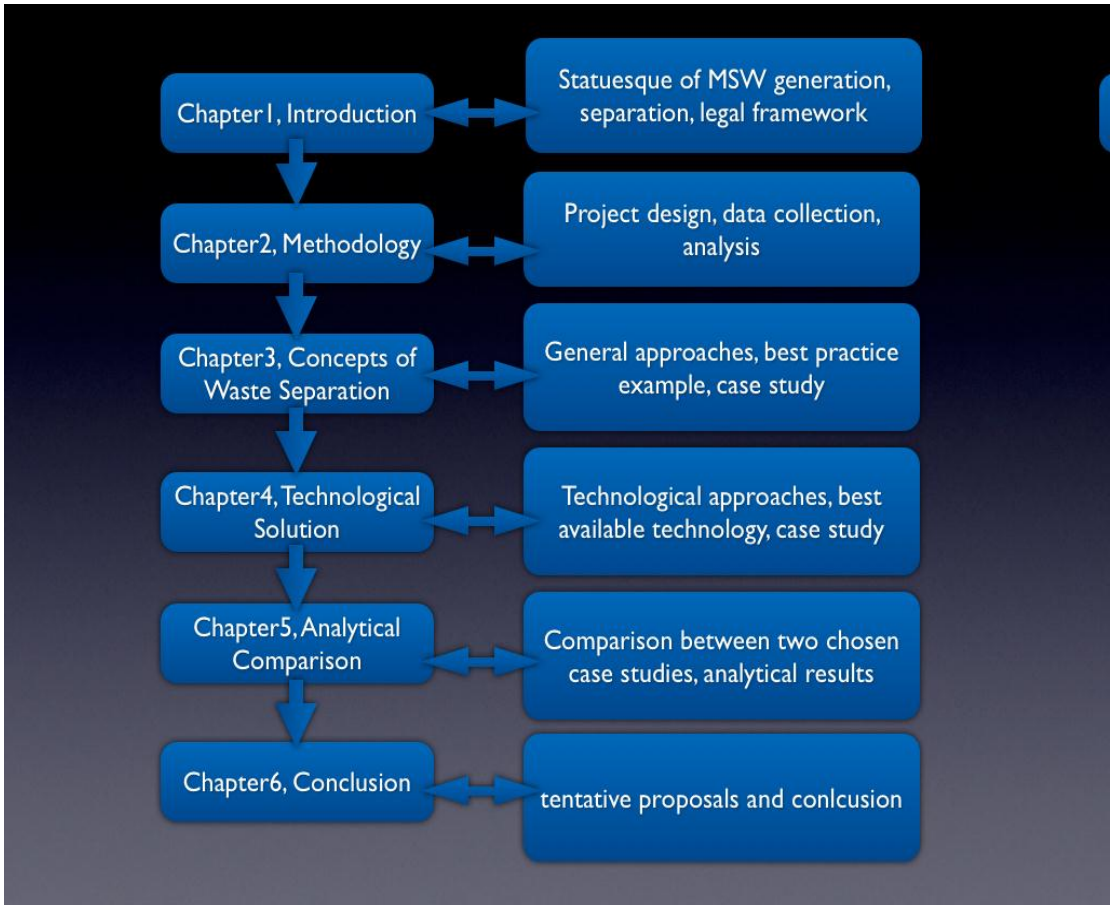
[12] The contents are translated from Chinese to English

# 2 Methodology

In this thesis, the author has described the status quo of the MSW generation, separation situation, as well as management in China to reflect the necessity of waste separation. By introducing the German MSW management systems, especially on separation aspect, an analytical comparison is conduct by two case studies of two cities in Germany and China. Based on the best available technological solutions from Germany, the author aims to proposal a proper waste separation scheme for the chosen city in China, with the hope to implement the proposed scheme on a larger scale in the future.

## 2.1 Thesis Layout Design

The layout design of this thesis is as the following:




Source: Own

Chart 5 Thesis Layout Design

## 2.2 Data Collection

The data collected concerning the MSW management for this thesis are mainly from academic publications, peer-reviewed journals, and scientific papers from universities or academies. A substantial amount of contents concerning the legal frameworks in both China and Germany are from government certified official websites and news agencies. The technological data and parameters are collected from the corresponding manufactures, based on which, economic factors are calculated.

What needs to be point out is that, due to the practical situation of collecting data concerning the both the case study in Germany and China, partially of the contents are not directly available in English, thusly, some contents have been adapted and translated from source data by the author.

## 2.3 Case Study and Analytical Comparison

It is of vital importance to conduct analytical comparison based on case studies for the MSW management. For China's situation, the uneven regional developments have made it very difficult to choose a particular city that presents all, thusly; the author has chosen the capital city of Liaoning Province-Shenyang to do the case study. And for the comparison analysis, the case studies are from Germany and Japan. For the at-source separation, these two countries have been the setting up extraordinary role models for separating and treating SMW. By enlisting the examples from these two countries, it is very insightful for comparing the advantages and disadvantages of the waste treatment systems in China and fatherly to propose better solutions.

**Why Germany and Japan?**

Besides the advanced economic development, the scientific knowledge and technology of these two countries are on top of the world, so it with the political frameworks. Take Japan for instance; there are the most specific and in-depth legal frameworks for garbage separations. A most comprehensive classification of garbage, the dumping days varies according to the different types of the wastes. In terms of

MSW recovery, Germany has already a recovery rate of over 58% in 2004[13]. And they have been transferring the technological know-how to different countries of the world. Therefore, it would be positively sense making to refer to these two countries for the comparison.

**Why Shenyang City?**

As the capital city of Liaoning Province, Shenyang City is an important industrial center in China, one of the most prominent and the biggest cities in Northeast. The following is the geographical location.


Source: Wikipedia

Chart 6 Location of Shenyang in China

Shenyang has a population of 7,760,000 (by 2008), covers a territory of 12, 924 km$^2$ (urban area 3,495 km$^2$) and has a GDP of over 500 billion by 2010[14]. Huge political and economical power ensures Shenyang City with the best opportunities for establishing project sites. Many leading scientific institutes and university provide the

[13] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Waste Management In Germany, A driving force for jobs and innovation, 2006, http://www.cleaner-production.de/fileadmin/assets/pdfs/_73_Engl._broschuere_abw_deutschland_01.pdf

[14] Figures are selected from Wikipedia http://en.wikipedia.org/wiki/Shenyang

advantages for data collecting and researching conditions. All these factors have make Shenyang City an excellent candidate for the case study.

## 2.4 Contents of Chapters

For this section, the general contents from Chapter 3 to Chapter 6 will be introduced as guidance to make it easier for getting a grasp of what each chapter is about.

Chapter 3
In this chapter, the general approaches for MSW treatment are introduced, and in-depth descriptions are included for the German MSW treatment schemes. The waste classification system in Japan is enlisted to showcase what might be achievable for China.

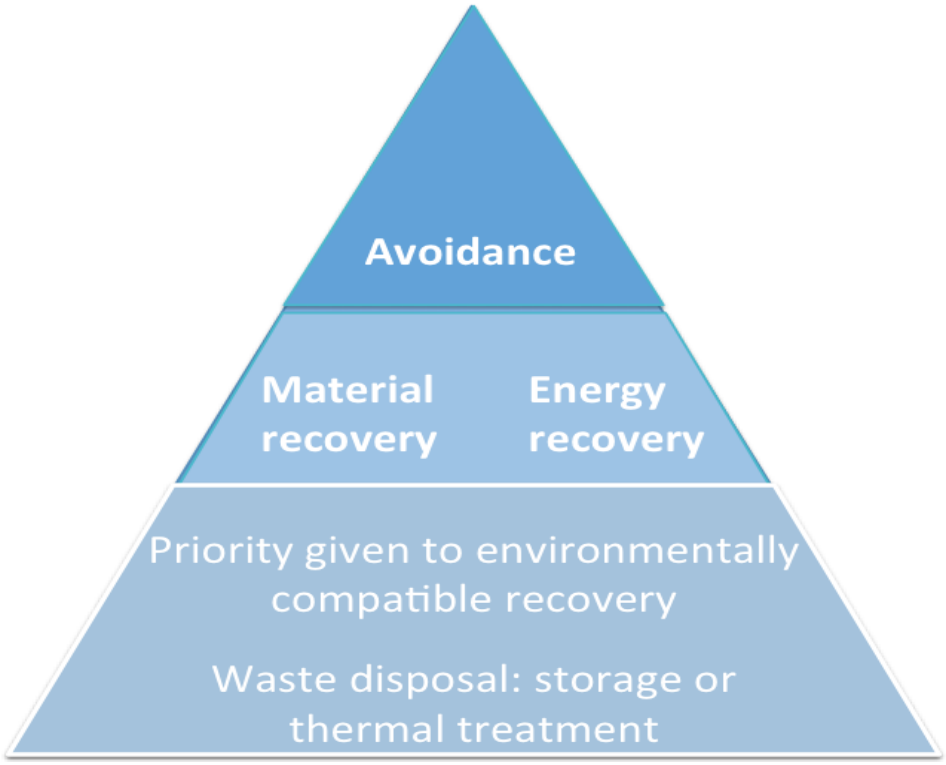
Chapter 4
In this chapter, the best available technological solutions and technology descriptions are introduced concerning the waste collection and separation. Most of the enlisted waste treatment technologies are from Germany, where they have been widely applied. Case study is also included for demonstrating the performances and outcome of these technologies.

Chapter 5
This whole chapter has been used for comparing the case studies in China and Germany, to determine the advantages and disadvantages of both case studies, and illustrate what are the potential improvements for the existing situation in China's waste collection and separation systems by implementing German technology.

Chapter 6
In the finally chapter, based on the technologies and management schemes described in chapter 5, proposals are made concerning the waste collection and separation in Shenyang City with different scenarios, as well as the projected outcomes and results for these proposals.

# 3 Concepts and Approaches for Waste Management

The waste recovery and management in Germany has been on the right track for decades. Ever since the first law of waste management came into effect in 1972[15], the waste treatment mechanism have been transformed from simply landfill dumping into high-tech oriented, specialized closed cycle management, turning yesterday's trash into the resource for tomorrow. The following diagram chart shows the waste management pyramid in Germany[16]. The biggest difference compared to China's waste pyramid (refer to chart1) is in Germany; a significant amount of waste is "Avoided", afterwards, the material and energy is recovered instead of simply treated. Only the non-recyclable and non-recoverable wastes are stored or thermally treated, while in China, the majority of wastes are landfilled and incinerated.




