Development of Waste-To-Energy in China; and Case Study of the Guangzhou Likeng WTE plant

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EXECUTIVE SUMMARY

This thesis consists of two parts. The first is an overview and update of the overall Chinese waste-to-energy (WTE) industry, its environmental performance, and economics. The second part is a case study of the application of WTE in Guangzhou City in China that included a field trip report of the Guangzhou Likeng WTE plant.

Part 1: Development of WTE industry in China

Accelerated industrial development and improved living standards in China have led to the generation of constantly increasing municipal solid waste (MSW). Disposal of solid wastes has become a serious environmental and land-use problem with which China is currently confronted. In January to December 2011, the Earth Engineering Center of Columbia University investigated the waste management system of China. The first part of this thesis describes the status of the MSW generation and disposition in China and identifies by region the application of Sustainable Solid Waste Management in China. In the past three decades, MSW collection in China increased by five times, from 31 million tons in 1980 to 157 million tons in 2009. Presently, more than one third of the cities in China are facing the problem of MSW disposal, resulting from the lack of space for landfilling; this presents both a challenge and an opportunity to China, in particular with regard to the WTE industry. Significant improvements have been made in the WTE sector. For example, lots of large cities are aggressively moving towards WTE as a alternative of landfilling. The study illustrated that since the beginning of the 21st century, Chinese WTE capacity increased from 2.2 million tons/year to 23.5 million tons/year in 2009. This makes China the fourth largest user of WTE, after E.U., Japan, and the U.S. By 2009, there were 93 operating WTE plants in China. Even though the pace of China's solid waste improvement is significant, China's WTE industry is stilling facing momentous opposition from some local residents and environmental activists.

The Earth Engineering Center (EEC), in collaboration with scientists of WTERT-China, has been investigated in the WTE emissions in China. In particular, EEC has focused on dioxins and furans, the most feared emission of WTE plants. This valuable information is difficult to collect due to the lack of reliable and consistent source, and the lack of transparency in the data collecting systems. After one year of research through literature reviews, a field trip and interviews, the dioxin emissions of twenty WTE plants in China have been identified. The results showed that the dioxin emissions of these 20 MSW WTE plants ranged from 0.002 to 0.22 NG TEQ /Nm^3; the average value was 0.0719 ng TEQ/Nm3, indicating that many of the WTE plants in China have as low emissions as those in the US and Europe. Eighteen out of twenty of the WTE plants that were reviewed operate below the E.U dioxin standard (0.1 NG TEQ /Nm^3), and two above the E.U dioxin standard, but still under the Chinese Dioxin standard (1 NG TEQ /Nm^3).

The report also shows a summary of National Chinese Laws and Regulations on MSW, and the purposed regulatory framework in Dioxin Emissions Reporting systems. With the new guidance "On Strengthening Dioxin Pollution Prevention" issued collaboratively by nice Chinese ministries on October, 2010, a long-term mechanism of dioxin pollution prevention shall be established.

An analysis of the capital investment profiles of over 44 WTE plants in China was also carried out in this study and showed that WTE investment costs in China are considerably lower than for E.U. and the U.S. On average, on the basis of the 44 WTE plants reviewed, the total annual capacity of these plants is 12.9 million tons, and the average capital investment in the order of $200 per ton of annual capacity. In comparison, the average capital investment for WTE plants in the nineties was in the order of $400 per ton, i.e., two times of that in China.

Part 2: Case study of the Guangzhou Likeng WTE plant in China

Guangzhou, the capital and largest city of the Guangdong province in China, has a population of 12.8 million and is the third largest city in China. Located in southern China on the Pearl River, about 75 miles north-northwest of Hong Kong, Guangzhou City is a key national transportation hub and trading port.

The municipal solid waste (MSW) generation in Guangzhou City is 17,800 tons/day and 6.5 million tons/year, accounting for 4.2% of the national MSW generation. The waste production per capita is 0.48 tons/year and is increasing by 5% annually. Since 1995, the MSW generation of Guangzhou has increased from 2,900 tons/day in 1995 to 8,200 tons/day in 2009. The forecast for MSW generation is 3.06 million tons/year in 2015, 3.2 million in 2020, and 3.31 million in 2025.

As one of the first cities in China to implement formal recycling, Guangzhou's MSW management relies heavily on landfilling (91% of post-recycling MSW). The city has six MSW disposal facilities, including one WTE plant and five regulated landfills. The Likeng WTE plant (started in Jan. 2006) has a design capacity of 1,040 metric tons per day and generates 130,000 MWh of electricity a year, by treating 10% of the post-recycling MSW of Guangzhou City.

As discussed in the first part of this thesis, many Chinese WTE plants have as low emissions of dioxins as those in Europe and the U.S. However, there is continuing opposition and much concern over the use of WTE technology by some of the local communities and environmentalists in China; the principal fear is that WTE plants may release significant amounts of toxics, principally dioxins and furans. In particular, it was surprising to read in the local press several adverse stories about WTE emissions from the Likeng WTE plant in Guangzhou which started operation in 2006 and incorporates the best of the E.U. and Japanese WTE technologies. In order to understand the true situation in Likeng WTE plant, the author travelled to Guangzhou and visited the Likeng WTE plant in December, 2011.

After a detailed tour of the Guangzhou Likeng plant, meeting with the plant manager, and also driving through several local villages and interviewing several local farmers, the author concluded that this WTE plant is well operated and has in place several effective ways of improving its environmental performance. Also, their environmental emission data are fully transparent to the general public and the press, with the exception of dioxin/furan emissions. One of the key findings through the interviews with the local residents was that some unpleasant odors that cause people to complain about the Likeng plant are not due to the WTE plant, but from leachate leaking out on the streets from the collection trucks transporting the wet MSW to the plant; as mentioned in several studies, the MSW in China has a high moisture content in all components, including paer and plastics. One recommendation of this report is that the municipalities provide covered bins for people to deposit their wastes and also require citizens and businesses to put out waste in closed bags, as is done routinely in western cities , such as New York. These measures would improve the appearance of the city and reduce the odor complaints of citizens.

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Yani Dong, December 2012

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART 1: DEVELOPMENT OF WTE INDUSTRY IN CHINA

1. INTRODUCTION

China has become the center of the world's attention over the last decade because of its booming economic growth, shifting from an agricultural to an industry and service-oriented economy. What this means for millions of Chinese is that they now have the ability to consume an enormous variety of goods and services that were previously either unavailable or unaffordable. With a population of about 1.33 billion, China has sustained a laudable GDP growth averaging 9.9% per year over the last three decades, reaching a milestone in 2010 by surpassing Japan as the second largest economy in the world. Yet many have casted doubts on the sustainability of China's impressive record, and urged a major transformation of its economy composition.

The rapid economic growth, urbanization and population growth (Figure 1) of China have been accompanied by a large and rapid increase in the generation of solid waste quantities that no other country has ever experienced before.

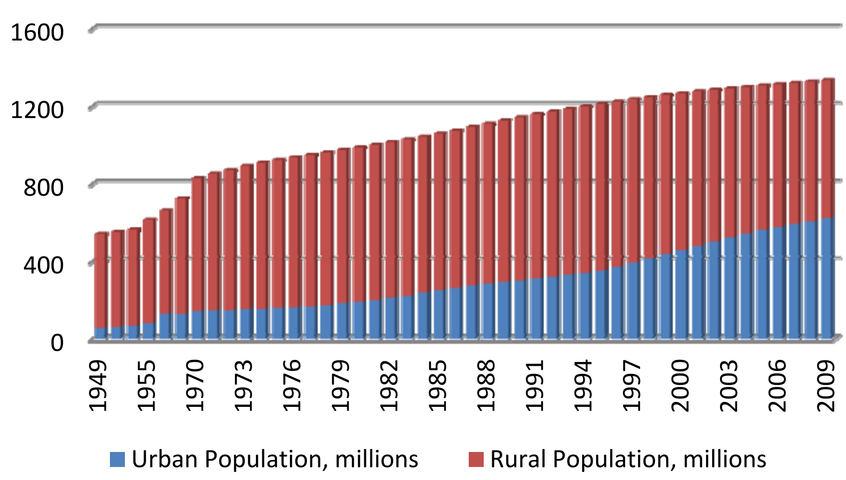


Figure 1 China Population and Urbanization Growth (1)

Consequently, the generation and disposal of municipal solid wastes (MSW) still poses a serious challenge considered by the Chinese government. More and more cities in China are facing the problem of MSW disposal. Large cities in China will not be able to further dispose its MSW as their previous method because of the lack of space for landfill. Therefore, Municipal Solid Waste Management (MSWM) is of significant importance for China's further development. The need for intelligent waste management has led to the concept of the "hierarchy of waste management" (2) that places the various means for dealing with MSW in the order of environmental preference. The most recent form of this hierarchy is shown graphically in Figure 2.

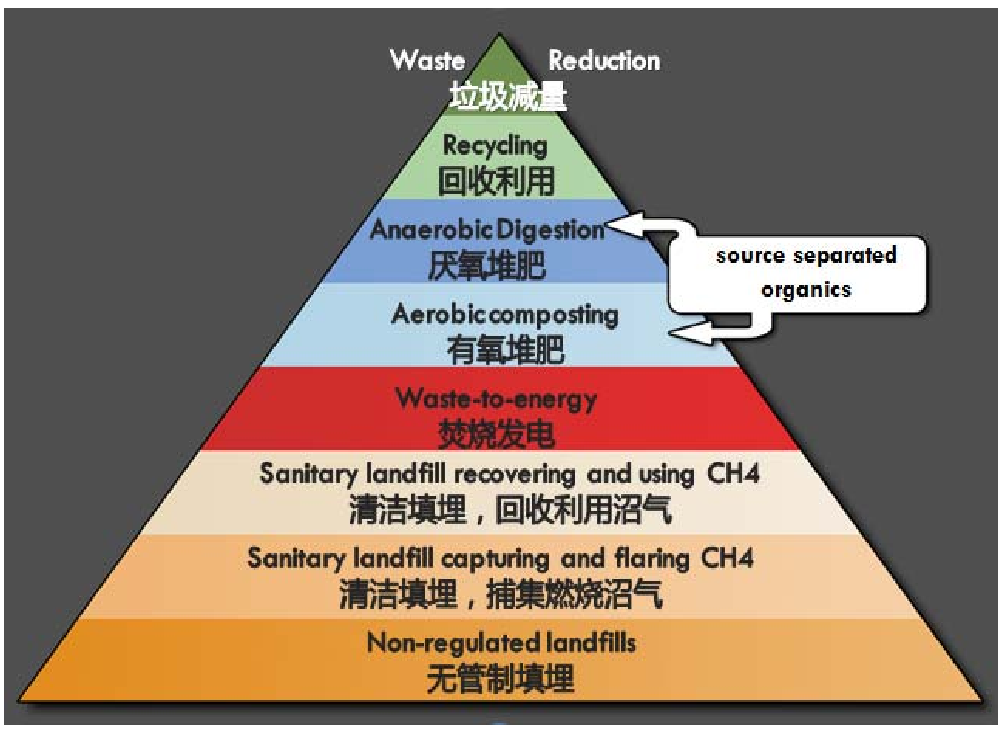


Figure 2 The Hierarchy of Waste Management (2) (chinese rendition by Y. Dong)

1.1 TECHNOLOGIES FOR SUSTAINABLE WASTE MANAGEMENT

As it shown in the hierarchy of the waste management, the first priority is to minimize the generation of wastes by means of better design of products and packaging. The next best thing after waste reduction is the recycling of materials. There are five categories of recyclable waste in China: paper, plastics, glass, metal and fabric.

- Paper includes newspaper, periodicals, books, a variety of wrapping paper, office paper, cardboard, etc.
- Plastics includes all kind of plastic bags, plastic packaging, disposable plastic food container and utensils, toothbrushes, cups, water bottles, toothpaste tubes, etc.
- Glass includes a variety of glass bottles, broken glass mirrors, light bulbs, etc.
- Metals include all kinds of metallic objects cans, mental container and so on.
- Fabric includes used clothing, linen, towels, bags, etc.

However, as demonstrated by the most environmentally conscious nations such as Japan and Switzerland, the goal of "zero waste", as preached by some environmental organizations is simply not attainable for practical reasons.

The next step down the hierarchy of waste management is composting of organic wastes (green and food wastes), either aerobically to carbon dioxide and a compost product, or anaerobically to methane, carbon dioxide, and a compost product. However, experience has shown that composting is practical only for source-separated organics. Other methods include covered aerated static piles and in-vessel bioreactors.

After all possible recycling and composting has been done, there are only two possible ways to deal with the remainder of "post-recycling" wastes: Waste-to-Energy (WTE) or landfilling. Contrary to many assertions made by environmental groups, waste-to-energy facilities have a number of environmental benefits. According to the Intergovernmental Panel on Climate Change:

"Net GHG emissions from WTE facilities are usually low and comparable to those from biomass energy systems, because electricity and heat are generated largely from photosynthetically produced paper, yard waste, and organic garbage rather than from fossil fuels. Only the combustion of fossil fuel based waste such as plastics and synthetic fabrics contribute to net GHG releases, but recycling of these materials generally produces even lower emissions." (3)

Because of the advantages of WTE over landfilling, such as rapid volume reduction (approximately 90%) and mass reduction（approximately 70%）combined with energy recovery, an increasing number of cities have built or are planning to build WTE plants, in spite of the significant capital and operating costs involved. In addition, a sanitary landfill is filled within 10-20 years, and the WTE plant can continue to serve future generations at a relative low cost per ton of MSW disposed. On the other hand, the disadvantages of landfills are in at least three major ways: First, Greenfields are constantly and forever converted to cemeteries of garbage; Second, of more immediate and global interest is that the methane generated in uncontrolled landfills represents an important contribution to greenhouse gases and to the already observed climate change issue; The third reason is that burying of a ton of MSW is equivalent to wasting a barrel of oil (600 kWh of electricity) per ton of MSW landfilled. Therefore WTE has been playing a very important role in MSW management. Figure 3 shows how MSW is disposed in several developed and developing nations.