Source: BMU

Chart 7 The waste pyramid: Avoidance, reuse, and environmentally friendly disposal

[15] The federal *Waste Disposal Act* 1972 was introduced in Germany
[16] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

## 3.1 General Approaches of Waste Management in Germany

In Germany, due to the implementation of the governmental regulations concerning waste management, remarkable results have been seen over the past decades. According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) of Germany, there was an average economic growth of 15% from 1992 to 2004 while the total volume of domestic wastes remained basically the same. And the recovery of municipal waste had been increased to 58% up to the year 2004[17]. The following chart shows the guiding principal for German waste policy:

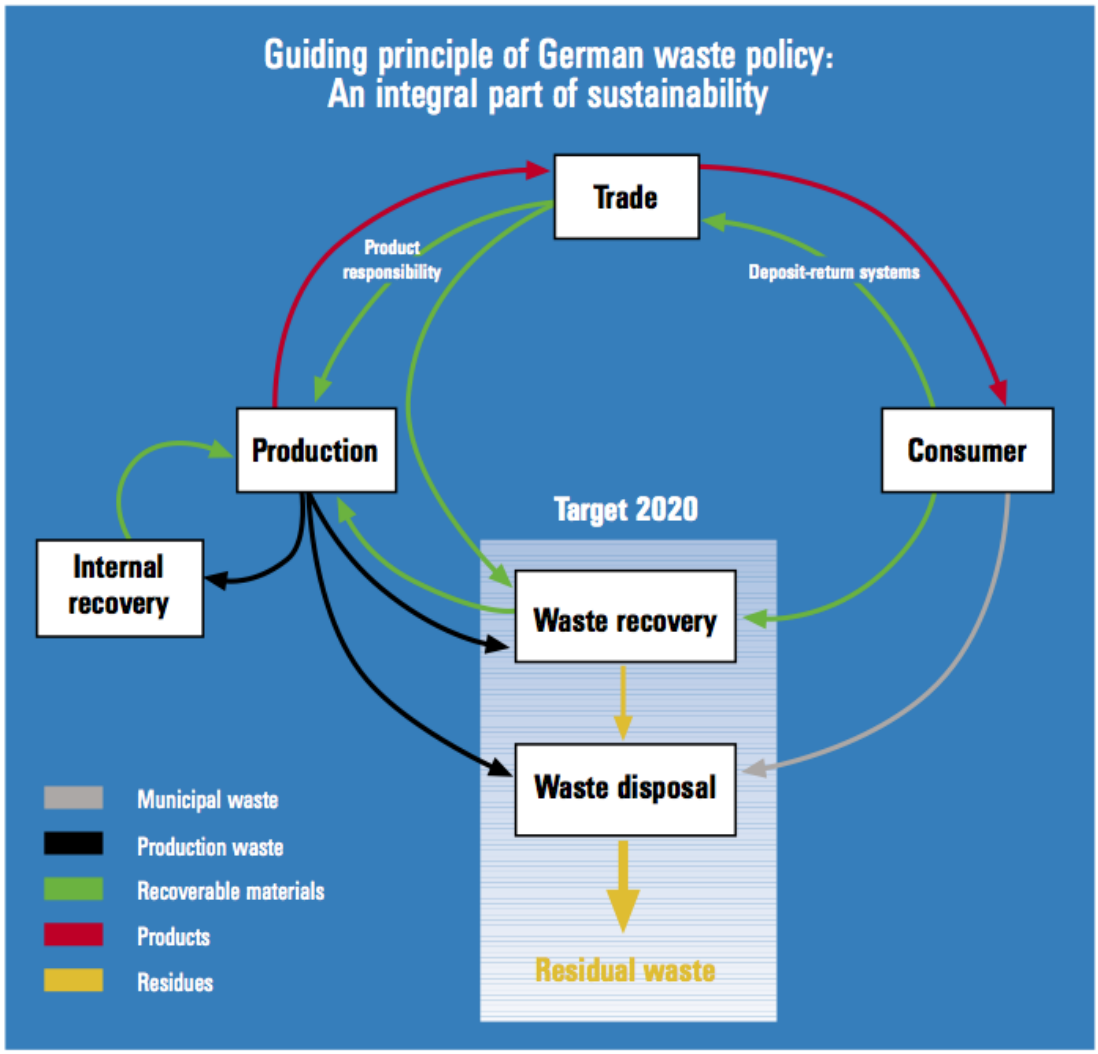
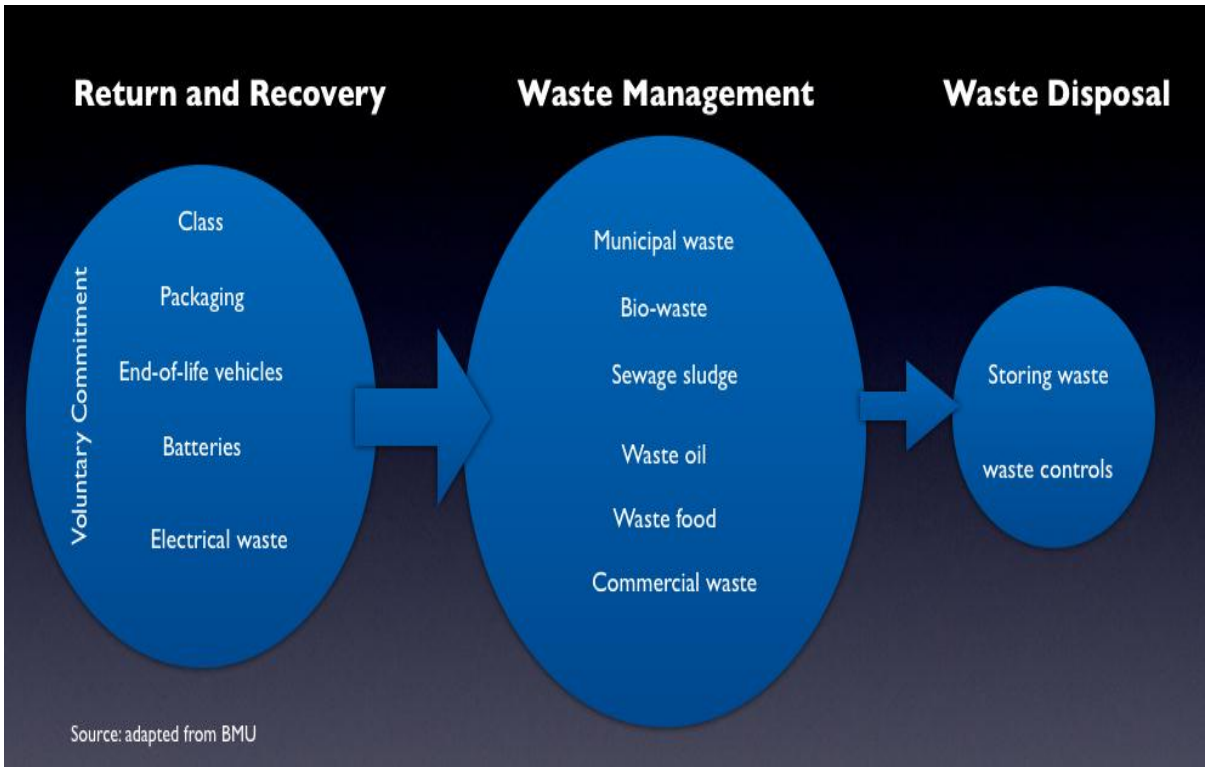



Chart 8 Guiding principle of German waste policy: An integral part of sustainability

[17] Ibld.

The current situation of waste management is Germany can be summarized into three phases, “”Return and Recovery”, “Waste Management” and “Waste Disposal”. German industries have shouldered the voluntary commitment for conserving resources and avoiding wastes. Reinforced by obligations for returning and recovering recyclables such as glass, packaging material, metals etc. As for end-of-life vehicles, batteries and electrical wastes, which contain toxic substances, are obliged for the states to separately collect and recover.

For the waste that cannot be directly recyclable or recovered, the high-tech concentrated waste treatment process are applied to recovery as much value as possible from them. The values retrieved from the treatment processes include biomass based fuels, organic utility materials, energy carriers etc. And finally, only the “real waste” that cannot be economically further treated are disposed and strong standards. And since 2005[18], no un-treated wastes were allowed in landfill in Germany. The following chart illustrates these three phases.




Source: Own

Chart 9 Three Phases of Waste Management in Germany

[18] Ibid.

## 3.2 MSW Management in Germany

In Germany, municipal waste has been defined as, "waste from private households and similar institutions, as well as domestic-type waste produced by trade and industry". Municipal waste includes, for example, household waste, separately collected recoverable materials such as glass and paper." Whilst in China, MSW normally doesn't include domestic-type waste produced by industry, which normally has a large volume and more difficult for treatment.

Due to the high standards in waste management, there were totally 48.5 million tons of municipal wastes generated in the year 2004, of which, around 58% was recovered[19].

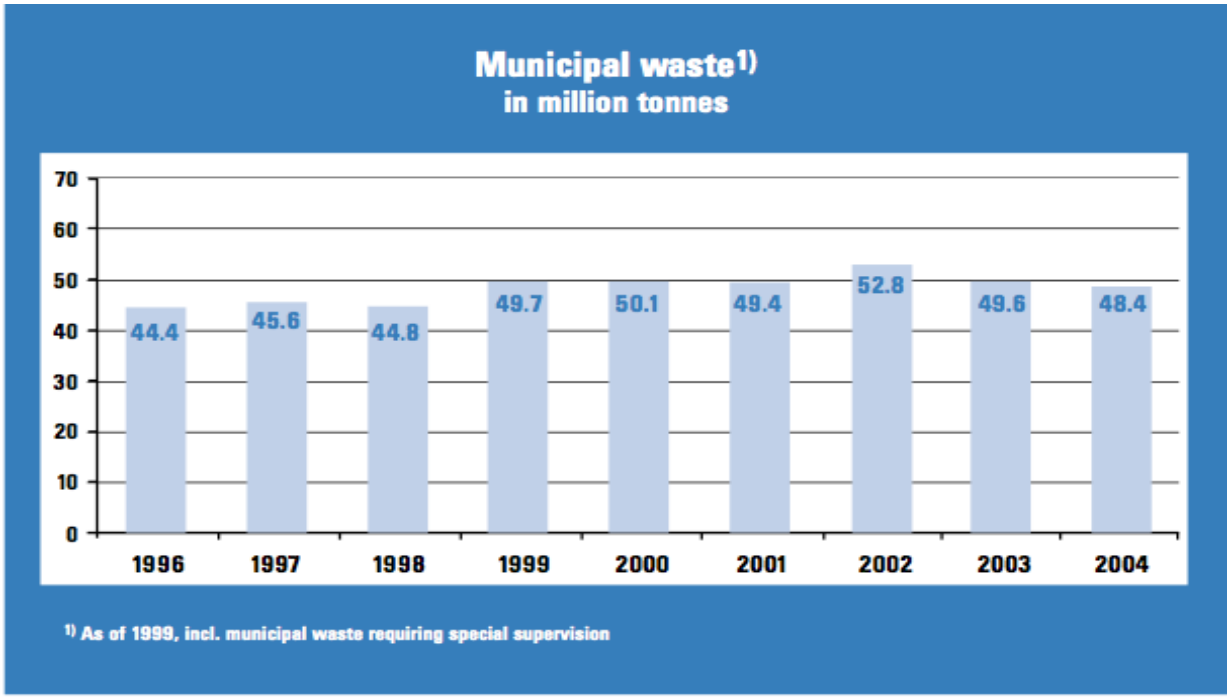
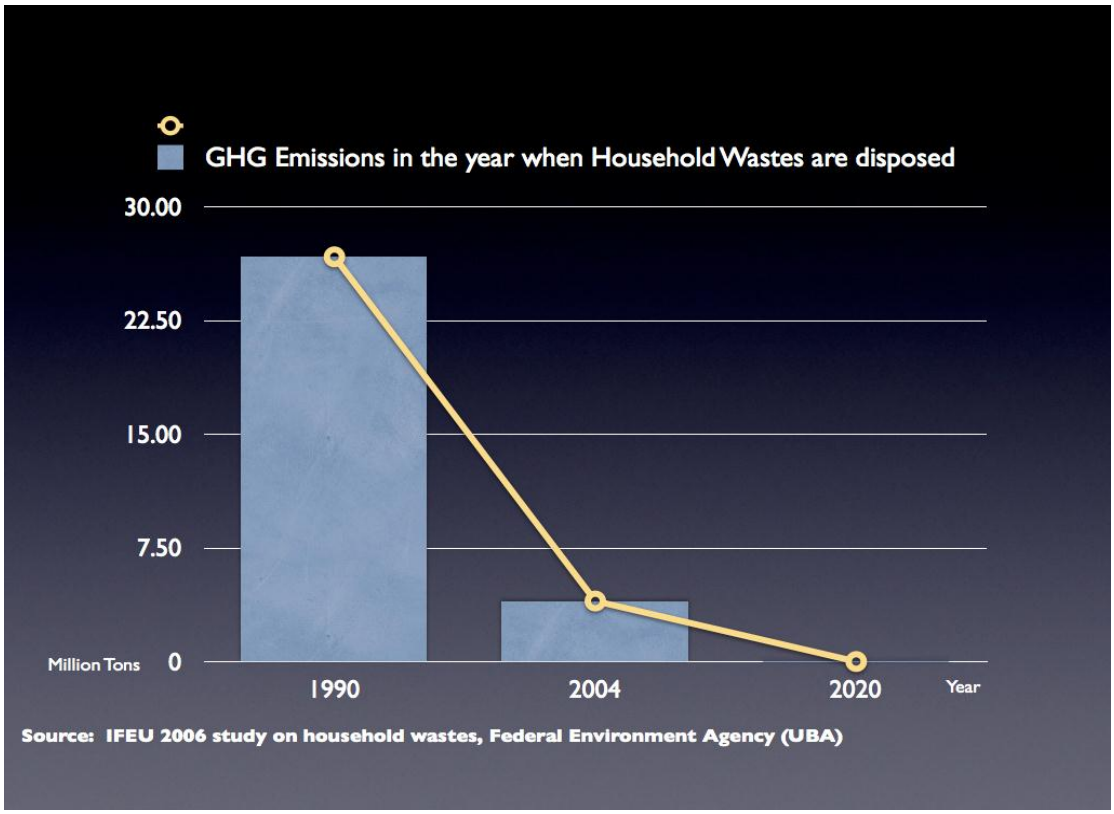