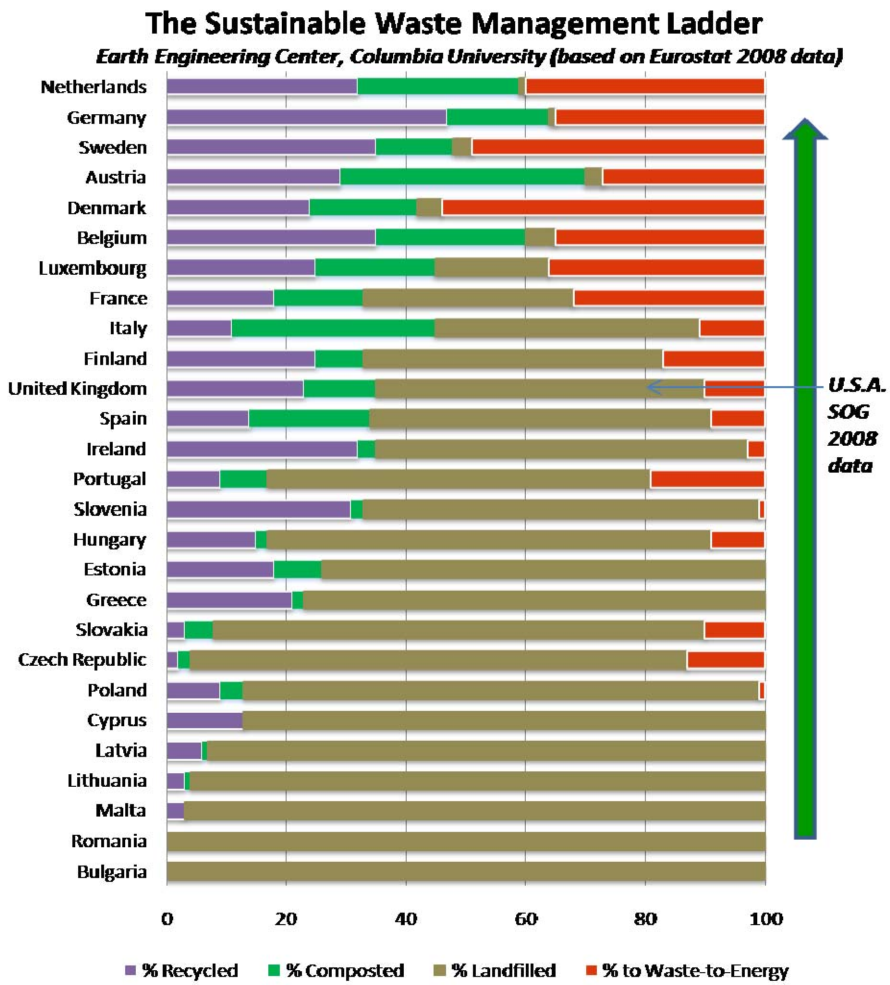


Figure 3 The "ladder" of sustainable waste management; nations that are landfilling nearly all of their MSW are at the lowest rungs of the ladder (4)

2. GENERATION OF MUNICIPAL SOLID WASTE IN CHINA

In the past three decades, with the rapid development of economy and industry, MSW collection in China increased by five times, from 31 million tons in 1980 to 157 million tons in 2009 (1), shown Figure 4.

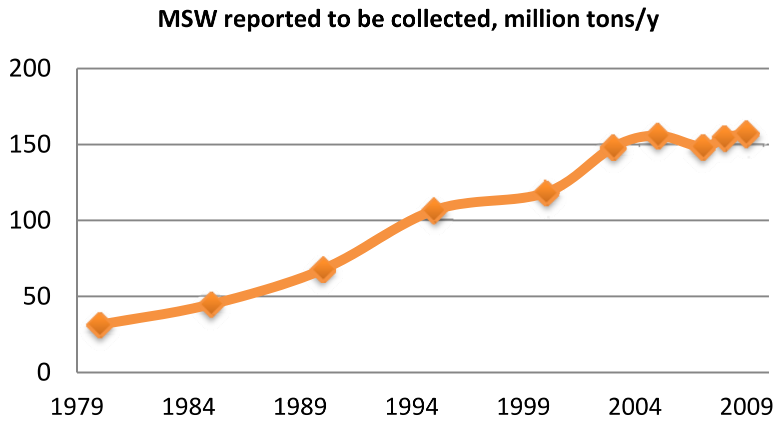


Figure 4 Collected and transported municipal solid waste in China, 1980-2009

*Most available information is based on "waste collected" data rather than "waste generated" data, the reasons for that will be explained in the disposal chapter.

China has twenty-two provinces, four autonomous cities (Beijing, Tianjing, Shanghai, Chongqing), five autonomous regions (Guangxi, Inner Mongolia, Tibet, Ningxia, Xinjiang), and two special administrative regions (Hong Kong and Macau). Taking into account of the large differences of the population, economic development and urbanization between different provinces and cities in China, the most densely populated areas included the Chang Jiang Valley (of which the delta region was the most populous), Sichuan Basin, North China Plain, Zhu Jiang Delta, and the industrial area around the city of Shenyang in the northeast, therefore, the generation of MSW varies greatly. Table 1 and Figure 5 show the differences of MSW collection among different regions in China (2008).

Table 1 MSW generation in various regions of China (2008)

Region	Population, millions	MSW collected and transported, thousand Tons	MSW collected, tons/capita
Autonomous cities			
Beijing	61.35	6566.1	0.107
Chongqing	28.39	2251.9	0.079
Shanghai	18.88	6760	0.358
Tianjin	11.76	1738	0.148
Autonomous regions			
Guangxi	48.16	2485.3	0.052
Inner Mongolia	24.14	3580.7	0.148
Ningxia	6.18	957.4	0.155
Tibet	2.87	230	0.08
Xinjiang	21.3	2925.8	0.137
Provinces			
Anhui	61.35	4269	0.07
Fujian	36.04	3989.5	0.111
Gansu	26.28	2624.3	0.1

Regions	Population, Million person	MSW collected and transported, Thousand Tons	MSW collected, Tons/capita
Guangdong	95.44	18683.6	0.196
Guizhou	37.93	1905.4	0.05
Hainan	8.54	847.5	0.099
Hebei	69.89	6627.7	0.095
Heilongjiang	38.25	8986.4	0.235
Henan	94.29	7570.4	0.08
Hubei	57.11	6807.6	0.119
Hunan	63.8	5427.9	0.085
Liaoning	43.15	7967.1	0.185
Qinghai	5.54	635.5	0.115
Shaanxi	37.62	3197	0.085
Shandong	94.17	9914.4	0.105
Shanxi	34.11	3540.7	0.104
Sichuan	81.38	5509.6	0.068
Yunnan	45.43	2837	0.062
Zhejiang	51.2	8067.8	0.158
China, total	1328.02	154377	0.116246

Figure 5 Distribution of MSW generation per capita in China

According to Table 1, the collection of MSW varies from 358 tons per capita in Shanghai to only 50 tons in the rural region of Guizhou. In terms of total municipal solid waste collected and transported, Guangdong, Shanghai, and Jiangsu have the highest generation of 18683 million tons, 9914 million tons, and 9345 million tons, respectively. The Guangdong province alone accounts for 12.1% of China's MSW generation. The reasons for that rely on three key aspects, urbanization, urban population growth, and increasing affluence. Urban residents produce two to three times more waste than their rural counterparts regardless of income levels because of a higher economic activity, including commercial, industrial and institutional activities (5). Most of Chinese large cities with a population of at least 750,000 people are in the eastern region, and the waste generation rate tends to decrease from eastern coastal cities to the west.

3. DISPOSITION OF MUNICIPAL SOLID WASTE IN CHINA

3.1 OVERVIEW OF MSW TREATMENT IN CHINA

Formal treatment and disposal of MSW was started in the 1980s in China. Before the 1970s, MSW was transported to rural areas as fertilizer because the quantity of generated MSW was small and consisted mostly of food and green wastes. From the 1970s to the mid-1980s, the composition of MSW changed, chemical fertilizer became widely used, and MSW contained other materials and could no longer be used as fertilizer. A large quantity of MSW was dumped in ponds, scrubland, and roadsides around the cities. Cities were literally becoming surrounded by MSW. From the mid-1980s, local governments began to pay attention to the disposal of MSW and disposal facilities began to be built. (6).

There is no one single solution for waste management, from collection, transfer to treatment. A mix of treatment systems under the guidance of the Hierarchy of Sustainable Waste Management is typically preferred. The "harmless treatment rate" is defined as the percentage of the weight of the MSW treated by recycling, composing, Waste-To-Energy (WTE) and sanitary landfilling vs. the total MSW. Figure 6 shows the harmless treatment rate of MSW in China from 2001-20081.

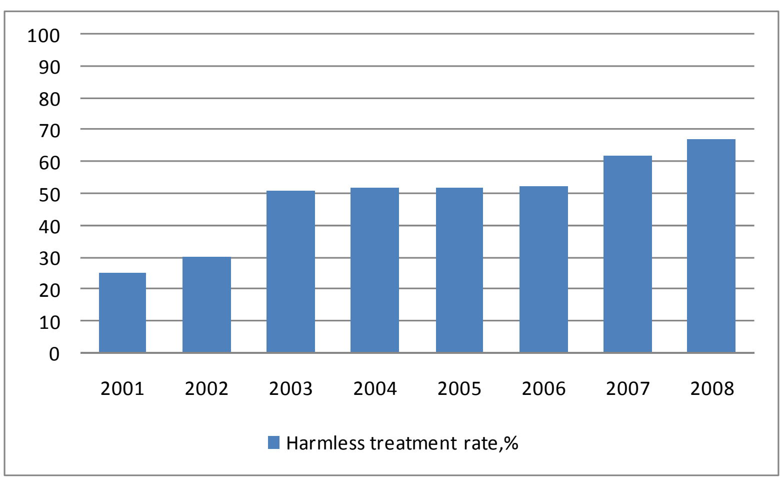


Figure 6 "Harmless" treatment rate of MSW in China from 2001-2008 (1)

3.2 RECYCLING

Recycling is an important component of any integrated waste management system. In China, there is a considerable percentage of formal and informal waste sorting and recycling component in the overall waste management systems. Based on the World Bank report's estimation, there are likely around 1,300,000 people who work in the formal urban waste collection system (paid by local government or business—their main jobs is the collection and transport of waste, selling recycled materials is only a secondary revenue stream) and another 2,500,000 in the informal sector (paid mainly by the sale of collected materials) (7). Because of the large number of people working as waste pickers both formal and informal in China, much of the municipal solid waste is recycled from the residences and commercial or industrial fields before the formal collection, and that's why the "recycling" data is difficult to calculate in China, and most available data is based on "waste collected" rather than "waste generated" which is more useful since it includes recyclable materials. Improving the reliability of waste management data will be a critical task in China, and getting more reliable data from the recycling sector and the overall MSW system is extremely important.

Importing the low-cost secondary materials from developed countries has played a large and adverse role in China's current recycling system by affecting the secondary materials market. In 2002, the US exported an estimated $1.2 billion in scrap and secondary materials to China- up from $194 million five years earlier (8). Another example is that the Hangzhou JinJiang Paper Company in Linan imported up to 90% of its feedstock paper from the US. The reason for the high-income countries to export these materials is to avoid using their limited landfill capacity and paying their higher costs of disposal, together with more stringent environmental regulatory requirements. According to World Bank report, the secondary materials market in China is affected by several factors, including: value to the recycler, avoided disposal costs and price paid in the exporting country, avoided disposal costs and price paid to domestic producers, cost of domestic and international transportation, and cost of enacting environmental safeguards associated with recycling the material.

With the ever-increasing amount of garbage pilling up at a rate exceeding the capacities of landfills and WTE plants in the short term, the Chinese authorities now seek to deal with the problem at the source, i.e. households and commercial establishments. Earlier waste sorting campaigns were carried out in some selected communities in cities like Beijing and Shanghai as trial projects but were not very successful as residents did not sense that sorting of their waste is necessary. To raise public awareness, the government considered making recycling mandatory in selected cities, such as Guangzhou with a recycling rate of 33% of the MSW. However, China's total recycling rate remains unknown.

In China, MSW is classified into four categories, recyclables, kitchen waste, hazardous ("harmful") waste and other waste, as shown in Figure 7.

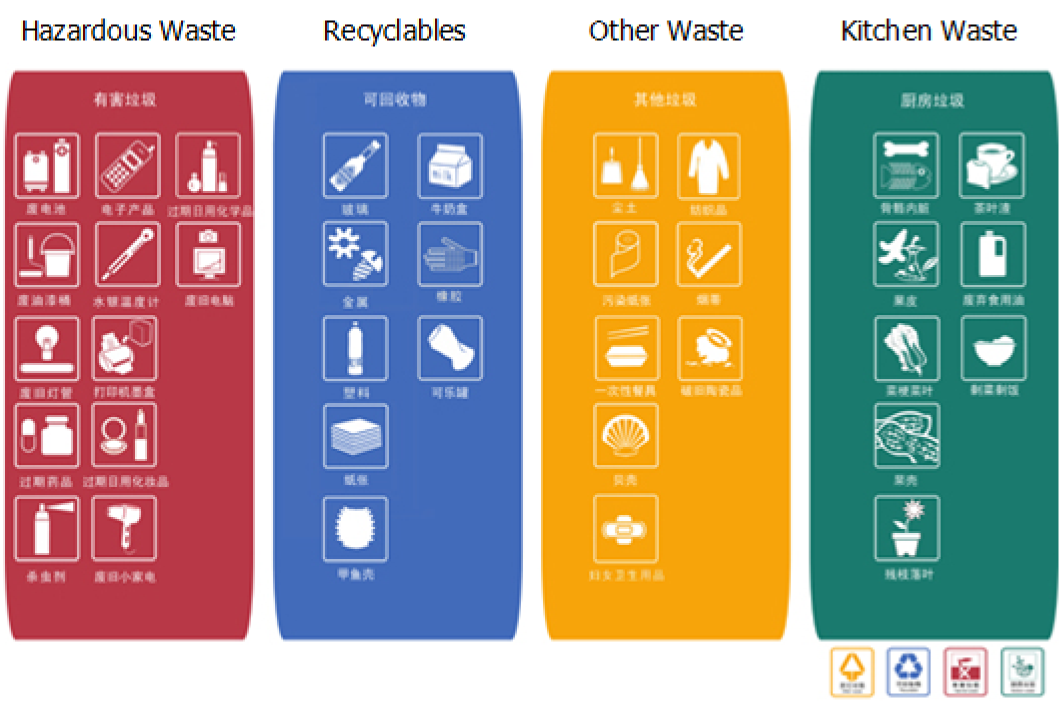


Figure 7 Four categories of MSW in China

There are five categories of recyclable waste: paper, plastics, glass, metal and fabric.