Figure 8 Municipal Waste Generations and Recovery Rate in Germany 2004

The residual wastes of the recovered municipal wastes are pre-treated by thermal or high-end mechanical biological treatment (MBT) before landfilling. The purpose of this pre-treatment is to "turn fermenting, rotting and foul-smelling residues into slag

[19] Ibid.

or a substance resembling soil which is no longer harmful to the environment." Thusly, to reduce the generation volume of landfill gases (LFG) into almost zero.




Source: IFEU

Figure 9 LFG Emission Reductions from Waste Treatment in Germany (Projection to 2020)[20]

And the overall goal for municipal waste management in Germany is by the year 2020; all municipal wastes are to be recovered as much as possible and aboveground landfills are to be practically abolished.

## 3.3 Waste Separation in Germany

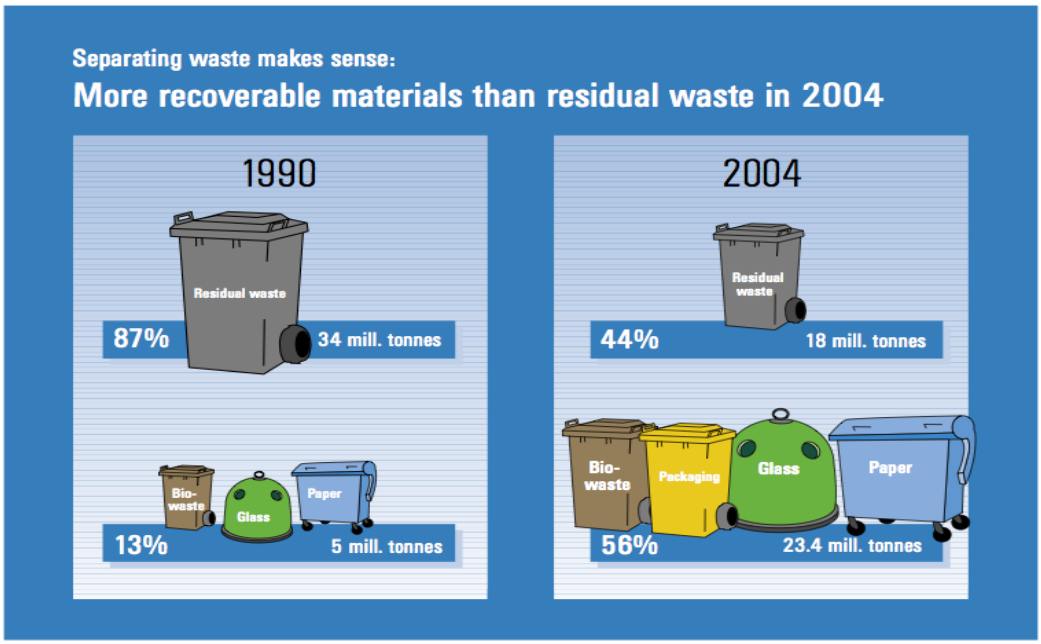
When it comes to waste separation, two different processes are included for this term, namely, at-source waste separation and on-site waste separation. At-source waste separation refers to the separation of waste streams where they were generated, such as households before they are mixed. And on-site waste separation refers to the

[20] Figures adapted from IFEU 2006 study on household wastes, Federal Environment Agency (UBA)

separation of a mixed waste stream, usually taken place at resource centers, landfills, etc. where wastes of a mixture are concentrated and stored.

### 3.3.1 At-source Separation

As early as 1998, there was a survey conducted to determine people's practices of waste separation[21]. The result shows that about 91% of German house owners separate their waste in order to contribute to environmental protection. And according to the German Society for Consumer Research (GfK), over 83% of German people disapprove of garbage incineration while as high as 96% disapprove of landfills[22]. Bides individual's willingness for participation, the endeavor taken by organizations have also played an significant parts for recycling and separation, for instance, in 1991, the "Der Grüne Punkt" also known as "The Green Dot[23]" was introduced in Germany. The results are enormous; up to 2004, there were 56% of the household wastes were recovered, exceed the residual wastes (refer to figure 10).




**Source: IFEU (Institute for Energy and Environmental Research) 2006 study on household waste, Federal Environment Agency (Umweltbundesamt, UBA)**

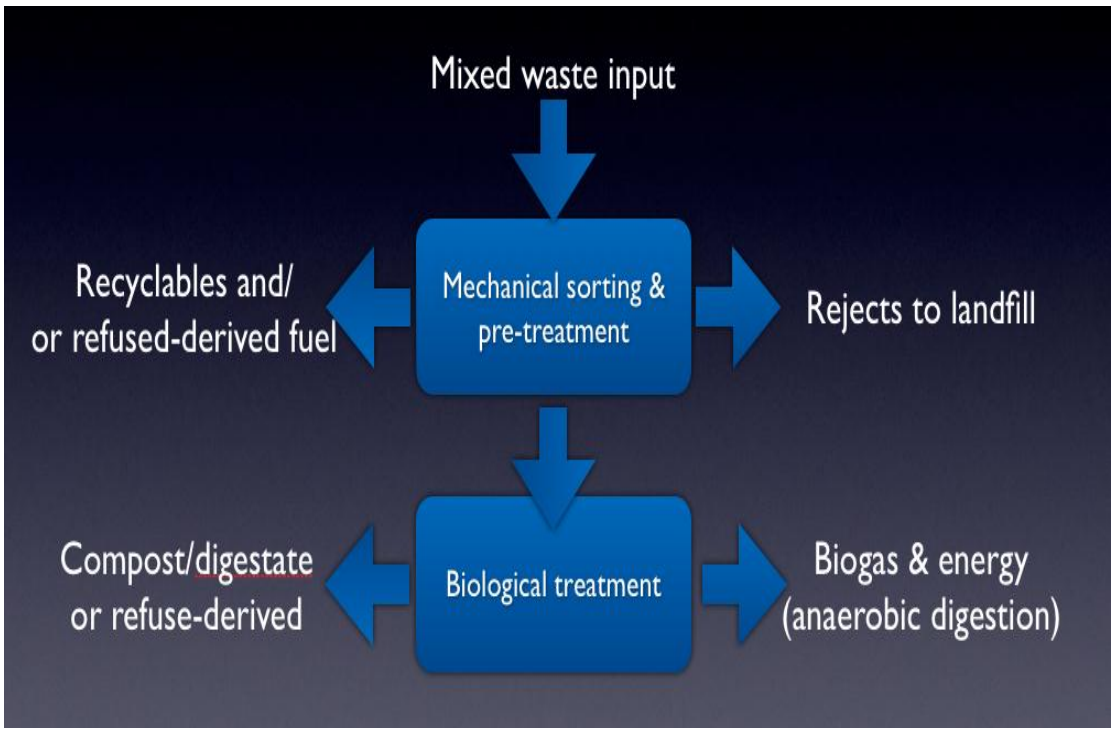
Figure 10 Household Waste Recoveries in Germany (Comparison between 1990 and 2004)

[21] http://textronics.com/Country-Profiles/Germany/recycling-and-waste-separation-in-germany.html
[22] Ibid.
[23] The Green Dot is the license symbol of a European network of industry-funded systems for recycling the packaging materials of consumer goods. The logo is trademark protected worldwide. (Wikipedia)

Normally each household have been equipped with different bins or containers for different wastes, such as glasses, papers, organics, packaging etc. The detailed technological descriptions are discussed in the next chapter.

### 3.3.2 On-site Separation

One of the important on-site separation mechanisms is though mechanical-biological treatment (MBT). And there are over 7 million tons of residual solid wastes are annually treated in MBT plants (Matthias et al., 2007), enabling MBT the pillar procedures for MSW management in Germany. Bides MBT, there are also variations of on-site waste separation and treatment technologies such as mechanical-biological waste treatment plant with biological drying (MBS), mechanical physical drying (MPS), or purely mechanic waste treatment plants (MA) etc. (Ibid.) The basic working principles of MBT is as follows:




Source: chart adapted from Wikipedia[24]

Chart 10 Basic Working Principles for MBT

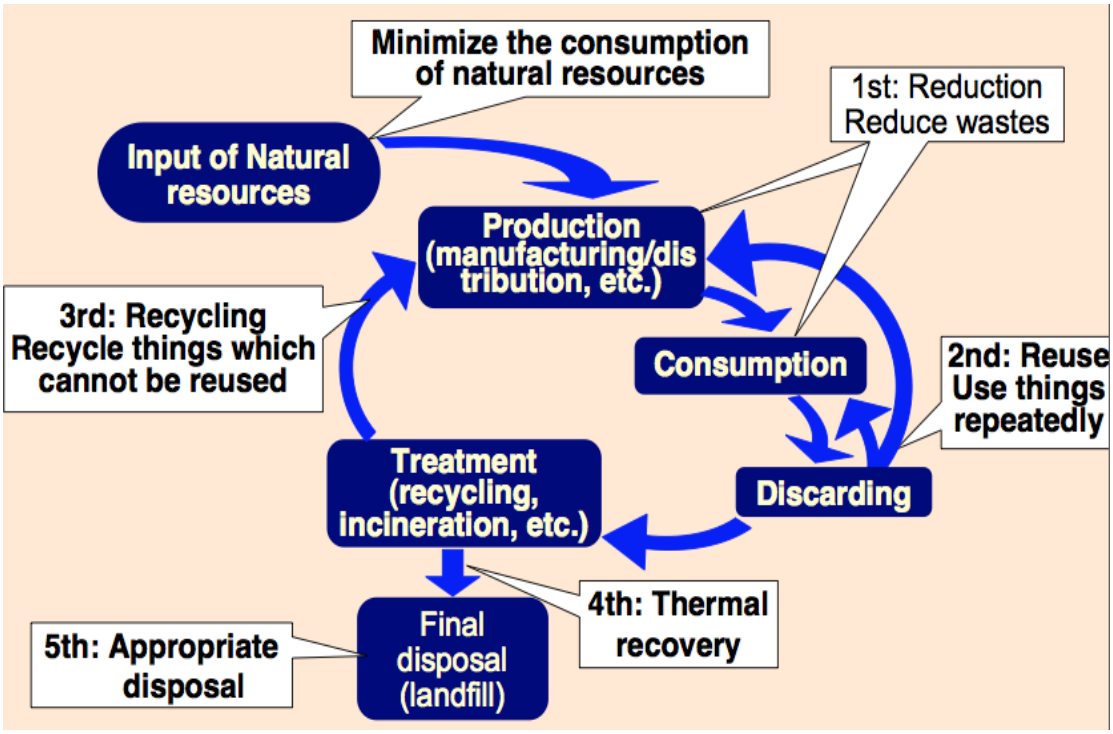
The purpose of having a MBT is to separation the mixed wastes, thusly to be able to recover the materials contained within the mixture. Generally, the materials that can

[24] http://en.wikipedia.org/wiki/Mechanical_biological_treatment

be retrieved from the mixture of waste stream include ferrous metal, non-ferrous metal, plastic, glass, organics and some others.