Paper: includes newspaper, periodicals, books, a variety of wrapping paper, office paper, cardboard, etc.

3.3 COMPOSTING

Composting is another important tool for waste management systems. In theory, there is an unlimited market for quality compost—returns organic matter to the soil where is originally came from. In addition, since China's MSW contains over 60% biodegradable organic matter, and is usually in excess of 50% moisture, which leads to a relative low heat value of MSW compared to US, European and Japanese, composting should be an important waste management tool in China. However, both the aerobical composting and the anaerobical composting requires the feedstock as source-separated organics, and the market demand depends on the price of the finished compost, the cost of separation and transportation, as well as the price willing to be paid by the end-user. Currently, composting accounts for 2% of the total MSW management system in China.

3.4 WASTE-TO-ENERGY

WTE is an important component of an integrated waste management system in China, especially in large cities, where space for landfills is limited. WTE plants are costly to build but have many advantages, such as volume reduction (approximately 90%) and mass reduction（approximately 70%）, less land use combined with energy recovery, and greater benefit from carbon credits for renewable energy resources. For these reasons, the central government has been very pro-active regarding increasing WTE capacity in China. In addition, in order to encourage investment, the government of China has issued a series of favorable policies with respect to the WTE industry, such as prioritized commercial bank loans, province level subsidy (2%) for loan interest, guaranteed subsidized price for purchase of electricity, carbon financing benefit as a renewable energy source. By 2009, WTE accounts for 18% of the MSW harmless treatment.

3.5 LANDFILLING

In China, landfilling remains the dominant means of waste disposal method. Of the MSW disposed by harmless treatment in 2009, 79% was landfilled, 18% incinerated and 2% composted (Figure 8).

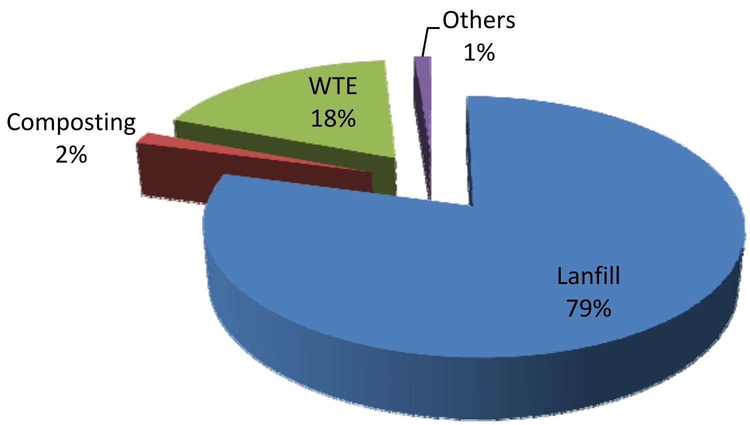


Figure 8 MSW "harmless" treatment in China

As the bottom of the sustainable waste management hierarchy, landfills in China are often not well operated. The main shortcomings are (7): 1) the presence of waste pickers, 2) inadequate slopes, 3) over design and premature construction of subsequent phases, 4) inadequate collection and treatment of leachate, 5) insufficient compaction and waste covering, 6) little, if any, landfill gas collection. Although these shortcomings are being remedied and significant improved with the modern sanitary landfill, landfill is still a waste of scarce land for large cities.

3.6 NON-REGULATED LANDFILLING (WASTE DUMPS)

Waste dumps are non-regulated landfills, referring to the dumping areas of the MSW with little or no control on the waste's impact on human health and the environment. Waste dumping presents a long term threat to the public health and environment, especially for their impact on groundwater. China's underground water is extremely valuable, even more than that of European and American cities due to the larger population densities and relative scarcity of water. In the movie "Beijing Besieged by

Waste”, the director Mr. Wang Jiuliang, a Chinese freelance photojournalist and independent filmmaker, spent two years of his life, starting in October 2008, in investigating landfill sites in Beijing. During this time, Wang traveled 15,000 kilometers all around in Beijing, visited roughly 500 landfills, and took 10,000 photoss plus 60 hours of raw footage (9). He reviewes in the movie the colossal problem of waste generation by a burgeoning population, expanding industry, and rapacious urban growth. He turned his lens upon the grim spectacle of garbage and refuse dumped on the landscape that surrounds China’s mega-metropolis, Beijing. Figure 9 is his famous Google Earth Picture of Beijing that shows the landfill sites surrounding Beijing.

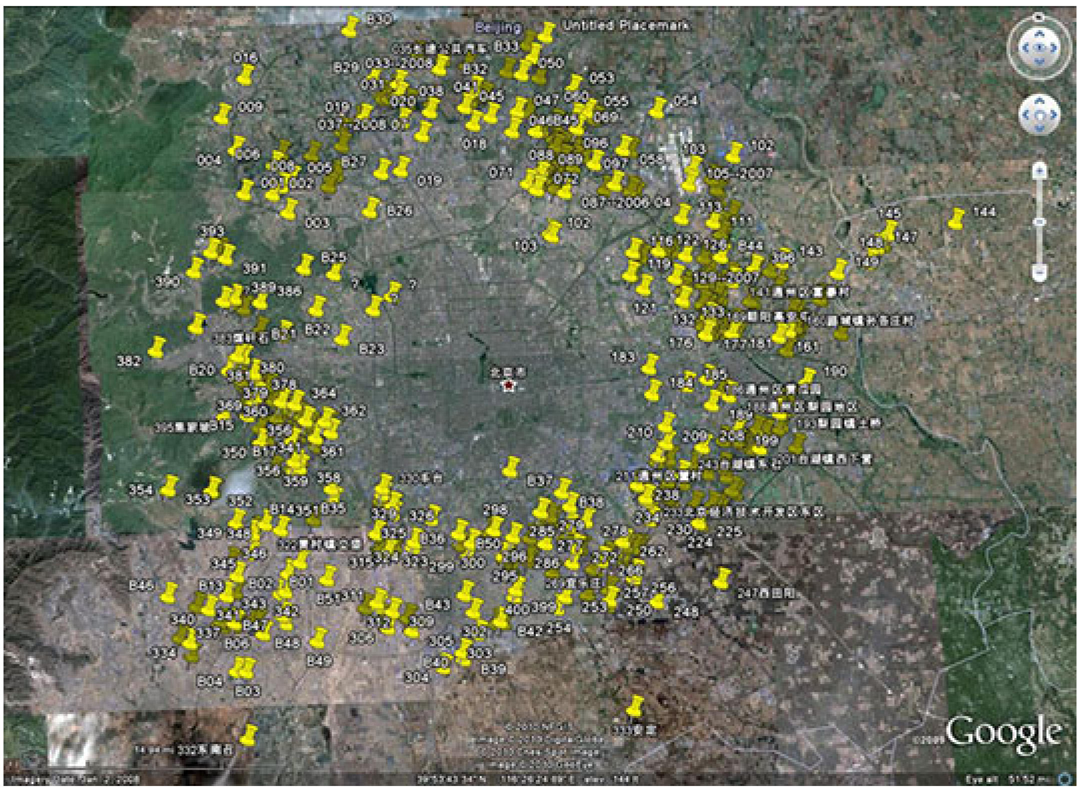


Figure 9 Google Earth Picture from Movie “Beijing Besieged by Waste” (2010) (10)

Picture 2 Movie "Beijing Besieged by Waste"

The legacy of waste dumps is a serious issue in most urban areas. There are efforts underway to improve the conditions of landfills in some cities in China, such as Shanghai, Guangzhou, but still a big number of Chinese cities are operating open dumps, and more urgent improvements need to be done. Estimated by World Bank Report, a city like Chongqing has about fifty dump sites, at least five of which need to be immediately cleaned up. Of the 660 cities in China over 1,000,000 populations, there are probably 5,000 dump sites needing cleanup. The experience with cities in the U.S and Europe argues strongly that measures to protect groundwater resources need to be carried out, and a more sustainable solid waste management system is of significant importance to China's future growth.

3.7 DISPOSITION OF MSW IN DIFFERENT PROVINCES AND CITIES

Municipal solid waste is collected and transported by local Sanitary Bureaus in China. Most MSW is produced in the daily life of local citizens, including dust (produced in coal furnaces for cooking and heating), paper, plastic, textiles, glass, metal, wood, and residual food. As mentioned in the previous sector, because of China's landscape is vast and diverse and the population density varies widely by regions. The MSW management systems of the local sanitary bureaus are also widely different. Table 2 shows the status of MSW management of the various regions in China in 2008.

Table 2 Post-recycling MSW treatment in China (2008)

Region	Total MSW collected, million tons/y	Compost, million tons/y	WTE, million tons/y	Sanitation Landfill, million tons/y	Non-sanitation Landfill, million tons/y
Autonomous cities					
Beijing	6.56	0.28	0.69	5.48	0.12
Chongqing	2.24	0	0.42	1.73	0.09
Shanghai	7.1	0.15	1.06	3.81	1.51
Tianjin	1.88	0	0.51	1.26	0.11
Autonomous regions					
Guangxi	2.4	0.08	0.13	1.86	0.33
Inner Mongolia	3.67	0.24	0	2.4	1.03
Ningxia	0.7	0	0	0.3	0.41

Region	Total MSW collected, million tons/y	Compost, million tons/y	WTE, million tons/y	Sanitation Landfill, million tons/y	Non-sanitation Landfill, million tons/y
Tibet	0.23	0	0	0	0.23
Xinjiang	2.98	0.15	0	1.66	1.17
Provinces					
Anhui	4.33	0	0.33	2.3	1.69
Fujian	3.92	0.05	1.29	2.29	0.29
Gansu	2.64	0	0	0.85	1.78
Guangdong	19.61	0	4.11	8.61	6.77
Guizhou	2.09	0	0	1.71	0.38
Hainan	0.89	0	0.04	0.54	0.31
Hebei	6.78	0.33	0.14	3.49	2.78
Heilongjiang	9.12	0	0.16	2.57	6.4
Henan	6.79	0.21	0.32	4.59	1.68
Hubei	6.81	0.04	0	3.63	3.02
Hunan	5.12	0	0	3.41	1.71
Jiangsu	9.57	0	3.87	4.8	0.86
Jiangxi	2.81	0	0	2.37	0.44

Region	Total MSW collected, million tons/y	Compost, million tons/y	WTE, million tons/y	Sanitation Landfill, million tons/y	Non-sanitation Landfill, million tons/y
Jilin	5.21	0	0.35	1.66	3.21
Liaoning	8.13	0.22	0.15	4.5	3.26
Qinghai	0.87	0	0	0.57	0.3
Shaanxi	3.56	0	0.02	2.44	1.1
Shandong	9.58	0.04	1.11	7.22	0.91
Shanxi	3.75	0	0.33	2.02	1.39
Sichuan	5.9	0	0.72	4.2	0.97
Yunnan	2.82	0	0.42	1.75	0.54
Zhejiang	9.26	0	4.05	4.99	0.22
China, total	157.34	1.79	20.22	88.99	45.01

According to Table 2, Guangdong, Zhejiang, and Jiangsu have the top three waste-to-energy capacities of 4.06 million tons, 3.11 million tons, and 2.05 million tons, corresponding to 34.04%, 42.99% and 24.09% of the total MSW disposed in these three regions respectively. There are still 11 regions and provinces in China that do not have any WTE capacity.

As of 2009, there were 567 regulated disposal facilities for MSW in China, including 447 landfill sites, 16 composting plants, and 93 incineration plants. The majority of WTE plants are located in eastern China (Table 3), because of the relative higher economic growth, population density and urbanization. Although, compared to the sanitary landfill sites, there are thousands of non-regulated open dumps in China, for example, Beijing alone has over 500 dump sites surrounding reported Wang Jiuliang, director of movie "Beijing Besieged by Waste".