## 3.4 Waste Separation in Japan

In Asia, one the leading country in terms of waste recycling and treatment is Japan. Their aim is to shape Japanese society into a "material-cycle society"[25]. Besides people's fondness of green environment and clean atmosphere, their first legislative framework for environmental protection can be dated as early as the year 1900, when "Public Cleansing Law" came into affect[26]. Further more, great efforts are made to transform Japan into a "3R"[27] society mode. The following chart illustrates the principals for "3R" and proper disposal scheme in Japan (Yasuhisa, p11).




Source: Yasuhisa

Chart 11 Principals for developing material-cycle society

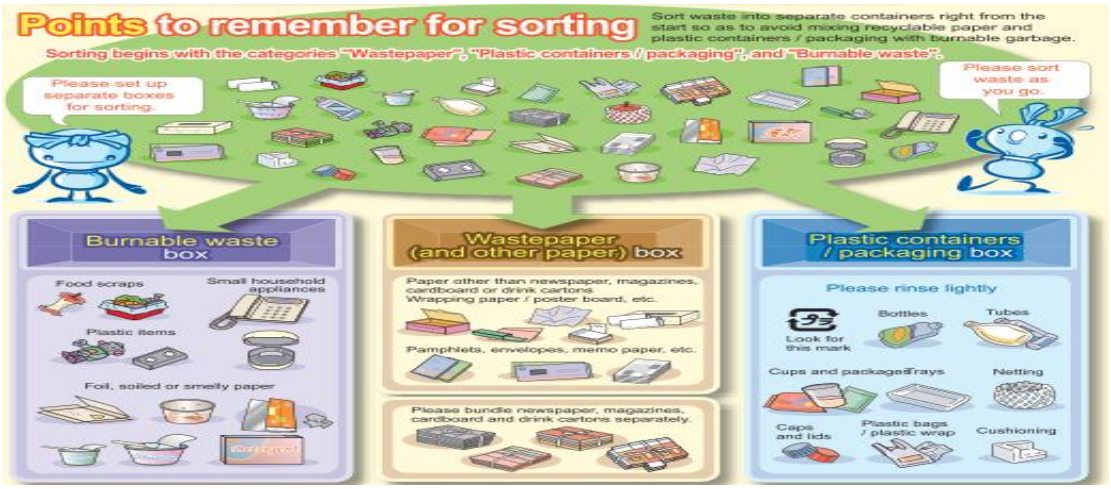
[25] Yasuhisa Tsukada, Waste Management Division, Bureau of Environment, Tokyo Metropolitan Government, Legislative System of Waste Management in Japan, http://www.asianhumannet.org/db/datas/Legislative_en.pdf
[26] Ibid.
[27] "3R" means, Reduce, Reuse and Recycle.

What make Japan's case unique are their thorough and comprehensive classification and definition of wastes that are to be separated and recycled by law. They categories the wastes into three columns, "General Waste", "Industrial Waste" and "General/Industrial Wastes Under Specific Control", within which, further specific classification are made, which is shown as Chart 10 (Ibid).


Source: Ibid

Chart 12 Classifications of Wastes under the Waste Management Law

Under the "Waste Management Law", there are subsequent laws such as "Containers and Packaging Recycling Law", which regulates the corresponding tasks for different parties for separating and recycling basically all the packaging materials like various bottles, cans, of different materials. "Home Appliance Recycling Law", for examples, requests the collective efforts taken by retailers, manufactures and households to separation and recycle household utilities such as TV set, Air conditioner, Washing machine etc. Just to show how in-depth and specific the garbage at source separation is in Japan, the following chart selects only a small part of the separation requirements.




Source: Japanese Government Website

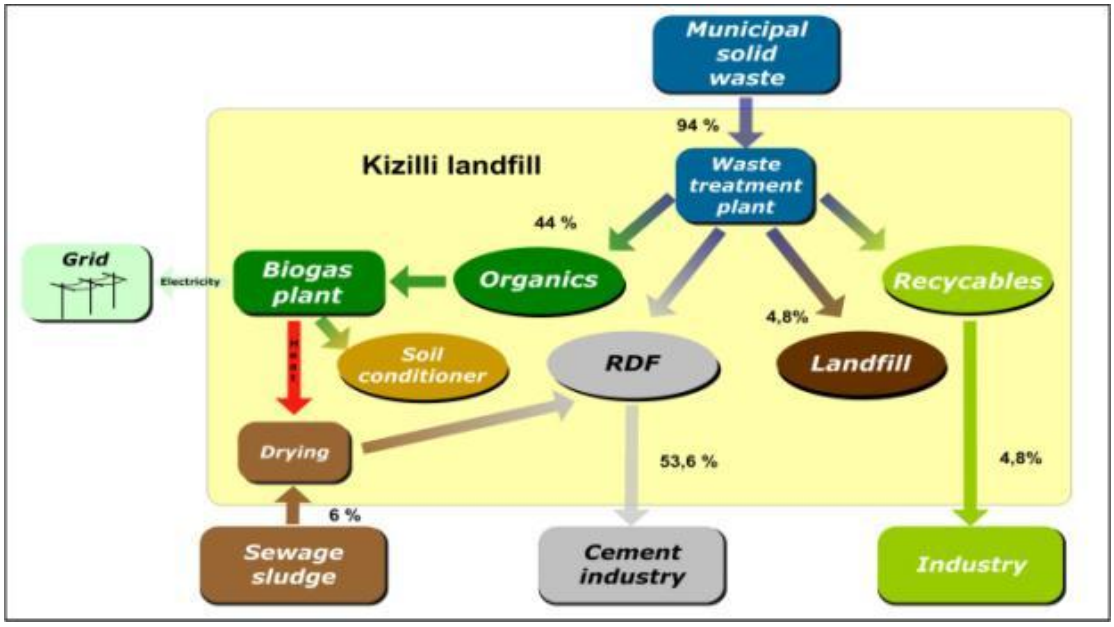
Chart 13 Garbage Sorting Pointers in Japan (selective)

## 3.5 Software Tool for Waste Management

Technological advancement is indeed crucial for problem solving, but more importantly for successful waste management is to apply the appropriate software tools for managements. For the waste sectors for example, there is not necessary to have the scientific breakthroughs like curing cancer, or space exploitation and alike, the most currently available technologies have been more than suffice to fulfill the needs for the desired integrated waste treatment results. The problems, is how to management and reallocate the existing resources for maximum results.

The concept of material flow management (MFM), for example, is a great management tool for dealing with waste problems, which have been adopted and applied in some industrialized countries, especially in Germany. MFM is defined as "a goal oriented, efficient use of materials, material streams and energy. The goals are given by ecological and economical areas and by observing social aspects.[28]" By taking a holistic approach from interdisciplinary aspects, there are more solutions available for better solving the problems. The aim of applying MFM is to develop integrated MSW management approaches, to minimize the negative impacts and maximize and realize the potentials from wastes. The following chart shows the working scheme of MFM in a landfill (Heck, 2010).

[28] http://en.wikipedia.org/wiki/Material_flow_management




Source: Heck 2010

Chart 14 MFM Integrated Landfill Working Scheme

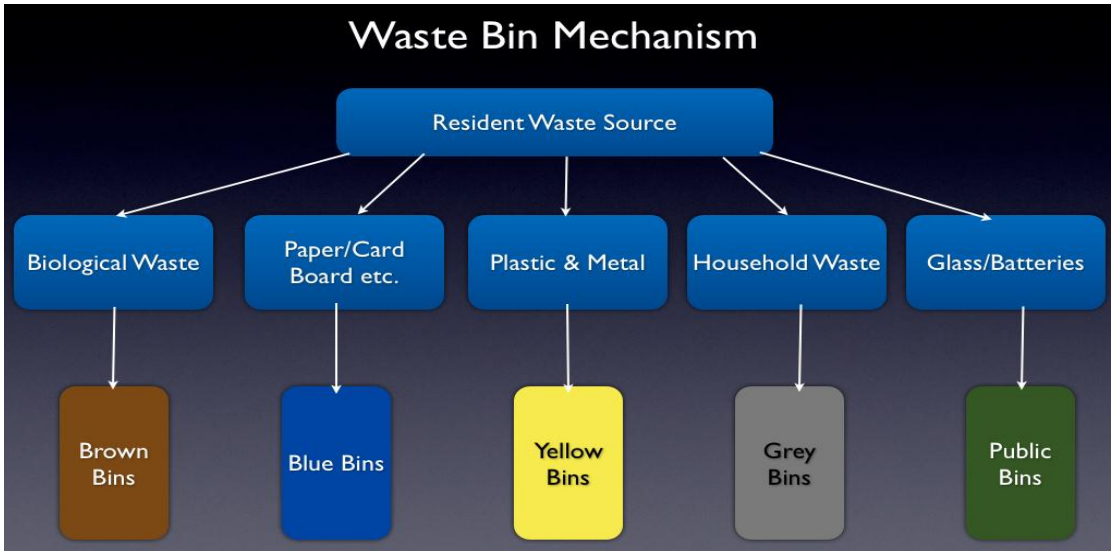
# 4 Technological Solutions on Waste Separations

To achieve the goal of efficient and effective waste separations, the application and implementation of sound and appropriate technologies are extremely necessary. Some processes need high-tech input in order to have maxim results, while, some process require more of the implementation of already established technologies. Take at-source separations for instance, no cutting-edge technologies but different bins for separations are necessaries, the key issue is how to properly manage and implement this separation bin systems. However, when it comes to on-site waste separation, especially, for MBT, expensive and complex machineries are needed for dealing with the mixed waste to have the separation waste streams, which will lead to material or energy recovery.

## 4.1 Technologies for At-source Waste Separation

According to the content features of the waste, and the locations the collection sites, there are a variety of technologies available for at-source separation. The most commonly seen is waste bin system. By setting up different waste bins for the corresponding wastes. The flowing chart shows the Waste Bin Mechanism in Germany[29].

[29] The chart is made based on http://blog.mygermancity.com/do-you-know-how-to-recycle-in-germany




Source: Based on Footnote 29

Chart 15 Waste Bin Mechanisms in Germany

**Brown Bins**

Brow bins are used for collecting biological wastes from households. These wastes include kitchen wastes (e.g. food scraps, coffee filters, tea bags without paper tag, feathers, sawdust, and hair etc.) and green waste (such as garden clips, yard waste) (Josef Barth, 2002).

**Blue Bins**

Blue bins are used for paper-based wastes such as paper and cardboard. As long as there are paper, boxes, magazines, and even tea tags. And the box-shaped cardboard should be flattened and dried before thrown into the bin.

**Yellow Bins**

Yellow bins are for metals and plastic materials. Mostly these bins are marked with the "Der grüne Punkt" sign[30]. Plastic wrap, yogurt cups, food cans, shopping bags, as well as soap bottles and alike should be in this kind of bins.