Table 3 Regulated MSW disposal facilities in China (2009) (1)

	Waste-To-Energy	Sanitary Landfill	Composting	All harmless treatment facilities
Zhejiang	21	31		52
Guangdong	17	19		37
Jiangsu	14	27		41
Shandong	6	45	1	54
Fujian	5	15	1	21
Sichuan	5	25		31
Shanxi	3	12		15
Shanghai	3	4	1	12
Tianjin	2	5		7
Jilin	2	7		9
Heilongjiang	2	16		18
Henan	2	33	3	38
Guangxi	2	14	1	17
Yunnan	2	12		15

	Waste-To-Energy	Landfill	Composting	All harmless treatment facilities
Beijing	1	16	2	19
Hebei	1	18	3	23
Liaoning	1	11	1	13
Anhui	1	13		14
Hainan	1	2		3
Chongqing	1	12		13
Shaanxi	1	10		11
Inner Mongolia	0	16	1	17
Jiangxi	0	13		13
Hubei	0	17	1	19
Hunan	0	15		15
Guizhou	0	11		11
Tibet	0			
Gansu	0	11		11
Qinghai	0	3		3
Ningxia	0	2		2
Xinjiang	0	12	1	13

	Waste-To-Energy	Landfill	Composting	All harmless treatment facilities
China, Total	93	447	16	567

"The ladder of sustainable waste management" of EEC (Figure 3) ranks the waste management system of the member nations of the European Union by the amount of MSW that is landfilled, either in regulated or non-regulated landfills. According to the ladder, countries with the minimum percentage of MSW landfilled are on the top of the ladder and those who depend mostly on landfilling are at the bottom. One can look at how the others in the international community are doing with the intention of keeping as much out of the landfill as possible. The author has constructed a similar "ladder" for the various regions of China. Figure 9 shows the Chinese Ladder of Sustainable Waste Management that ranks provinces and cities according to the hierarchy of waste management, especially their efforts on WTE and composting. The Chinese ladder distinguishes between regulated and non-regulated landfills. Figure 9 shows that regions that use non-regulated landfill the least, and have higher WTE capacity are higher up at the Ladder of Sustainable Waste Management.

It should be noted that the discussion on the MSW generation and disposal in China does not include recycling, the reasons, stated in the early recycling chapter, are that the recycling is mostly done by formal and informal waste pickers from homes and businesses before the waste collection. And the MSW tonnages reported in this study refer to the MSW collected and disposed after the recycling has taken pace.

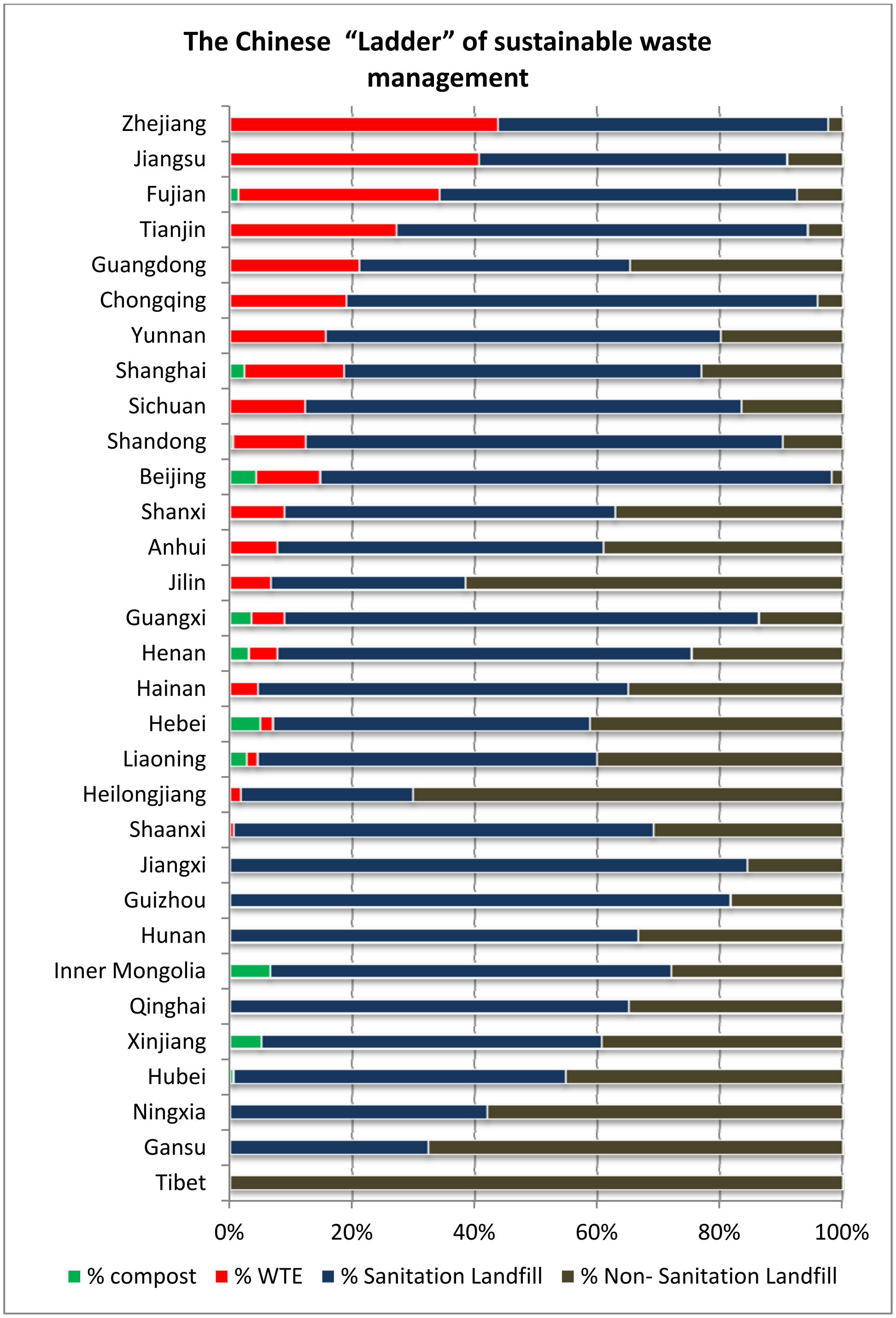


Figure 10 The Chinese Ladder of Sustainable Waste Management

4. WASTE-TO-ENERGY IN CHINA

4.1 STATUS OF WTE INDUSTRY IN CHINA

In China, MSW WTE technology was initially introduced at the end of 1980s, and has undergone rapid development ever since. In 1988, the first MSW WTE plant using Japanese technology was built in Shenzhen with capacity of 450 tons/day and, generating 22.7 million Kwh of electricity per year.8 From 2000 to 2003, approximately 20 new WTE plants were built, mostly in big cities, such as Shanghai, Guangdong, Shenzhen, Hangzhou, Zhengzhou and Haerbin. For example, with a total investment of $60.6 million, City Ningbo located in Zhejiang Province, built the first 1000-ton per day y WTE plant in 2001. Currently, more and more large and middle-scale cities are constructing more WTE power plants. Figure 10 shows that the Chinese WTE capacity has increased steadily from 2.2 million tons in 2001 to nearly 23.5 million tons by 2009 (1), making China the fourth largest user of waste-to-energy (WTE) in the world, after E.U., Japan, and the U.S.

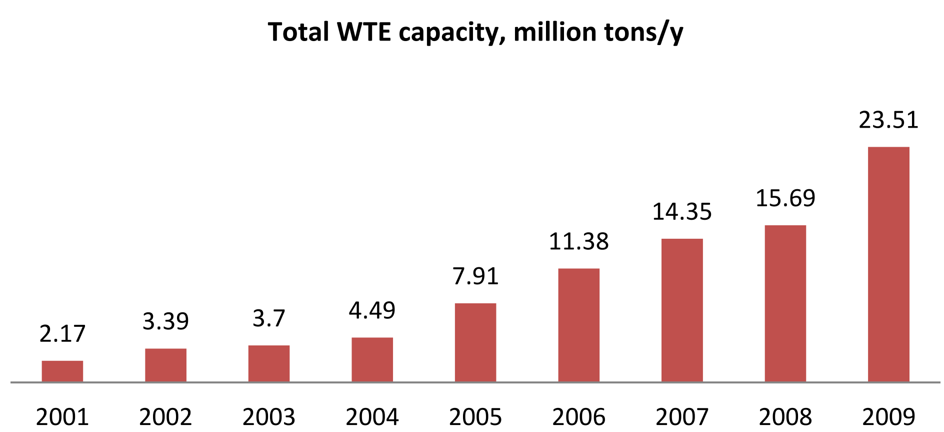


Figure 11 Growth in WTE capacity in China, 2001-2009

Figure 12 shows that the number of WTE plants in China increased from 36 plants in 2001 to 93 plants in 2009. Also, the average, plant capacity increased from 183 to 766 tons per day.

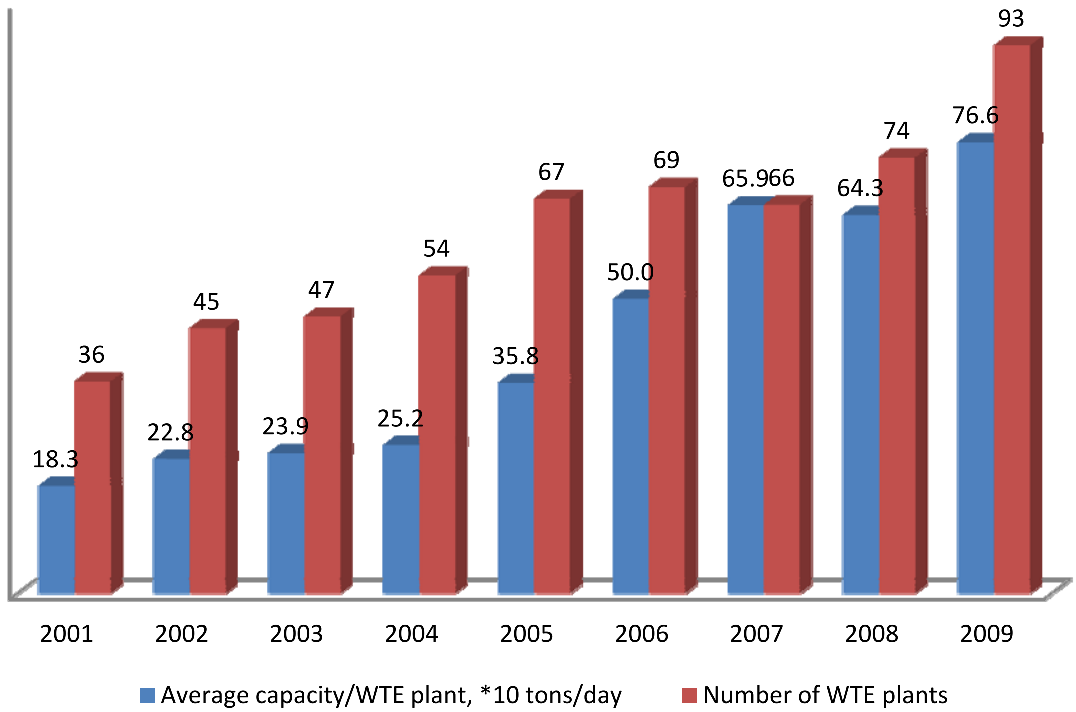


Figure 12 Growth in number and capacity of WTE plants in China

Most WTE plants are located in eastern China, especially in the regions of the Changjiang and Pearl River Deltas. As of 2009, three provinces in these two districts, Zhejiang, Guangdong and Jiangsu accounted for 21, 17 and 14 WTE plants, respectively. These plants constitute 63.6% of the existing WTE capacity in China. This can be explained by the relatively rapid economic development in these provinces. Also, WTE plants are mostly constructed in big cities with high generation rates of MSW, such as Guangzhou, Shenzhen, Beijing, Shanghai, Hangzhou, Wuxi, Xiamen, etc.

Table 4 Geographic distribution of WTE plants in China (2009) (1)

Waste-To-Energy Facilities in China	
Zhejiang	21
Guangdong	17

Waste-To-Energy Facilities in China	
Jiangsu	14
Shandong	6
Fujian	5
Sichuan	5
Shanxi	3
Shanghai	3
Tianjin	2
Jilin	2
Heilongjiang	2
Henan	2
Guangxi	2
Yunnan	2
Beijing	1
Hebei	1
Liaoning	1
Anhui	1
Hainan	1
Chongqing	1
Shaanxi	1
National Total	93

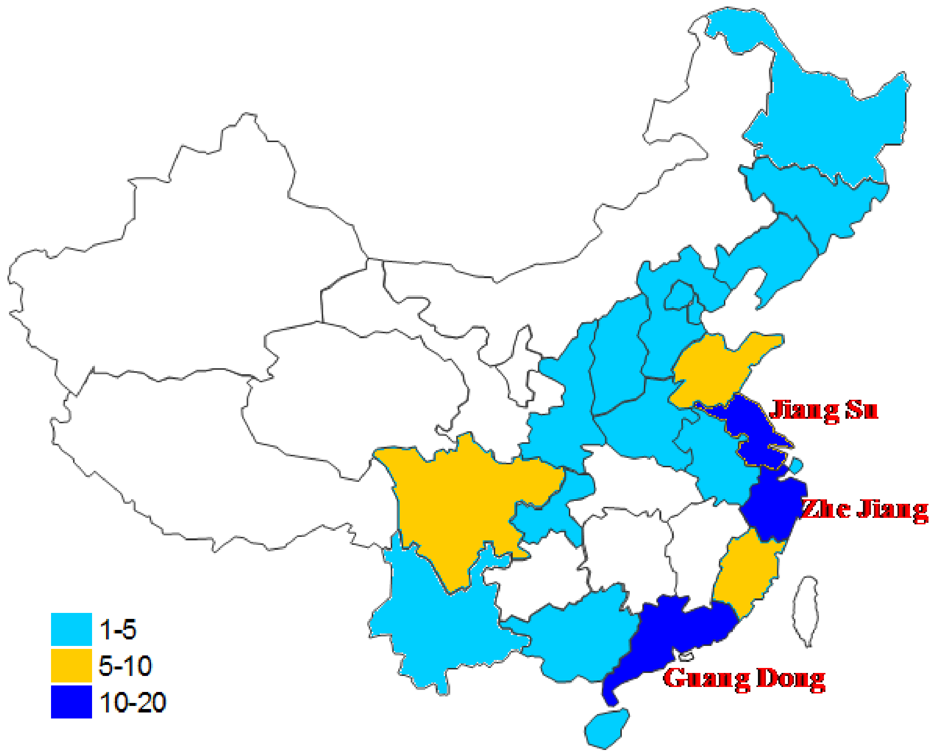


Figure 13 Geographic distributions of WTE facilities in China

4.2 WTE DEVELOPMENT CHALLENGE IN BEIJING

The capital city of Beijing generates 18,000 tons of garbage per day while the city has the capacity to deal with only 11,000 tons of it (11). In 2010, only two percent of the waste was treated in the two operating incineration plants in the city. Beijing expects to have 40 percent of its MSW processed by WTE by 2015 as seven more plants come online. Officials estimate that all of the city's 13 landfills will be full by 2015 and have announced plans to build more waste treatment facilities – and waste-to-energy plants in particular - to tackle the garbage crisis.

These plants are being vigorously opposed by residents living near existing or planned Waste-To-Energy projects. Government guidance on the treatment of household waste released on June 19, 20107 state that cities that are short of land should consider garbage incinerators as a way to tackle the mountain of trash. However anti-incineration activists oppose the government's plans.

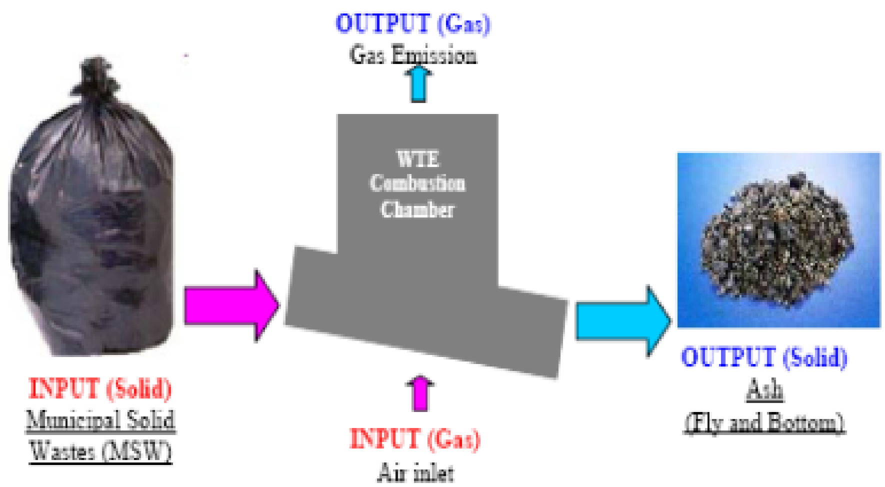
According to the Beijing Municipal Commission of City Administration, the 6.72 million tons of garbage produced in 2008 had a volume of 16.8 million cubic meters. Wang Weicheng, the chairman of the Beijing Energy Conservation and Environmental Protection Association, estimates that in the next five to 10 years, Beijing will have no land left to bury garbage. "Garbage incineration plants are inevitable in big cities in China where the pressure to find enough land for landfills is huge," Wang told METRO (11). He added that each city should be free to deal with garbage in the best way for that particular city. "In cities like Beijing, Shanghai and Tianjin, there is no way to continue the use of landfills as the main solution," he said. "After proper garbage sorting, incineration plants can not only reduce garbage but produce heat and electricity. We can transform garbage into new energy," said Wang, who participated in the drafting of a law on renewable energy in 2005.

The construction of the Asuwei WTE plant in the Changping district of Beijing is scheduled to start up this year, according to a municipal government document released in June 2011 (11). The building of the second stage of another WTE plant, in Shunyi district, will also begin this year and plans for the Nangong WTE, in Daxing district, are also in an advanced stage. Wang revealed that plans for the incineration plants date back to 1998 but the projects have been postponed again and again because of the public's concerns about dioxins. He said, in Western countries, where there is a long history of using such incinerators as a way of treating garbage, the WTE emissions are very low and residential communities have grown around older plants.

4.3 WTE TECHNOLOGY USED IN CHINA

4.3.1 COMBUSTION TECHNOLOGY OVERVIEW IN CHINA

There are three main types of incineration technologies used in China. These are the mechanical stoker grate (e.g., the Pudong MSW incinerating plant located in Shanghai and the Changping incineration plant located in Beijing), the rotary kiln (e.g., the Longgang incineration plant located in Guangdong province) and the fluidized bed (e.g., the Xiaoshan MSW incinerating plant located in Hangzhou, Zhejiang Province) (12). In comparison with Europe, e.g., where most plants in operation are grate systems (13)(Vehlow, 1996), China uses the mechanical stoker gate and fluidized bed technology for incinerating municipal waste, which together account for about 80% of the existing systems. (14)11



Picture 3 WTE grate combustion of as received MSW

According to a preliminary survey of 100 WTE plants in operation or under construction in China4, most of the MSW WTE Plants are of the grate combustion type (”mass burn”) shown in Figure 14, and are based either on imported or domestic technologies. The Circulating Fluidized Bed (CFB) WTE plants, shown in Figure 15, co-fire MSW with coal (up to 15% coal by weight) and have been developed by Chinese academic research centers, such as Zhejiang University, Chinese Academy of Sciences (CAS), and Tsinghua University. Most of the new plants are based on the stoker grate design, shown in Table 5.

Table 5 Types of combustion systems of existing and planned WTE plants in China (4)

Combustion system	Number of plants	Total capacity, tons/day	Capacity distribution
Stoker grate, imported	45	47,585	52%
Stoker grate, domestic	18	12,885	14%
Circulating Fluidized Bed(CFB)	37	31,920	34%
Total	100	92,390	100%

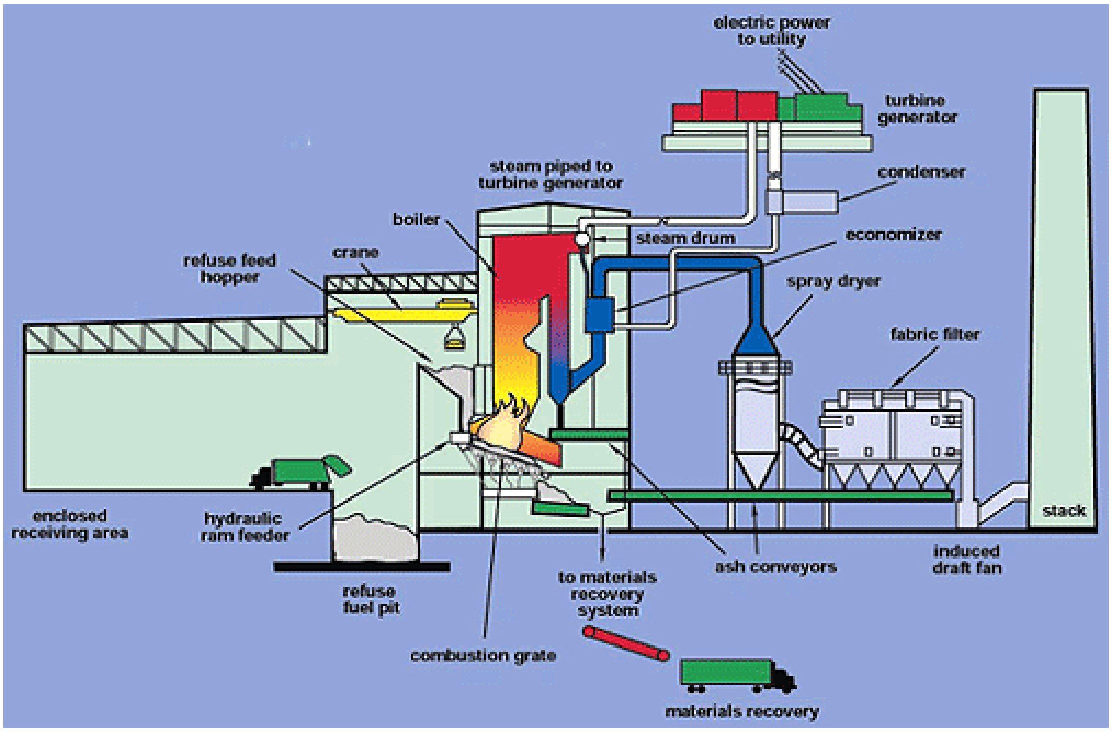


Figure 14 Diagram of moving grate WTE Plant

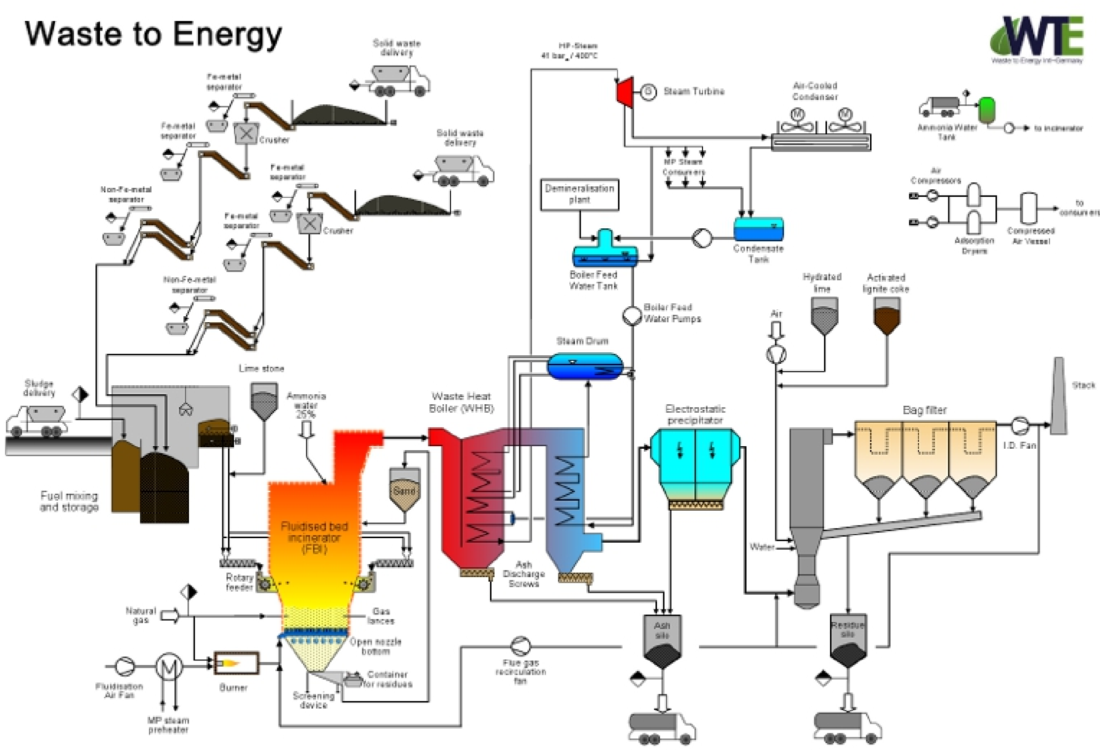


Figure 15 Diagram of Circulating Fluidized Bed (CFB) WTE Plant

It appears as though large cities such as Shanghai and Beijing are mainly constructing grate combustion systems, while smaller and medium sized cities on the other hand appear to prefer fluidized bed combustion (12).

Table 6 Investigated China WTE Plants (in operation and under construction)

Province	Plant name	Capacity, ton/day	generator /MW	Electricity Prodcution/ MWh/year	Operting Year	Technology
Autonomous cities						
Beijing	Beijing Chaoyang Gaoantun	1600	47	225000	2005	Grate
Tianjing	Shuanggang	1200	18	115000	2004.1	
Shanghai	Shanghai Pudong	1094		300000		
	Shanghai Jiangqiao	1500	36	212000	2002.12	Grate
	Shanghai Yuqiao	1050	17	110000	2002.5	Grate
chongqing	Chongxing tongxing	1320				Grate
	Chongqing second WTE	1800				Grate
Autonomous regions						
Guangxi	Luoding	600	12	70000	2004	
Inner Mongolia	Hutehaote	1500	15	250000		
Provinces						
Anhui	Wuhu	600	12	137000	2002	CFB
Fujian	Fuzhou Hongling Miao	1000	16	100000	2004.12	
	Jinjiang Luoshan	600		90000	2005.4	
	Xiamen Houkeng	400		40000	2005.10	
	Quanzhou	400		60000	2002.3	
	Jinjiangshi WTE	1000				Grate

Province	Plant name	Capacity, ton/day	generator /MW	Electricity Prodcution/ MWh/year	Operting Year	Technology
	Zhangzhou Pujiangling 1	1750	18			
Guangdong	Dongyuan Qingxikeng	600				CFB
	Likeng	1040	22	158000	2006.01	
	Zhuhai	600	6	20000	2000.11	grate
	Shantou	1200	24			
	Shunde	600				
	Nanhai	400	12			grate
	Huizhou	600	12			
	Shenzhi Shizhenghuanwei	450		22700	1984	grate
	Shenzhen Nanshan	800	12	75000	2003	
Guangdong	Shenzhen Laohukeng	600				
	Shenzhen longgang pinghu	675	12			
	Zhongshanshi Zhongxinzutuan	1050				grate
	Shenzhen Luohu	450	4.5		1988.11	grate
	Shenzheng Baoan	1200		110000	2004	
Hainan	haikou	1200				
Hebei	Shijiazhuang Yucun	500	8.2	612000	2002.6	
	Shijiazhuang Qili	500		84000		CFB
	Handan	1000			1999 invest 2006	
	Luancheng		24			
	Baoding	1200				
Heilongjiang	Haerbin	200	3	21000	2002.1	CFB
Hubei	Wuhan	1000				
	Hanyang Guodingshan	1500	25	310000	2004.6	
Henan	Zhengzhou Rongjin	700	24	180000	2002.1	