**Grey Bins**

[30] Der grüne Punkt is a round circle with two arrows pointing to each other

Grey bins are used for household waste, which is also known as Restmüll in German. Old model light bulbs; baby diapers, tissues, cigarette buts, and photograph films are taken in here. Later, these wastes are incinerated after collection.

**Glass and Batteries**

These two kinds of wastes are collected publicly. Normally, there are larger waste bins in certain shopping malls or supermarkets for taking glass and batteries. Each of these two kinds is separately collected.

The following picture is a demonstration of Bin models[31]

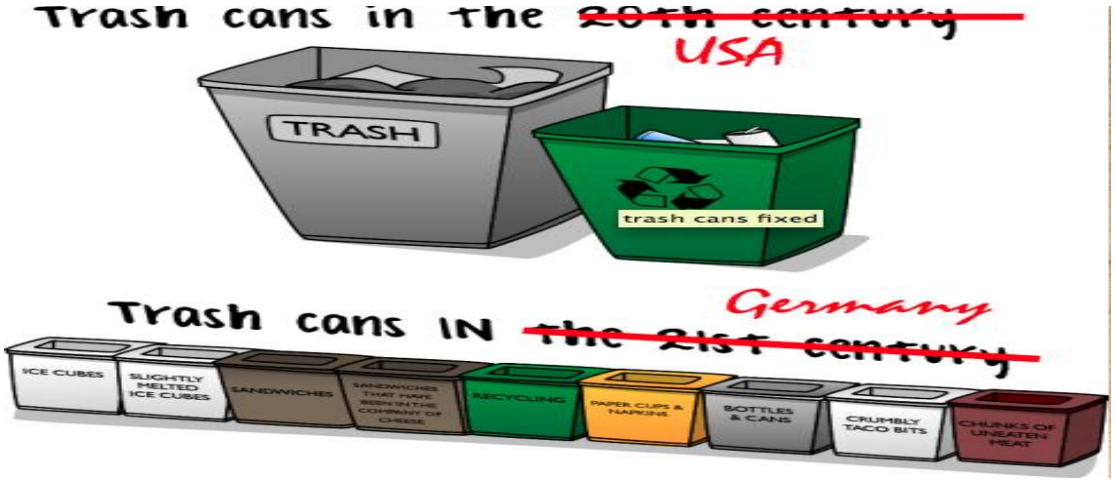

Source: Footnote 31

Chart 16 A Demonstration of Waste/Garbage Bins in Germany

The previously enlisted "technologies" cannot be too complicated to apply; the practical issue is if there is strong determination and regulation to implement these "technologies". The following comic style picture reflects an American's humorous view on German waste bin's variety[32].

[31] Picture source: http://www.alibaba.com/product-tp/11280647/Waste_Mobile_Garbage_Bin_Basket_Dustbin/showimage.html

[32] Picture Source: http://bathrobeman.wordpress.com/category/travel/germany/

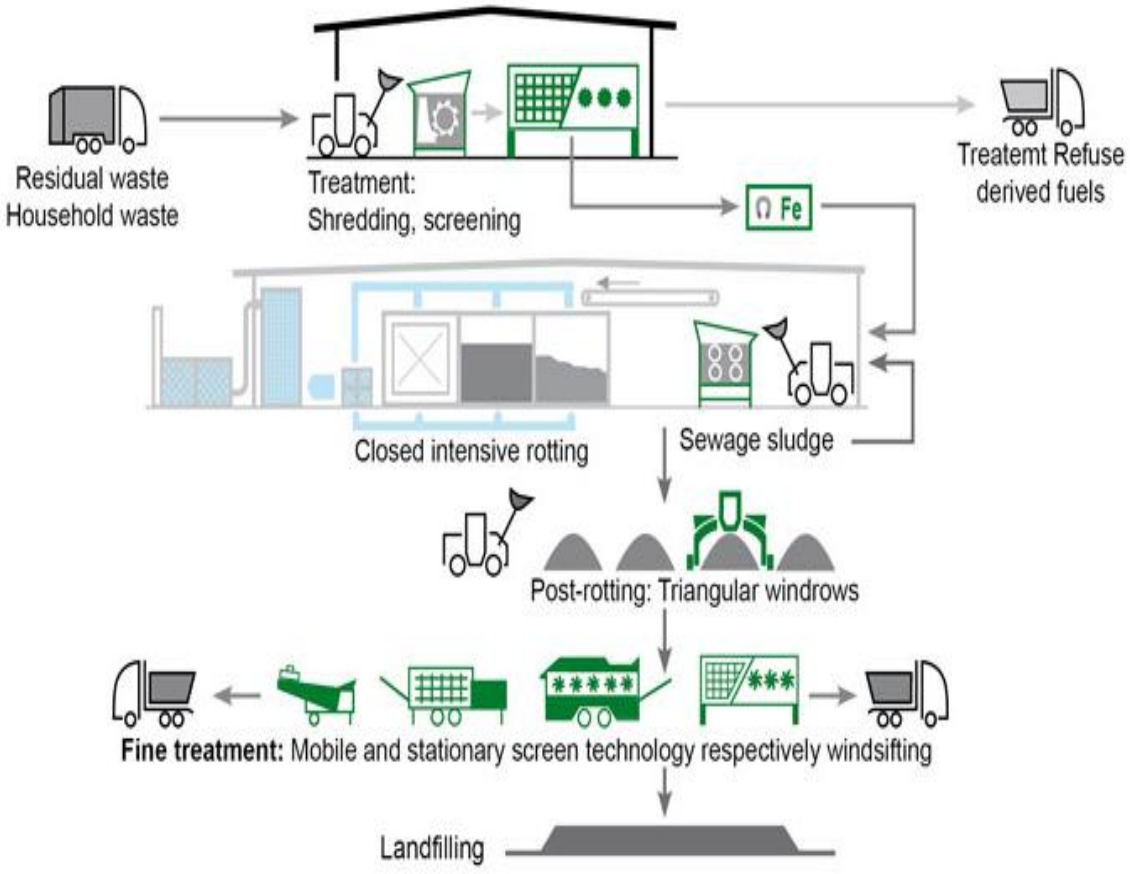



Source: Ibid

Chart 17 Waste Bin Types in Germany and U.S.A.

## 4.2 Technologies for On-site Waste Separation

On-site waste separation in Germany usually is integrated as part of the whole treatment mechanism, take MBT for example, this integrated waste treatment mechanism consist of mechanical treatment and biological treatment. MBT has been a proven technology applied in Europe for quite some time. One key advantage for MBT is it's "multi-tasking" other than simple waste separations. There is a range of technology combinations, serving a set of purposes.




Source: Footnote 33

Chart 18 General Working Schemes of MBT[33]

When MSW or RW (HW) is transported to MBT plant, there are two treatment stages waiting, mechanical treatment stage and biological treatment stage. Mechanical sorting, shredding, screening recover the recyclable materials recovered, together with another clarify-rich fuel known as refuse derived fuels (RDF), while the organic fractions are digested or composted in the biological treatment. The major useable output from this stage is methane, which can be refined into natural gas. The inert wastes are finally landfilled.

And in mechanical treatment process, there are also a series of technologies available for waste sorting and separations, and so it is the case with biological treatment.

[33] Source: http://www.komptech.com/en/waste/mechanical-biological-treatment.htm

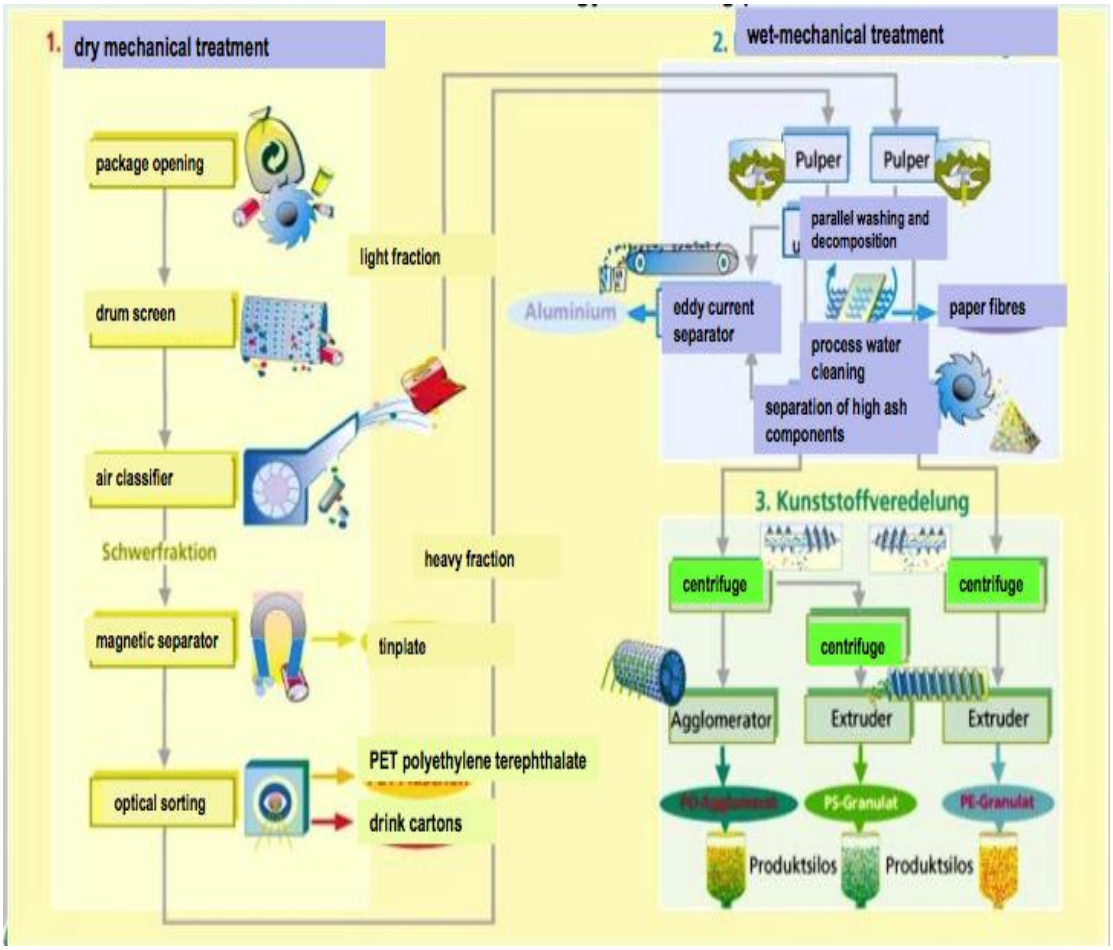
### 4.2.1 The Mechanical Treatment Stage

There are often two major roles in this stage[34]:

To broken down waste into smaller parts, e.g. by shredding

To remove recyclable materials

The following chart shows the mechanical sorting technology schemes of dry mechanical treatment and wet mechanical treatment (Hartard, p39).



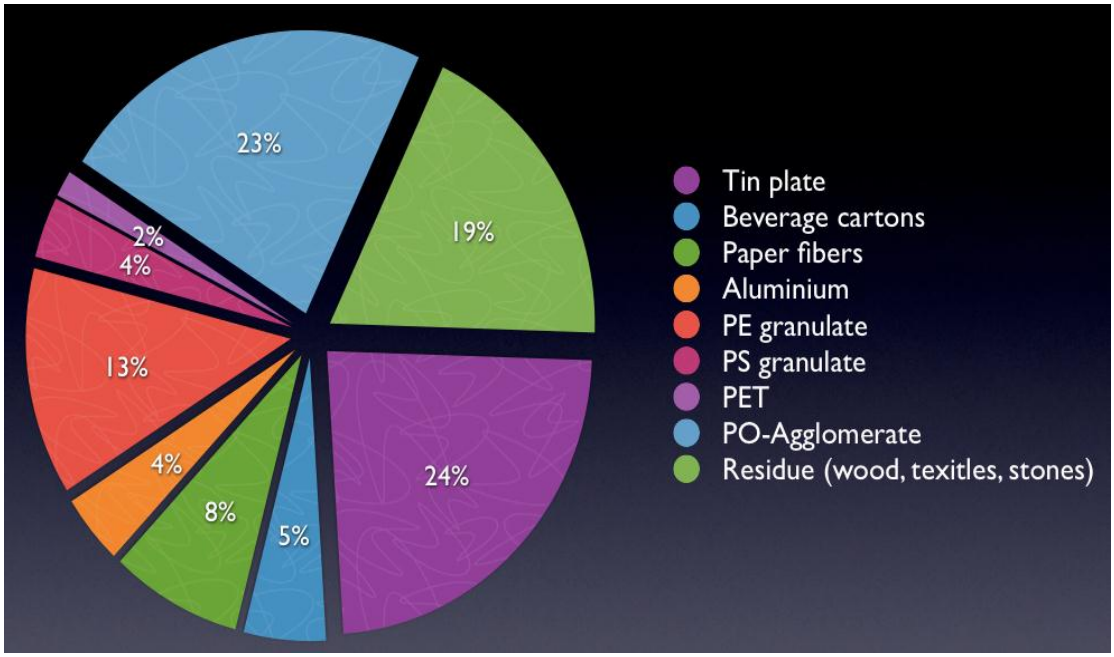

Source: Hartard, 2010

Chart 19 Mechanical Sorting Technologies for packages

This set of technologies has been field texted with remarkable results for sorting and recovering package materials of various kinds, including tin plate, beverage cartons, paper fibers, aluminum, PE, PS, PET, POA, and residues such as wood, textiles, stones. The following table shows the output of test plant results (Ibid). As shown,

[34] Briefing Mechanical and Biological Treatment (MBT), http://www.foe.co.uk/resource/briefings/mchnical_biolo_treatmnt.pdf

over 80% of the material input are classified and recovered, which can later be recycled.




Source: Ibid

Chart 20 Test Plant Performance of MBT

Further sorting technologies could be coupled in the mechanical stage, however, the cost is thusly varies according to the corresponding implementation (Ibid.). The following table enlists a number of waste separation technologies, which can be coupled as part of the mechanical treatment stage (Defra, 2007).

Table 4 Waste Separation Technologies in MBT

| **Separation Technique** | **Separation Property** | **Materials targeted** | **Key Concerns** |
|---|---|---|---|
| Trommels and Screens | Size | Oversize-paper, plastic Small-organic, glass, fines | Air containment and cleaning |
| Manual Separation | Visual examination | Plastics, contaminants, oversize | Ethic of role, Health, Safety |
| Eddy Current Separation | Electrical Conductivity | Non ferrous metals | Proven Technology |
| Magnetic Separation | Magnetic Properties | Ferrous metals | Proven Technology |
| Wet Separation | Different | Floats-Plastic, organics | Produces wet |

| | | | |
|---|---|---|---|
| | Densities | Sinks- stones, glass | waste streams |
| Air Classification | Weight | Light-plastics, paper<br>Heavy-stones, glass | Air cleaning |
| Ballistic Separation | Density and Elasticity | Light-plastics, paper<br>Heavy-stones, glass | Rates of throughput |
| Optical Separation | Diffraction | Specific plastic polymers | Rates of throughput |

Extruders:

Image Source: (Hartard, 2009)

Near-Inferred-Technology (NIR) X-Ray-Sorting



Image Source: (Ibid.)

### 4.2.2 The Biological Treatment Stage

For this stage, the organic wastes are obtains from the previous mechanical stage, and normally in a closed system, these waste are either composted or digested. Both anaerobic and aerobic digestion methods could be applied for the organic waste digestions. The methane, which is produced during the digestion process, can be used as energy carrier for producing biogas or natural gas. The residuals can be used to produce organic fertilizer[35].

The biological stage processes usually include the following three:

- Aerobic Bio-drying
- Aerobic In-vessel composting
- Anaerobic digestion

The treatment technologies do not include too many variations but the complexity of the technology are more or less the same (Ibid.).

Table 5 Biological Treatment Technologies in MBT

| Options | Biological Treatment |
|---|---|
| I | Aerobic - Bio-drying/ Bio-stabilization: Partial composting of the (usually) whole waste |

[35] Ibid.

| | |
|---|---|
| II | Aerobic – In-Vessel Composting: may be used to either bio-stabilize the waste or process a segregated organic rich fraction |
| II | Anaerobic Digestion: used to process an segregated organic rich fraction |

# 5 Discussion of Waste Separation Future in China

As is shown obviously in the previous chapters, it makes perfect sense to do waste separation as means for resource recovery and reduce the ecological as well as environmental impacts. So in this chapter, the feasibility of doing waste separation in China will be discussed, to determine what are the necessities and what are the drives of doing waste separation in China.

## 5.1 Necessities for Waste Separation in China

With the current consumption rate and population growth rate, the raw materials for productions are getting scarcer with ever-faster pace. On the contrary, the waste generation has been exceeding the Chinese waste treatment capacity, which has already been describes in chapter 1. In terms of the currently applied mechanism for waste management, mainly, landfilling and thermal treatment (incineration without energy or material recovery), the secondary pollutions caused by which, leads to severe environmental problems, and meanwhile, the economical burdens to solve these problems and the financial resources put into operating these "business as usual" management mechanisms have just been "the less of the two evil".

### 5.1.1 Environmental Impacts by Landfilling

The environmental impacts of landfills exists as long as landfills do, even if a landfill site is closed or shut down, as long as the contents are still piled or filled there, the impacts will continuously grow from landfill gases pollutions, leachate pollutions, land space reduction and contaminations etc. (Johannessen et al., 1999). The mostly common seen types of landfill in China are *open dump* type and *semi-controlled dump* type, and *operated dump* is not widely implemented on a national level but developed urban cities.

According to Mercosur Carbon Gmbh[36], there are 1000 landfills without any methane extraction devices (methane is the major component of LFG), and more than 100 "very large sized "landfills. And the total landfill sites commissioned reached 3539 from 2000 to 2007 with the total capacity over 620 million tons (Xu, 2007). The following table shows the landfill sites commissioned and capacities. The GFL collection rate can hardly reach up to 20% in China (Ibid.).

Table 6 The Number of SMW Landfill Sites (2000 to 2007)

| Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| Landfill sites | 484 | 571 | 528 | 457 | 444 | 365 | 324 | 366 |
| Landfill quantity (million tons) | 62.4 | 78.4 | 74.04 | 72.55 | 78.48 | 81.08 | 78.73 | 94.38 |

The LFG contains mainly methane ($CH_4$), some hydrogen sulphide ($H_2S$, a poisonous and flammable gas), and ammonia ($NH_3$, a caustic hazardous gas) among other gases, which are harmful to both people and environment[37]. The Methane is a GHG with 21times of GHG potential of $CO_2$, which is a great contributor to global warming, besides it's bad smell and flammability.

The leachates from landfills when water passes through the wastes, which consists of many different organic and inorganic compounds, are another troubling problem for local soil condition and underground water bodies[38]. Normally, landfill leachates have high concentrations of nitrogen (N), iron, organic carbon, manganese, chloride and phenols, with also possibly other chemicals like pesticides, solvents and heavy metals[39]. Without proper management, the leachates are extremely harmful.

### 5.1.2 Environmental Impacts by Incineration

[36]The publication year is not applicable
http://www.erec.org/fileadmin/erec_docs/Projcet_Documents/RES_in_China/Kochbxl.pdf
[37]https://climatefriendly.com/skins/files/file/pdf/project_page/Suzhou_Qizi_Mountain_Landfill_Gas_Recovery_Project_Profile.pdf?PHPSESSID=l52vii0nmj23rchhaao4aofkd2
[38] http://www.vsep.com/pdf/LandfillLeachate.pdf
[39] http://www.wisegeek.com/what-is-landfill-leachate.htm

Land use is a constant topic for urban planning in China, due to the landfills taking too much space, and still increasing numbers of being built, to cope with the waste increasing capacity, the central government are planning more incarceration plants, which gradually take place the major share of waste treatment instead of landfilling, though currently, landfilling still takes the lion's share.

Incineration might sounds the "best available" way for dealing with SMW in China, however, the downsides and impacts especially to the environment is as profound, if not more, as landfilling's. Due to the low standard for exhaust emission controls or lack of filtering devices for those incineration plants, the hazardous matters coming out of the incarnation, for instance, Dioxin, COx, NOx, fine particles, ashes etc.

Dioxin is a very toxic pollutant, for both animal and human beings. The inhalation or intake of Dioxin can cause animal's death in 1 to 6 weeks for some acute cases, and for human beings, it cause great syndromes to human body with cancer being one of them[40] if the amount exceeds certain level.

Another example is the ashes from incarnation plants, which include heavy metals, together with concentration of dioxin and many other kinds of pollutants. The treatment of these ashes have been really tough and costly, thusly, the most used way to deal with these ashes are still landfill, even in many industrialized western countries. There are expensive filtering systems and other related technologies for treating these end-of-process ashes, but the costs are usually too high for normal incineration plants to take.

### 5.1.3 Economical Impacts

Due to the fact there is not standardized separation of MSW in China, the potential values of the wastes cannot be realized. For example, recycling 1 tons of waste paper can make 850 kilograms of paper, saving 300 kilograms of wood and produces 74% pollution lesser than making paper with new materials; 1 ton of residential wastes, which includes leftovers, bones, vegetables residuals etc. would produce 0.3 tons of

[40] http://en.wikipedia.org/wiki/Dioxins_and_dioxin-like_compounds

organic fertilizer if applied with proper biotechnological treatment (Chen, 2009). Besides, the investment for building and operation infrastructures for landfilling and incineration plants, including waste collecting, transpiration and final treatment or disposal has been enormous but with less satisfactory results.

Take Shandong province in China for example; with the capacities of landfills being exceeded, more waste incinerators have been under construction with a capacity of 700,000 tons/a alone in 2009, which will triple the previous capacity for incineration plants (ecoprog, 2009). The following table enlists the known projects in that province (Ibid.).

Table 7 Known investment projects in Shandong Province

| Location | Type | Realization | Status |
|---|---|---|---|
| **Jinan Jin Yang** | Construction of a waste incineration plant with a capacity of about 700,000 tons per year. Investment volume: about 940 million RMB | 2009 | Under construction |
| **Rizhao** | Construction of a waste disposal site with receiving capacity of about 73,000 tons per year | n/a | Under construction |
| **Weihai** | Construction of a waste incineration plant with a capacity of about 250,000 tons of waste per year | 2010 | Approved |
| **Shanxian** | Construction of a waste incineration plant with a capacity of about 220,000 tons per year. Supplier is ZhongDe | n/a | Approved |
| **Qingdao** | Construction of a waste incineration plant with a capacity of about 500,000 tons per year | n/a | Planted |
| **Qingdao** | Construction of a waste incineration plant with a capacity of about 500,000 tons per year | n/a | Planned |

On a national level, billions of more investment will be used to build "Regional Circular Economy" and "Resource-Conserving Society" according to China's 12th Five-Year-Plan, but the question lies in is it more economical to build waste treatment facilities like shown in Shandong Province case, or to establish waste separation schemes?

## 5.2 Biogas Potential of BMW in China

Biogas has always been the favorite for organic waste utilization. However, the problem for China's situation is the mixture of both organic and in-organic fractions from MSW, which dramatically reduce the methane yields if taken as a input material for biogas plants. That is why it makes more sense to do waste separation in China. In the year 2007, China's fuel gas consumption is $693500*10^6 m^3$, and the annual biogas potential if fully realized (from BMW, septic feces, sewage sludge, crop straw and manures) can provide as much as 51% of the total consumption (Heck, 2011).