Province	Plant name	Capacity, ton/day	generator /MW	Electricity Prodcution/ MWh/year	Operting Year	Technology
	Xuchang	450	15		2004.6	
Jiangsu	Nanjing		5.2	21000	2002.5	
	Wuxi Taohuashan		2	15300	2004.8	
	Wuxi Yiduo	1000	24			
	Suzhou Qizicun	1200	24	150000	2005.12	
	Xuzhou	2000				
	Yancheng Panhuang	600	30	260000	2004.11	
	Yixing	500		238000		Grate
	Jiangyin	1200		590000		Grate
	Huilian Wuxi	1200				CFB
	Changzhou	800		413000		Grate
Liaoning	Shenyang	950	15			
Sichuan	Chengdu Longquan Luodai	1200			2005	
Sichuan	Sichuan Deyang	300				
Yunnan	Kunming Dongxiao	1600	45	300000	2010.04	CFB
	Qujing	800		100000		CFB
	Kunming Wuhua	1000	30	210000	2008.3	CFB
Shanxi	Taiyuan Lizequ Haozhuang	1000		98800	2004	
Shaanxi	Xian					CFB
Shandong	Heze	600	12		2002	
	Zaozhuang		30		2003.4	CFB
	Linyi Dujiang	520	15	58000		CFB
	Zibo		24			
Zhejiang	Hangzhou Tianziling	1400	20	16000	1998.8	加技术
	Hangzhou Qiaosi	800	12	78000	2003.12	CFB
	Hangzhou Jinjiang	800	6	40000	1998.8	CFB
	Xiaoshan	800	24	156000		CFB
	Ningbo	1050	20		2002.1	Grate
	Zhejiang Shaoxing	1200		266000	2001.8	CFB
	Zhuji	400	18	120000		
	Wenzhou Dongzhuang	320		25000	2000.1	Grate

Province	Plant name	Capacity, ton/day	generator /MW	Electricity Prodcution/ MWh/year	Operting Year	Technology
	Wenzhou Linjiang	600				
	Zhejiang Huachuan	1000				CFB
	Yiwu WTE	400				CFB
	Lvneng Huanbao	450				
	Binjiang WTE	450				Grate
	Cixi WTE	1500		216000		
	Wenzhou Yongqiang	900				
	Wenzhou Cangnan	450				
	Shaoxing Xinmin	800				CFB

Table 7 New Operating WTE Plants in 2009

Province	Plant name	Capacity, ton/day	generator /MW	Investment/ million USD	Operting Year	Technology	Owner
Jiangsu	Suzhou (Phase two)	1000	24	69	2009.02	Grate	Everbright Environment Protection and Energy (Suzhou) Corp.
Jiangsu	Xuzhou	1200	24	64	2009.06	Grate	Baoli Xiejin Renewable Energy Corp.
Guangdong	Zhongxin Beibu Zutuan	1000	24	0	2009.04	Grate	Guangzhou Tianyi Group
Fujian	Nanan	300	6	24	2009.04	Grate	Shengyuan Environment Corp.
Hainan	Qionghai	225	3	15	2009.11	Grate	Qionghai City Construction Bureau

Province	Plant name	Capacity, ton/day	generator /MW	Investment/ million USD	Operting Year	Technology	Owner
Zhejiang	Haining	600	8	38	2009.12	Grate	Green Power Corp.
Zhejiang	Cixi	1000	30	57	2009.08	CFB	Cixi Zhongke Zhongmao Corp.
Shanxi	Datong	1000	30	54	2009.09	CFB	Datong Fuqiao WTE Corp.
Shandong	Taian	1000	30		2009.08	CFB	Taian Zhongke Environment Corp.

The Clean Development Mechanism (CDM) is defined in Article 12 of the Kyoto protocol and is intended to assist developed countries (Annex II) in attaining their greenhouse gas reduction commitment by investing in "green" projects in developing countries. Table 8 is a list of CDM WTE projects that were approved in China, in 2009.

Table 8 Approved CDM WTE Projects in 2009

Development and Reform Commission approved the application of CDM WTE projects (2009)				
Project Name	Project Name (Chinese)	Project Owner	Internaional Partner	Purposed Emission Reduction (tCO2e)
Qianhuangdao WTE Retrofitting Project	秦皇岛生活垃圾焚烧发电改建项目	Hebei Construction & Investment Group Co., Ltd	European Carbon Fund	108,692
Tianyi WTE Project	天乙城市固体垃圾焚烧发电项目	Zhongshan Tianyi Power Corp.	Natsource Assert Management Corp.	120,017
Zhejiang Nhaining Hanyang WTE Project	浙江省海宁市翰洋生活垃圾焚烧处理项目	Haining HanYang Environmental Thermoelectric Co., Ltd	Dexia Carbon Captial SarL	81,551
Hubei Wuhan Hankou WTE Project	湖北省武汉市汉口城市固体生活垃圾焚烧发电项目	Wuhan Hankou Green Energy Co, Ltd	Dresdner Bank	131,949

Changshu WTE Project	常熟生活垃圾焚烧发电项目	Changshu Pudong Development Thermoelectric Energy Limited	Spain Sand Electricity Company	55,481
Wuhan Wuchang WTE Project	武汉武昌城市生活垃圾焚烧发电项目	Wuhan Green Energy Co., Ltd	Dresdner Bank	65,374

4.3.2 AIR POLLUTION CONTROL SYSTEMS IN CHINA

Most of the air pollution control systems built in the Chinese WTE plants are similar to the established gas control systems in the U.S. and E.U.: A combination of semi-dry scrubber, activated carbon injection, to remove volatile metals and organic compounds, and fabric filter bag house to remove particulate matter. In some WTE plants, selective non-catalytic reduction (SNCR) is also included to reduce emission of nitrogen oxides, as, for example, the WTE plants under design for Guangzhou, Shantou, and Chongqing.

5. ENVIRONMENTAL PERFORMANCE OF WTE PLANTS IN CHINA

5.1 HISTORY OF EMISSIONS OF WTE

In view of the concern over the environmental risks of waste-to-energy, this section discusses the general trend of emissions from WTE facilities, especially dioxin emissions which are the most feared.

Waste-to-energy has historically been thought of as a major source of air pollution due to the presence of dioxins, mercury, lead, and other harmful substances. Although harmful pollutants were emitted by WTE facilities in the eighties, the technology and pollution control equipment has advanced so rapidly that the US EPA regards it as "a clean, reliable, renewable source of energy," and one that has "less environmental impact than almost any other source of electricity." (15) Today, emissions of pollutants from WTE facilities are well below the national standards.

Emissions from waste-to-energy facilities worldwide have decreased dramatically since the eighties as a result of a stricter regulatory environment and continuous improvements in technology. Tables 9 and 10 show the percentage decrease in emissions from WTE facilities within a decade for the US and Germany, respectively. Today approximately 26 million tons of MSW are diverted to waste-to-energy facilities in the US each year. (16) The waste incineration capacity in Germany increased from 9.2 million tons in 1990 to almost 14 million tons in 2000 even as emissions have decreased across the board (17).

Table 9 Emission Reductions from U.S. WTE facilities between 1990-2000 (18)

Pollutant	Reduction (%)
Dioxins/Furans	99.7
Mercury	95.1
Cadmium	93
Lead	90.9
Particulate matter	89.8
Sulfur dioxide	86.7

Table 10 Emission Reduction from German WTE facilities between 1990-2001 (19)

Pollutant	Reduction (%)
Mercury	98.7
Lead	99.8
Particulate Matter	<88

In addition, Table 11 compares emissions per unit of heating value from coal-fired and WTE plants in the US. Emissions of sulfur dioxide, nitrogen oxides, particulate matter, and cadmium are higher from coal-fired plants than waste-to-energy facilities, while emissions of hydrogen chloride, lead, and mercury are higher from waste-to-energy facilities than coal-fired plants. (18)

Table 11 Emissions per unit of heating value of plants in the US (kg/GJ) (16)

	Coal-fired plants	WTE facilities
Sulfur dioxide	0.452	0.013
Nitrogen oxides	0.194	0.151
Hydrogen Chloride	0.017	0.087
Particulate matter	0.03	0.002
	Coal-fired plants	WTE facilities
Lead	2.6*10-6	15*10-6
Mercury	2.6*10-6	7*10-6
Cadmium	1.9* 10-6	1.1*10-6

In China, the environmental movement by local residents and "environmental activists" has long been opposed to WTE facilities and distributes misleading information about actual emissions from such facilities. Table 12 shows the emission standard changes for incineration and WTE plants in China since 1970.

Table 12 Change in WTE Plant emission levels in China (20)

Year	GasTreatment Methods	Soot, mg/Nm3	HCl, mg/Nm3	SO2, mg/Nm3	Nox, mg/Nm3	CO, mg/Nm3	Hg, mg/Nm3	Dioxins, ng TEQ/Nm3
<1970	Vortex	500	1000	500	300	1000	0.5	
1970-1980	Static	100	1000	500	300	500	0.5	
1980-1990	Static+ Emission	50	100	200	300	100	0.2	1.0
>1990	Currrent Emission	≤30	≤75	≤150	≤200	≤100	≤0.2	≤1.0

	Control

5.2 HISTORY OF DIOXIN EMISSIONS OF WTE PLANTS

Dioxins are a group of compounds that have similar chemical characteristics. Approximately 30 compounds fall into three groups: chlorinated dibenzo-p-dioxins (CDDs), chlorinated dibenzofurans (CDFs) and some polychlorinated biphenyls (PCBs). The term "dioxin" is also used to refer to one of the most toxic of these compounds, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The toxicity of dioxins is measured in terms of Toxic Equivalents or TEQs, which is the equivalent amount of TCDD in a mixture of dioxin compounds. Dioxins are carcinogenic and lipophilic, which means that they can easily dissolve in fats, oils, and lipids, and hence bioaccumulate in humans and wildlife, causing significant concern about the risks associated with them (21) (22). Dioxins are commonly formed when organic material is burned in the presence of chlorine.

According to the US EPA, some of the major sources of dioxins are coal-fired plants, metal smelting plants, diesel trucks, and trash burning. However, in a span of twenty years, from 1987 to 2007, dioxin emissions from waste-to-energy facilities in the US decreased from 10,000 21g/year to 12 g/year. At present, dioxins from waste incineration constitute less than 0.05% of the total US inventory (23). In comparison, backyard burning of municipal waste in some rural areas where it is still allowed results in emissions of 580 g/year of dioxin (24), as shown in Figure 16. In many cases, the stack gas from WTE facilities is found to be cleaner than the ambient air in some US cities (24). With regard to Germany, it is estimated that residential fireplaces emit 20 times more of dioxins than do the most modern WTE facilities in Germany.

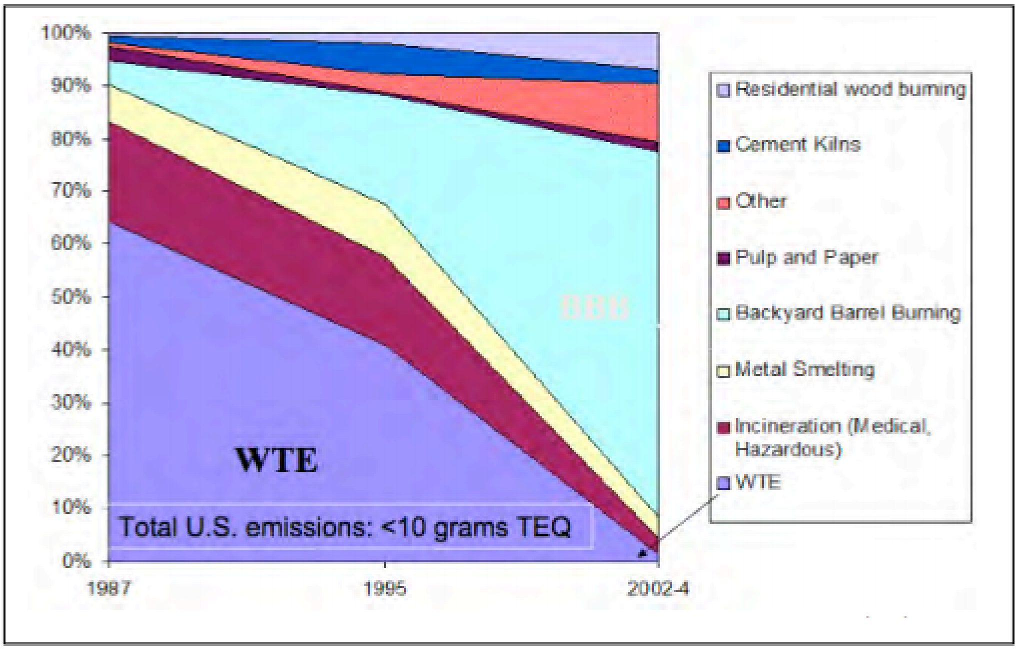


Figure 16 Dioxin Emission in the US between 1987 and 2002

It is interesting to note a recent study by the Earth Engineering Center of Columbia University on French WTE plants. France introduced the dioxin standard of 2 ng/Nm3 in 1991 and the more stringent standard of 0.1 ng/Nm3 in 2002, that is several years later than other northern European nations, the U.S., and Japan. Because of this, as late as 2001, the French MSW incinerators emitted 150 grams TEQ of dioxins (Figure 17) (25). This amount was ten times higher than the dioxin emissions of U.S. incinerators that combusted twice as much MSW. However, it must be noted that the 2 nanogram standard in France, in effect from 1991 to 2002, was about 50 times lower than the dioxin concentration in incinerator stack gas before the dioxin problem was recognized internationally.

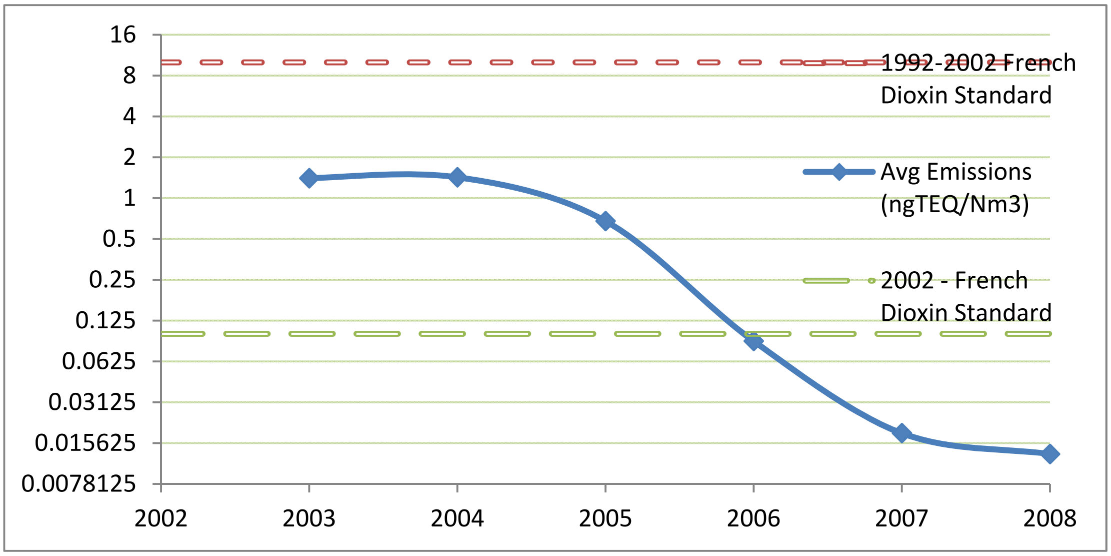


Figure 17 Decrease in average dioxin emission of 124 French incinerators, 2003-2008

5.4 DIOXIN EMISSIONS OF WTE PLANTS IN CHINA

China has formulated and implemented Dioxin emission standards in a few industrial sectors, such as waste incineration. For release reduction and control of Dioxins, technical requirements and technical guidelines have been developed according to the Environmental Impact Assessment Law, the Clean Production Promotion Law, the Regulations on Environmental Management of Construction Projects, etc. so as to achieve the convention implementation goals.

There are over twenty dioxin analysis labs and institutions that are certified by the Certification and Accreditation Administration of China (CNCA). These include the dioxin labs of Chinese Academy of Science (CAS) in Beijing, Dalian, Guangzhou and Wuhan, the dioxin labs in Tsinghua University, Peking University, Zhejiang University, the dioxin labs of Chinese EPA, the labs of Chinese Environmental Monitoring Center in Zhejiang, Shanxi and Guangdong provinces, and the dioxin labs of Chinese Center for Disease and Prevention in Beijing and Zhejiang province (4).

The emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (dioxins) from 19 MSW incinerators in China were investigated by the Chinese Academy of Science (CAS) (26). Sixteen stoker grate and three circulating fluid bed incinerators with capacity from 150-500t/d were examined, and the results are shown in Table 14 and Table 15. The Earth Engineering Center has carried out a similar study aiming to get more dioxin emission data from the rapid expansion of WTE capacity in China. After one year of research, through literature review, a field trip and contact interviews, 20 WTE plants' dioxin emissions have been identified by the author. During this investigation, the author faced a huge difficulty in obtaining information on dioxin emissions, due to the inadequate transparency as to the emissions of the WTE plants in China. Due to the agreement with the data providers, the author will not provide specific plant names that provided dioxin emission data, so that the plants are identified only by a number. The results are shown in Table 13.

Table 13 Capacity and dioxin emissions of 20 WTE plants in China, EEC (2011)

Plant Number	Capacity, ton/day	dioxin (I-TEQng/N.m3)	Dioxin as % of E.U. Standard
1	800	0.0068	6.8%
2	800	0.087	87.0%
3	1000	0.243	243.0%
4	800	0.047	47.0%
5	400	0.007	7.0%
6	400	0.002	2.0%
7	400	0.22	220.0%
8	1200	0.36	360.0%
9	600	0.004	4.0%
10	600	0.017	17.0%
11	1000	0.05	50.0%
12	1200	0.1	100.0%
13	1000	0.053	53.0%

Plant Number	Capacity, ton/day	dioxin (I-TEQng/N.m3)	Dioxin as % of E.U. Standard
14	1000	0.038	38.0%
16	1200	0.038	38.0%
17	1040	0.056	56.0%
18	800	0.031	31.0%
19	600	0.049	49.0%
20	1000	0.011	11.0%

The results of this study showed that the dioxin emissions of these 20 MSW WTE plants ranged from 0.002 to 0.22 nanograms TEQ /Nm3; the average value was 0.072 ng TEQ/Nm3. The results show clearly that although the present dioxin emission standard (1.0 ng TEQ/Nm3, is higher than that in the Europe and US (0.1 ng TEQ/Nm3), most of . the WTE plants examined in this study have as low dioxin emissions as those in the US and Europe. Eighteen out of twenty of the WTE plants that we reviewed operate below the E.U dioxin standard, and two above the E.U dioxin standard, but still under the Chinese Dioxin standard. All the grate combustion WTE plants, and the Circulating Fluidized Bed WTE plants examined with one exception, are using Activated Carbon Injection which is essential for capturing dioxins and also volatile metal mmolecules.

Table 14 Capacity and dioxin emissions of 13 grate combustion WTE plants in China (2)

Plant # (Ni et al)	Tons/day	Micrograms TEQ per ton MSW	Nanograms TEQ per Nm3 of stack gas*	Activated carbon injection (ACI)ACI
1	225	0.286	0.06	Yes
5	150	10.72	2.14	
7	500	0.343	0.07	Yes
8	385	1.887	0.38	
9	385	1.973	0.39	
10	250	1.871	0.37	Yes
11	500	1.279	0.26	Yes
12	385	0.935	0.19	Yes
13	385	0.848	0.17	
14	225	1.592	0.32	
16	200	0.169	0.03	
17	500	4.789	0.96	Yes
19	400	5.04	1.01	Yes
Average	345	2.441	0.49	
Ave. tons/y	114,000			
Total t/y	1,482,000			
E.U. and U.S. standard:		0.1 ng TEQ/Nm3 of dry stack gas		

Table 15 Capacity and dioxin emissions of six Circulating Fluid Bed WTE plants in China (26) (2)

Plant Number (Ni et al)	Tons/day	Micrograms TEQ per ton MSW	Nanograms TEQ per Nm3 of stack gas	Activated carbon injection (ACI)ACI
2	385	0.678	0.14	Yes
3	500	0.226	0.05	Yes
4	200	0.581	0.12	
6	225	0.390	0.08	Yes
15	165	0.294	0.06	Yes
18	250	0.811	0.16	Yes
Average of six plants	288	0.497	0.10	
Ave. tons/y	95000			
Total t/y	570000			
E.U. and U.S. dioxin standard	0.1 ng TEQ/Nm3 of dry stack gas			

6. GOVERNMENT ROLE IN OPERATION OF WTE PLANTS

6.1 LAWS AND REGULATIONS ON MSW

As it is the same to most countries, China's solid waste management is a municipal responsibility. According to the national legislative and regulatory framework for solid waste management, each level of government has its own roles and responsibilities. Such as, the central government set laws for solid waste service responsibilities with basic standards including occupational and environmental health and safety standards to local governments. And Each Municipal government then sets its own requirement and defines practice of each waste generator. Table 16 Shows the summary of Chinese National Laws and Regulations on MSW.

Table 16 Summary of National Chinese Laws and Regulations on MSW

Laws and Regulations (English)	Laws and Regulations (Chinese)	Brief Description	Issuer	Effecitive Time
City Appearance and Environmental Sanitary Management Ordinance	城市市容和环境卫生管理条例	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	August 1, 1992
Regulations Regarding Municipal Residential Solid Waste	城市生活垃圾管理办法	Regulations regarding the management of collecting, transferring and treating residential solid waste.	The Ministry of Construction of PRC	September 1, 1993
Law on Prevention and Control of Environmental Pollution Caused by Solid Waste of PRC	中华人民共和国固体废弃物污染环境防治法	First law to regulate the management of MSW.	The Standing Committee of the National People's Congress	April 1, 1996
Laws and Regulations (English)	Laws and Regulations (Chinese)	Brief Description	Issuer	Effecitive Time

Law for Promotion of Cleaner Production of PRC	中华人民共和国清洁生产促进法	From each step of the production, the manufacturers should take measurements to reduce pollution.	The Standing Committee of the National People's Congress	January 1, 2003
Technical Policies on the Disposal of Domestic Waste and the Prevention of Pollution	城市生活垃圾处理及污染防治技术政策	Guidance and standards of the technologies applied in the MSW treatment.	The Ministry of Construction of PRC, National Development and Reform Commission	June, 2000
Comments on Promoting the Industrialization of Municipal Waste Water Treatment and Municipal Solid Waste Treatment	关于推进城市污水处理，垃圾处理产业发展的意见	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	September, 2002
Law for Environment Impact Assessment of PRC	中华人民共和国环境影响评价法	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	September 1, 2003
Laws and Regulations (English)	Laws and Regulations (Chinese)	Brief Description	Issuer	Effecitive Time

11th Five-year: Constructing Plan of the City Municipal Solid Waste Harmless Treatment	全国城市生活垃圾无害化处理设施建设"十一五"规划		The Ministry of Construction of PRC	September, 2007
On Strengthening Dioxin Pollution Prevention Guidance	关于加强二恶英污染防治的指导意见	Emphzsize the importance of dioxin pollution prevention, and principle guidelines on long-term mechanism of dioxin pullution prevention system, including supervision and monitoring systems.	Nine ministries of China (Foreign Affairs, National Development and Reform, Science and Technology, Industry and Information Technology, Finance, Housing and Urban, Quality Supervision, Inspection and Quarantine.	October 19, 2010
12th Five-Year: General Program of Energy Saving and Emission Reduction	“十二五”节能减排综合性工作方案	Guidance of reduce the intensity of energy consumption, reduce emissions of major pollutants. Encourage waste incineration power generation and heating, the promotion of waste into resources.	The State Council	August 31, 2011

6.2 DIOXIN REPORTING SYSTEM IN CHINA

On October 19th, 2010, a new environmental protection law, "on the strengthening of dioxin pollution prevention guidance" (27) was issued by the Department of Environmental Protection and other agencies (27). According to this law, "a sound long-term mechanism of dioxin pollution prevention shall be established according which waste incinerator plants should carry out supervision and monitoring of dioxins at least once a year and report data to local environmental protection departments. This information is then to be transmitted to higher government levels. "

Also, environmental protection departments at all levels should fully grasp the basic information sources, the establishment of a sound source files and all kinds of key sources of information databases, and improve key source of dioxin emission inventories.

It would have been a relatively easy task for the author to collect the emission data for all WTE plants in China if this "on the strengthening of dioxin pollution prevention guidance" had been successful carried out. However, although the regulation was issued in October 2010, it is reported that this database will be available only by 2015. Therefore, it will be difficult if not impossible to gather data of dioxin emissions before that. In order to get the data, it will be necessary to identify the local or regional agency to which WTE plants report their emissions and determine how this information is transmitted to higher government levels and, also, disseminated to the public. The organization chart for reporting WTE emissions in China is shown in Figure 18.

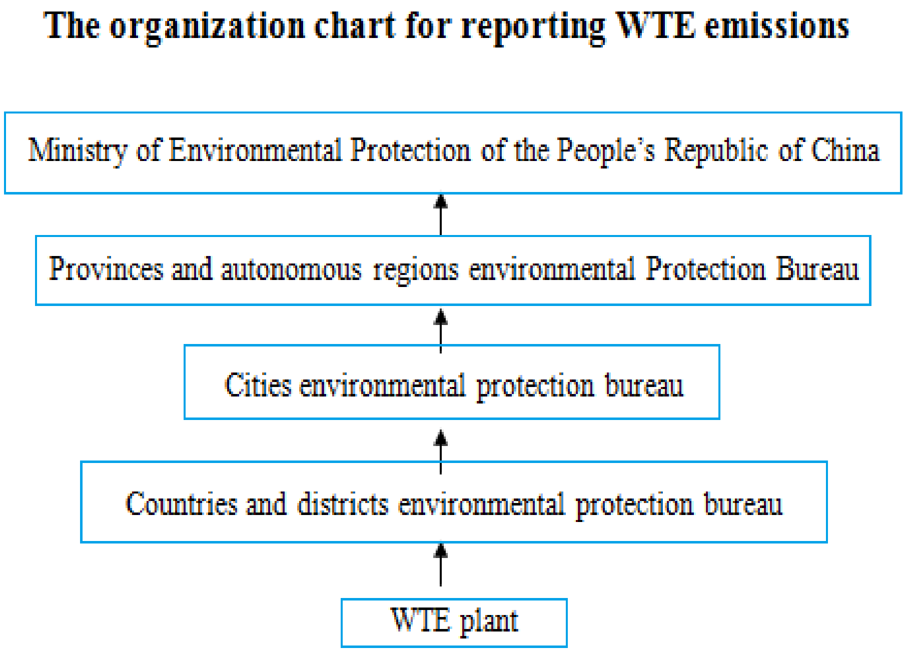


Figure 18 The organization structure of WTE emission reporting systems in China

7. CAPITAL INVESTMENT OF WTE IN CHINA

This study also analyzed the capital investment profiles of over 56 WTE plants in China. Table 17 and Figure 19 show that the capital investment per ton of WTE annual capacity in China is much lower than in E.U. and U.S.in China.