The BMW alone from MSW in China has the amount of $29.5 * 10^6$ tons (dry)/year, which equals $12,600*10^6 m^3$/year Biogas, or $274*10^9$MJ/year energy equivalence. The following table shows the biogas potential from biological waste in China (He, 2010).

Table 8 Biogas Potential from Bio-waste in China

| Bio-waste | Amount t-dry/a | Biogas $10^6 m^3/a$ | Methane $10^6 m^3/a$ | Energy $10^9$ MJ/a |
|---|---|---|---|---|
| BMW | $29.5 \times 10^6$ | 12600 | 7080 | 274 |
| Septic feces | $0.6 \times 10^6$ | 270 | 175 | 6 |
| Sewage sludge | $2.3 \times 10^6$ | 410 | 287 | 10 |
| Crop straws | $600 \times 10^6$ | 202500 | 141750 | 5125 |
| Manures | $710 \times 10^6$ | 319500 | 207600 | 7510 |
| Total | | | ~357000 | ~12900 |

Source: He Pingjing, Tongji University, IFAT 2010 Shanghai

Solely judging by the theoretical figure, the potential to produce biogas from bio waste of various sources can be of great attribution to China, saving both the fuel gas consumption on the one hand, reducing GHG emissions from the bio wastes of status quo remains. However, the more practical problem lays in, for example how to get the BMW from the mixture of MSW economically, how to collect other biomass input, etc. so that it's also profitable for people to realize the potentials from bio wastes.

## 5.3 Political Boost for Waste Separation in China

According to Dr. Yang Yong of Sichuan University, "the year 2010 has been a turning point for China's environmental policy transaction". In this year alone, there are 6 national policies and 11 technical standards for waste treatment. Up to now, there are 4 national law have came into effect since 2003, 14 national wide policies and 32 technical standards for waste and environment related technical implementations.

Phenomenal outcomes have shown due to the policy boots in terms of waste management. In 2009, there investment on the fixed assets of environment sanitation and hygiene piled up to 31.65 billion RMB (Yan, 2011).

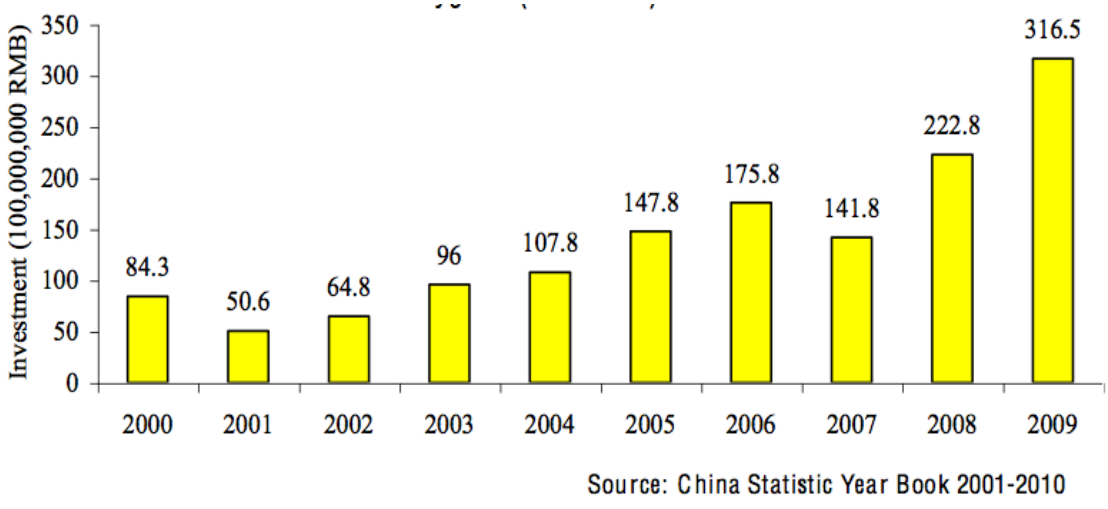



Figure 11 Investment on fixed assets of environment sanitation and hygiene (2000-2009)

Besides the government play and operation, more and more public and private stakeholders have been involved for waste management projects. From 2002, a national wide MSW disposal fee is imposed, which has less bounding effects, but to

the year 2007, over 59% of the cities (387 out of 866) in China have successfully imposed the MSW disposal fee within their jurisdictions, and in that year, a 3.8 billion RMB were collected for MSW disposal (Ibid.).

There is still a huge gap between the best-case scenario and the status quo for China's current situation. Are there better ways for the fees collected just for disposal of SMW? If the infrastructures for waste separation were wide spread and citizens have been well aware of the advantages of waste separation, wouldn't it make recycling and reutilization of MSW much easier? As a matter of fact it is indeed. The next case study in Shenyang has shown it is more than possible and feasible to do waste at source separation in China.

## 5.4 Case Study of Waste At-source Separation in Shenyang

The Institute of Clean Energy & Environmental Engineering (ICEE) of Shenyang Aerospace University has conducted a joint project with GIZ (used to be GIZ) about wastes at-source separation in Shenyang for over 5 years (from 2005 to 2010) to determine the residents' willingness of separating the waste streams at source (Li, 2010).

They have chosen 4 pilot project areas in four neighborhoods of different income levels representing different working class citizens in four locations of Shenyang City (refer to Chart 21).

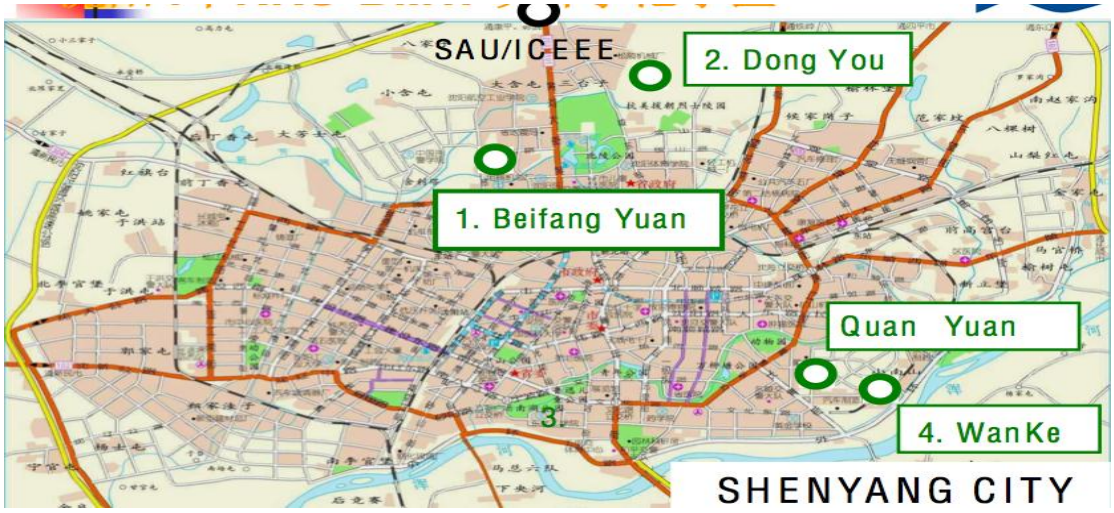



Chart 21 Shenyang At-source Waste Separation Project Map

They come up with 4 waste streams for the residents in the designated project areas to know and equip the neighborhood with 4 corresponding waste collection bins, namely, Biological Municipal Waste (BMW), Residual Municipal Waste (RMW), Recyclable Waste (RW), and Hazardous Waste (RW). Collection bins of each kind have been set up and placed into the chosen neighborhoods like shown in the following chart (Ibid.).


Source: Ibid

Chart 22 The Four Waste Stream System in Shenyang Project

Setting up the "hardware" is merely enough. A public campaign of advocating the advantages of waste separation and more importantly, the specific information of how to separation wastes are conducted by the researchers of ICEE together with their student assistants. Thusly, the local residents not only have the "hardware", but also have the "know-how" for waste at-source separation.

Source: Ibid

Chart 23 Public Campaign of Waste Separation Information

After the collection, the wastes are taken back to the lab for waste composition analysis, the results shows that the biological waste takes up averagely 73.7 % of the total MSW collected in the four areas. The following table shows the detailed composition and their share in the collected MSW from 2005 to 2009 (Ibid.).

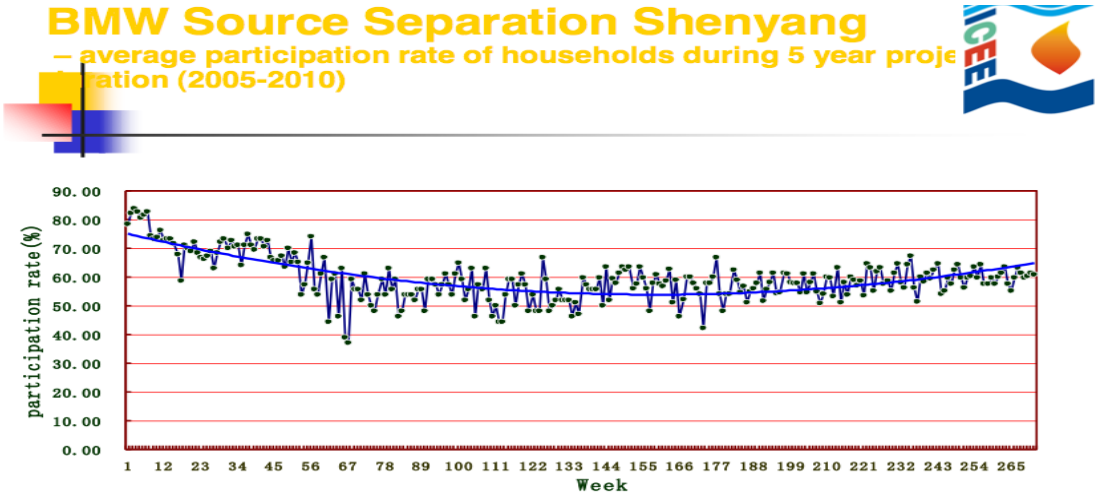
Table 9 MSW Compositions in Shenyang Waste Separation Project

| **Name** | **Percentage** | **Name** | **Percentage** |
|---|---|---|---|
| **BMW** | 73.7 % | Hazardous Waste | 1.4 % |
| **Wood/Bamboo** | 1.0 % | Complex product | 6.5 % |
| **Paper** | 6.5 % | Minerals | 6.8 % |
| **Glass** | 1.5 % | Others | 1.5 % |
| **Textiles** | 0.9 % | Fines < 10 mm | 4.1 % |
| **Metal** | 0.3 | | |

Among this 73.7 % BMW from the total collected MSW, the organic content takes up to over 97.6 % for the first two years (from 2005-2006, the remaining years data are not provided), which leads to huge potential for biomass utilizations such as biogas production, organic fertilizers etc.

Another important result of this project is the participations for local residents in terms of waste at-source separations. Over the 5 years project period, more than 60% of the households have been participating in the waste separation on average, which proves that **there are more Chinese residents will like to separate wastes than the**

**ones who won't.** And this is all on a voluntary base, without any legal obligation from the local government. The following chart shows the participation of the households in Shenyang Project on a weekly base (Ibid.).




Source: Ibid

Chart 24 Households Participation Rate for Shenyang Project

And once again, this Shenyang project shows the great potential for MSW in China, especially in the Northern cities of China. And waste at-source separation is possible, and economically feasible in China.

# 6 Conclusion and Recommendations

So the answer to the “million-dollar question” of “whether or not waste separation is necessaries in China” is definitely a “YES”. And a more important question is if it is feasible to do waste separation in China, the answer is still very positive, based on the discussions and case studies given in the previous chapters.

However, there are several key elements that will contribute to the success of conducting waste separations in China, and yet there are still some concerns left for continues working for solutions.

## 6.1 Key Elements Needed for Waste Separation in China

Based the practical situation of MSW management in China, there are several elements that the author deem are necessary and important for waste separation in China, based on the current status quo, management system, cultural background in China, to which proposals or suggestions are made.

### 6.1.1 Environmental Awareness and Education

People’s awareness is the most important the initial waste separations at an individual level, from their workplace, public area, as well as households. But in China, the environmental education has been insufficiently provided. This case is completely the opposite in the countries where waste separation has been successfully conducted, like in Germany, Denmark, and Japan etc. For sample, when the author went to Japan for postgraduate study, during the orientation periods, their resident assistant held a series of lessons for “garbage classifying and dumping”, besides the seemingly countless categories of wastes, there were even weekly quiz for testing the correctness of remembrance. And in Germany, the author also experienced the similar doctrine but less completed than the ones in Japan. All these awareness have thusly been

deeply affecting the attitude before the author tries to throw any garbage. Thusly, the following recommendations are made for raising environmental awareness by education in China:

**Offering Environmental Education at Schools**

Schools are most people's major choices for receiving formal education in China, though there is still a significant amount of people who don't have this "luxury". The best way is to integrate the environmental awareness education into the curriculum. Teaching even from the elementary school level, the advantages of doing waste separation, environmental protection related matters. For the kids, they probably wont fully understand the profound meanings for those teachings, but they can gradually accept this habit and understand with their growth. For higher institutions like colleges or universities, students should be offered courses regarding the waste separation and to be the role models for transferring these ideas into reality.

**Public Awareness Campaigns**

There are far more people who can not be reaches for schools, like peasants, everyday workers, senior residents and the list goes on. For the majority of people, a more effective means for raising their environmental awareness is though public campaigns. Through mass media like TV, radio, Ads, social activities, programs etc. to spread the idea of doing waste separations, and more importantly, to let me know how exactly to do it with in-depth instructions. Seeing other people doing it, there will be more and more people who would join the "main stream".

### 6.1.2 Legal Frameworks for Implementation of Waste Separation

Even though there are already existing regulations and laws concerning the waste management in China, but when it comes to real life implementation or reinforcement of them, there are still much more room for improvement. What is needed for the legal frameworks is to come up with specific standards from wastes definitions, parameters, to waste classifications and separations, until the final treatment and disposal processes. A further recommendation is as the followings:

**Wastes Classifications and Definitions**

For MSW, there should be a clear definitions and specific classifications according to the nature of the wastes. What shall be defined as recyclable wastes, organic wastes, what could be collected or sold directly, what must be properly disposed like E-wastes, which contains toxic metal. Leave less or no room for causing confusion when it comes to wastes for people.

**Reinforcement of Waste Management Fees**

Until now, the national policies of collecting waste management fees from citizens still have not covered all the cities and regions in China. Without further reinforcement, there are fewer funds for supporting the in fractures for waste treatments, and on the other hand, completion of this waste management fees could also increase the payers' awareness. However, due to the un-even development rate for different regions in China, corresponding standards should be applied according to the local situations.

**Punitive Measures for Failing Implementations**

One important reason for the ill or failing of implementation of waste separations despite the existence of regulations and laws are the lack of punitive measures. There should be a punishment funds for the people who do not separate wastes under the regulations on purpose. This serves as counter-forcing incentive, alarming them the potential economic lose if people do not do waste separations. However, it might be difficult for regulation bodies to come up with such measures, especially in China, since waste separation falls more into ethical and volunteering codes.

### 6.1.3 Improving Waste Separation Infrastructures and Increase Technological Investment

Besides the necessary "software", the "hardware" is also of the same level of importance for waste separation. For at-source separation, there is not yet technology-intensive infrastructures needed but good quality bins for collecting separately both in public areas and private or resident sites. For on-site separations, more funds should be put to invest on the technological solutions such as MBT and alike. This may seem

to be expensive especially for the initial investment, but on a longer term, by applying high-tech solutions for waste separation and treatment could more efficiently and effective recovery both the materials and energy from wastes, saving eventually outweigh the inputs. Moreover, there are many financial schemes, which can help financing those investments like CDM, Emission Trading etc.

## 6.2 Possible Financial Schemes for Waste Separation

As the saying goes, "Money makes the world goes around!" Everything goes easy if there are enough financial backups. One constant argument from the local government is the "lack of funds", which can be solved by setting up different possible financial schemes.

### 6.2.1 Funding from Emission Reductions and Savings

To provide enough financial supports for conducting waste separation, one efficient ways is to get money from emission reductions based on the waste separation projects or the savings from them. By integrating waste separations to replace the "business as usual" project activities, which will reduce the landfill or incineration amount, thusly has GHG emission reductions or energy savings to finance these projects. There are some schemes that have been widely applied worldwide.

**CDM Projects**

Take Clean Development Mechanism (CDM) Projects for example, according to the United Nation Framework Convention on Climate Change (UNFCCC), "The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of $CO_2$. These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol.[41]" These CERs can be partially the funding source.

[41] http://cdm.unfccc.int/about/index.html

**CER Projects**

Another emission trading funding scheme under of CDM is though certified emission reduction (CER) projects. The difference is these certified reductions can be traded within the European emission trading schemes, and usually bought by companies or countries to help them meet their targets for carbon emission reduction as well as for voluntary offsetting purposes[42].

**Savings for Technology Implementation**

Another important financial source comes from the "savings" bought by technologies implementation of waste separation. The recyclables can be sold at market prices as materials, which leads to savings for using less landfill capacity, operational cost, energy costs. And by-products from MBT, which includes, biogas, organic-fertilizer, RDFs, can also be sold to subsidize partially the investments for implementing these technologies.

### 6.2.2 Government Initialed Incentives

The government on different levels should come up with incentives such as subsidies or taxation under the legal frameworks, to demote the "business as usual" waste collection and treatment scheme, to promote waste separation, energy and material recovery, added value creation from the wastes.

For example, taxes should be imposed on the landfills or incinerations that have not the environmental standards. Landfills should be taxed by the mass of the wastes, and incineration plants by the emission amount.

Sides that, subsidies should be given to the enterprises doing project concerning the classification, collection, transportation of the wastes, as well as, the material or energy recovered from the wastes. By offering them subsidies, there are more chances for their projects to succeed.

[42] http://www.myclimate.org/en/carbon-offset-projects/project-standard/cer-projects.html

## 6.3 Final words

China has been a huge market for the world since centuries ago. Due to her population number and territory coverage, everything thing that happens domestically can lead to major changes on the world stage. Meanwhile, that may be one's trash could be another one's treasure, and the author firmly believe MSW being one of them. The practical solution is to tap this "resource pool" with proper management and organizational tools from different stakeholders to convert these huge amount of wastes into values, reducing the social, ecological and environmental burdens on the one hand, creating positive values from varies aspects from the other hand. There will be a bright future for China's "wastes".

# References

(Chen, 2009) Yingxu Chen, member of the National Committee of CPPCC (Chinese People's Political Consultative Conference), Professor of Zhenjiang University, 2009.

(China Statistical Yearbook, 2000-2009) National Bureau of Statistics of China.

(Christian et al., 2005) Christian Delvoie, Maryvonne Plessis-Fraissar, 2005, *Waste Management in China: Issues and Recommendations May 2005,* Urban Development Working Papers East Asia Infrastructure Department, World Bank Working Paper No. 9

(Defra, 2007) Department for Environment, Food & Rural Affairs (Detra) U.K., 2007, *Mechanical Biological Treatment of Municipal Solid Waste,* *http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/mbt.pdf*

(ecoprog, 2009) ecoprog GmbH, *Market Study Municipal Waste Management in China*, Cologne/Shanghai, March 2009. http://www.ecoprog.com/en/pdf/studies/studie_municipal_waste_management_china.pdf

(Heck 2010) Peter Heck, Spring Semester IMAT Program Lecture Material, 2010, *Regional Material Flow Management*, Institute for Applied Material Flow Management.

(Johannessen et al., 1999) Lars Mikkel Johanessen, Gabriela Boyer, 1999, Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America, Urban Development Division, Waste Management Anchor Team, The World Bank. http://www.worldbank.org/urban/solid_wm/erm/CWG%20folder/uwp3.pdf

(Josef Barth, 2002) Josef Barth, ECN/ORBIT e.V Source Separation Workshop 2003, *Situation of the Source Separation Collection of Biowaste in Germany,*

http://www.resol.com.br/textos/Situation%20of%20the%20source%20separate%20collection%20of%20biowaste%20in%20germany.pdf

(Li, 2011) Li Rundong, Sino-German Symposium on Circular Economy Symposium 2011, Conference Presentation, *Waste-to-Energy by Source Separation*, Institute of Clean Energy and Environmental Engineering, Shenyang Aerospace University.

(Lin Jiaoqiao et al., 2007) Lin Jiaoqiao, Lin Na, Qiao Liming, Zheng Jie, Tsao Chi-Chung, 2007, *Municipal Solid Waste Management in China*, Docstoc, p2, http://www.docstoc.com/docs/19960465/Municipal-Solid-Waste-Management-in-China

(Lybæk R B et al., 2010) Lybæk Rikke Bak, Klemmensen Børge, Li, Ruofei, Liu Sibei, 2010, *Municipal Solid Waste Management in China*, Roskilde University Digital Archive

(Matthias et al., 2007) Matthias Kühle-Weidemeier, Ulrich Langer, Frank Honmann, 2007, Environmental research program of the Federal Ministry of Environment, Environmental Protection and Nuclear Safety, *Plants for Mechanical-Biological Waste Treatment-Summary of the Final Report*, http://www.wasteconsult.de/Sachstand_MBA_Englisch.pdf

(Peter Heck, 2011) Peter Heck, Sino-German Symposium on Circular Economy Symposium 2011, Conference Presentation, *Material Flow Management: an innovative tool for sustainable urban waste management*, IFAS.

(Xu 2007) Xu Haiyun, 2007, *the development of MSW LFG in China*, China Urban Construction Design & Research Institute. http://www.globalmethane.org/documents/landfills_cap_china.pdf

(Yan, 2011) Yong Yan, Sino-German Symposium on Circular Economy Symposium 2011, Conference Presentation, *Policy transactions of municipal solid waste (MSW)*

*management in China*, Department of Environmental Science and Engineering Sihuan University.

(Yasuhisa, p11) Yasuhisa Tsukada, Waste Management Division, Bureau of Environment, Tokyo Metropolitan Government, Legislative System of Waste Management in Japan, http://www.asianhumannet.org/db/datas/Legislative_en.pdf

(Yi et al., 2007) Yi Xiao, Xuemei Bai, Zhiyun Ouyang, Hua Zheng, Fangfang Xing, 2007, *The composition, trend and impact of urban solid waste in Beijing*, p1, Springer Science, http://www.springerlink.com/content/8647w0m9h9471046/fulltext.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Public Relations Division, 2006, *Waste Management In Germany, A driving force for jobs and innovation*, p28, http://www.cleaner-production.de/fileadmin/assets/pdfs/_73_Engl.__broschuere_abw_deutschland_01.pdf http://www.xbjcyc.cn

PTL Group Publication, 2010, *Waste Management in China*, http://www.ptl-group.com/index.php/en/china-blog/528-waste-management-in-china

(Hatard, 2009)Susanne Hartard, Trier University of Applied Sciences-Umwelt Campus Birkenfeld, 2009, Lecture Material, *Basics of Environmental Technologies & Ecological Engineering*, UCB, Fh Trier