Table 17 Capital Investment of 44 WTE facilities in China, EEC

Plant name	Chinese Name	Capacity, tons/year	Investment/ million USD	investment/tons, USD/ton
Zhuji	诸暨	132,000	51.52	390
Shenzhen Laohukeng	深圳老虎坑	198,000	74.24	374
Xiamen Houkeng	厦门后坑	132,000	47.27	358
Plant name	Chinese Name	Capacity, tons/year	Investment/ million USD	investment/tons, USD/ton

Plant name	Chinese Name	Capacity, tons/year	Investment/ million USD	investment/tons, USD/ton
Guangzhou likeng 1	广州李坑	343,200	110	320
Haerbin	哈尔滨	66,000	21.21	321
Shanghai Yuqiao	浦东御桥	346,500	101.52	292
Suzhou Qizicun	苏州七子村	396,000	98.48	248
Shenzhen Nanshan	深圳南山	264,000	65.15	246
Shenzhen Yantian	深圳盐田	148,500	34.85	234
Quanzhou	泉州	132,000	30.76	233
Shuanggang	双港	396,000	90.91	229
Shanghai Jiangqiao	上海江桥	495,000	106.06	214
Zhejiang Shaoxing	浙江绍兴	396,000	83.33	210
Guangzhou Fanyu WTE	广州番禺生活垃圾焚烧发电厂	660,000	136.36	206
Chengdu Shuangliu Jiujiang	成都双流九江	330,000	68.18	206
Qinzhou	钦州	594,000	121.21	204
Hanyang Guodingshan	汉阳锅顶山	495,000	98.48	199
Wuhan Qingshan	武汉青山	330,000	65.15	197
Beijing Chaoyang Gaoantun	北京朝阳区高安屯	528,000	103.03	195
Beijing Gaoantun	北京高安屯	528,000	103.03	195
Shenzhen Baoan Baigehu	深圳宝安白鸽湖	396,000	75.76	191
Chengdu Luodai	成都洛带	396,000	75.76	191
Chenggong Xinqu	呈贡新区	231,000	43.94	190
Fuzhou Honglingmiao	福建红庙岭	330,000	60.61	183

Taiyuan Lizequ Haozhuang	太原理泽区郝庄	330,000	60.61	183
Ningbo	宁波北仑区枫林垃圾电厂	346,500	60.61	175
Zhengzhou Rongjin	郑州荣锦	231,000	36.36	157
Wuhu	芜湖	198,000	30.76	155
Jinjiang Luoshan	晋江罗山	198,000	28.18	142
Shenyang	沈阳	313,500	43.94	140
Huizhou	惠州	198,000	27.27	137
Zhongshanshi Zhongxinzutuan 1	中山市中心组团 1	231,000	30.30	131
Zhongshanshi Zhongxinzutuan 2	中山市中心组团 2	115,500	15.15	131
Wenzhou Dongzhuang	温州东庄	105,600	13.64	129
Shijiazhuang Qili	石家庄其力	165,000	21.21	128
Shijiazhuang Yucun	石家庄玉树	165,000	20.61	124
Shenzhen Luohuqu Caopu	深圳罗湖区草埔大坑	148,500	18.48	124
Heze	菏泽	198,000	24.24	122
Yiwu WTE	义乌市	132,000	16.06	121
Hangzhou Jinjiang	杭州锦江	264,000	31.82	120
Shenzhen longgang pinghu 2	深圳龙岗平湖	363,000	43.33	119
Hangzhou Qiaosi	杭州乔司	264,000	30.30	115
Cixi WTE	慈溪市	495,000	56.06	113
Xiaoshan	萧山	264,000	29.09	110

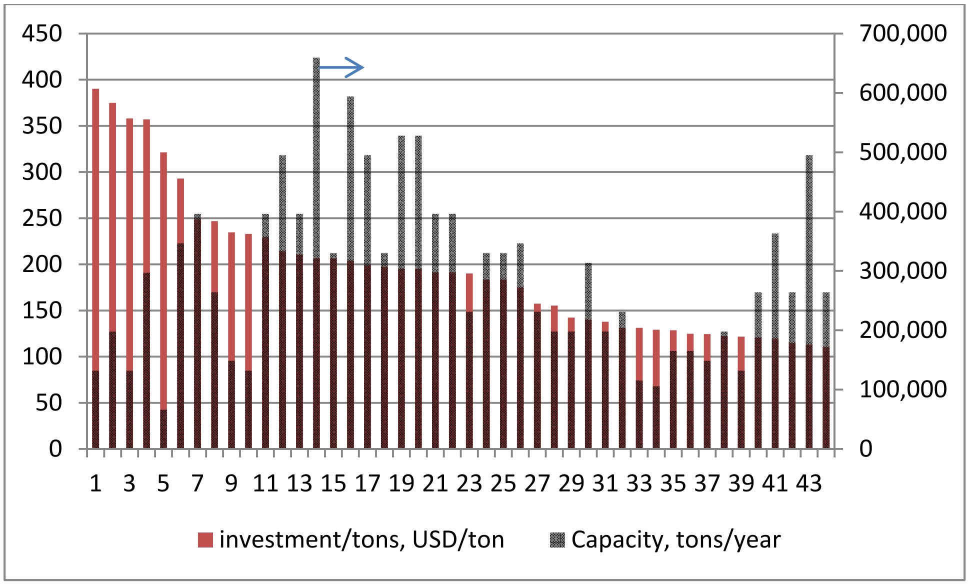


Figure 19 Capital Investment of WTE plant in China

As shown in Figure 19, the investment per ton of WTE capacity in China is ranging from 100 to 400 USD/annual ton. On average, on the basis of the 44 WTE plants in China reviewed so far, the total annual capacity of these plants is 12.9 million tons, and the average capital investment was $200 ton/capacity. In comparison, the average capital investment for WTE plant built in the U.S in the nineties was about $400 ton/capacity, i.e., two times of that in China (Table 18).

Table 18 Comparison of capital investment of WTE plants in China and the U.S, EEC

	China WTE Plant reviewed so far	Existing US WTE plants
Number of plants	44	87
Annual Capacity	12.9 million tons	26 million tons
Estimated Capacity Investment	2.5 billion USD	10 billion USD
Average Plant Capacity	293,000 tons/y	299,000 tons/y
Average Capitcal Investment/ ton	$ 200/ton capacity*	$ 400/ ton capacity*

* U.S.dollars at time of construction of these plants

8. CONCLUSION TO PART 1

The generation of billions of tons of solid wastes by humanity presents both a challenge and an opportunity to developing nations. The information presented in this article shows that China, more than any other developing nation, is taking major steps to increase its WTE capacity. Since the beginning of the 21st century, Chinese WTE capacity has increased from 2.2 million tons/year to 23.5 million tons/year in 2009. This makes China the fourth largest user of WTE, after E.U., Japan, and the U.S. There are 93 WTE plants in China by 2009. However, despite the support from the government, new WTE projects are being vigorously opposed by residents and "environmental specialists".

After one year of research through literature reviews, field trip and contact interviews, twenty WTE plants' dioxin emissions in China have been identified. Using dioxin emissions as a yardstick of the environmental performance of WTE plant, the results showed that the dioxin emissions of these 20 MSW WTE plants ranged from 0.002 to 0.22 NG TEQ /Nm^3; the average value was 0.0719 ng TEQ/Nm3, indicating that most of the WTE plants in China have as low emissions as those in the US and Europe. Eighteen out of twenty of the WTE plants we reviewed operate below the E.U dioxin standard (0.1 NG TEQ /Nm^3), and two above the E.U dioxin standard, but still under the Chinese Dioxin standard (1 NG TEQ /Nm^3). The lack of reliable and consistent source and the lack of transparency in the data collecting systems were discovered during the research.

The report also pays attention to the government regulation and guidance support, with a special case in the new guidance "On Strengthening Dioxin Pollution Prevention" issued collaboratively by nice Chinese ministries on October, 2010.

An analysis of the capital investment profiles of over 44 WTE plants in China is carried out in the report, which shows that WTE investment costs in China are considerably lower than for E.U. and the U.S. On average, on the basis of the 44 WTE plants in China reviewed so far, the total annual capacity of these plants is 12.9 million tons, and the average capital investment $200 ton/capacity. In comparison, the average capital investment for WTE plant in the U.S has been about $400 ton/capacity, i.e., two times of that in China.

PART 2: CASE STUDY OF LIKENG WTE PLANT IN CHINA

1. INTRODUCTION TO THIS SECTION OF THESIS

As presented in the report Part 1, China faces significant solid waste management challenges, which present numerous opportunities to improve methods in waste collection, transport, and disposal, especially in the WTE sector. Given that solid waste management directly affects public health, land use, and the environment, a more sustainable solid waste management systems need to be formulated, enforced, and monitored.

According to Earth Engineering Center's finding on the environmental performance of WTE plants in China, the results showed that most of the WTE plants in China have as low emissions as those in the US and Europe. Eighteen out of twenty of the WTE plants we reviewed operate below the E.U dioxin standard (0.1 NG TEQ /Nm^3). It was therefore surprising to read in the local press several adverse stories about WTE emissions from the Likeng WTE plant in Guangzhou that started operation in 2006 and incorporates the best of the E.U. and Japanese WTE technologies. In order to understand the true situation in Likeng WTE plant, EEC requested the author, as part of this M.S. thesis on waste management in China to visit Guangzhou and the Likeng WTE and get a first-hand impression of the operation of this plant.

2. BACKGROUND ON GUANGZHOU CITY

Guangzhou (Chinese: 广州) is the capital and largest city of the Guangdong province in China. Located in southern China on the Pearl River, about 75 miles north-northwest of Hong Kong, Guangzhou is a key national transportation hub and trading port (28) and one of the five National Central Cities. Guangzhou is the third largest city in China and as of the 2010 census had a population of 12.78 million (29). Guangzhou is a sub-provincial city with direct jurisdiction over ten districts and two county-level cities (Figure 20 and Table 19).

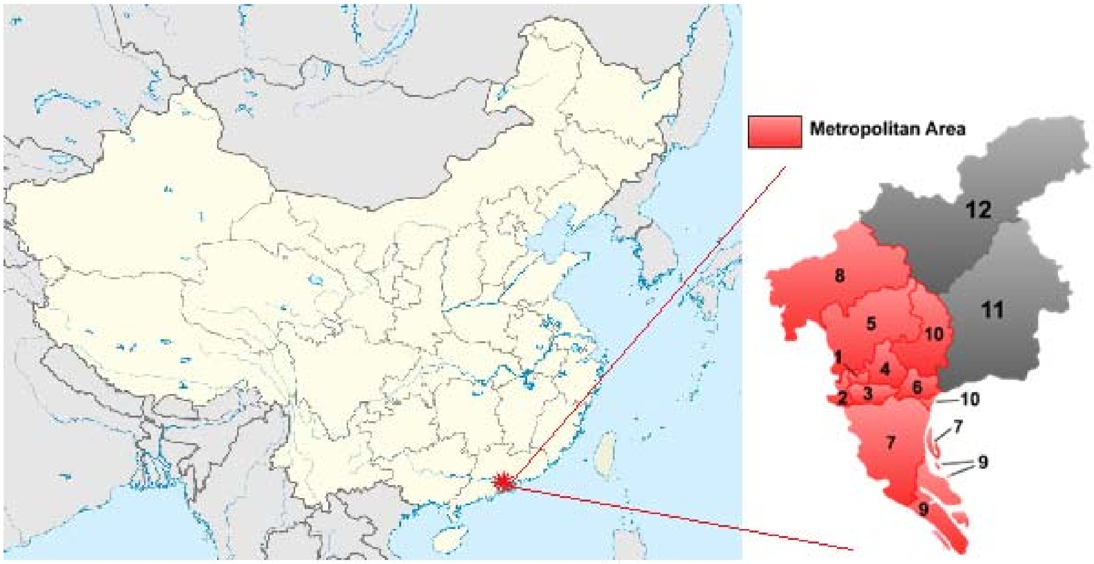


Figure 20 Map of Guangzhou City in China

Table 19 Guangzhou City and its sub-districts

	Name	Population, 2010 census	Area km2	Density /km2
Central City		7,727,163	1,166.37	89,377
1	Yuexiu District	1,157,277	33.8	34,239
2	Liwan District	898,204	59.1	15,198
3	Haizhu District	1,558,663	90.4	17,242
4	Tianhe District	1,432,431	96.33	14,870
5	Baiyun District	2,222,658	795.79	2,793
6	Huangpu District	457,930	90.95	5,035

	Name	Population, 2010 census	Area km2	Density /km2
New districts		3,343,491	2,677.06	1,249
7	Panyu District	1,764,869	786.15	2,245
8	Huadu District	945,053	970.04	974
9	Nansha District	259,899	527.65	493
10	Luogang District	373,670	393.22	950
County-level cities		1,630,146	3,590.97	454
11	Zengcheng	1,036,731	1,616.47	641
12	Conghua	593,415	1,974.50	301
Total		**12,700,800**	**7,434.40**	**1,70**

3. WASTE GENERATION IN GUANGZHOU CITY

Currently, the municipal solid waste (MSW) generation in Guangzhou City is 17,800 tons/day and 6.5 million tons/year, accounting for 34.78% of the total waste generation of Guangdong province, and 4.2% of the national MSW generation. The waste production per capita is 0.48 tons/year and is increasing by 5% annually. According to the annual report on urban construction of Guangzhou in China (2011), the MSW generation of the original central city of Guangzhou including six districts1 has increased from 2,875 tons/day in 1995 to 8,148 tons/day in 2009 (30). The forecast for MSW

[1] The central city includes Yuexiu District, Liwan District, Haizhu District, Tianhe District, Baiyun Disctrict and Huangpu District.

generation is 3.06 million tons/year in 2015, 3.2 million in 2020, and 3.31 million in 2025. Table 20 shows the Waste composition in Guangzhou City from 2004 to 2009.

Table 20 % Waste composition in Guangzhou (2004-2009) prior to recycling (30)*

year	Mixture <10mm	Organics	Wood	Paper	Fabric	Plastics	Rubber & Leather	Metal	Glass	Brick & Ceramics	Batteries
2004	5.97	56.33	2.79	6.88	5.88	16.98	0.25	0.32	1.59	2.96	0.05
2005	4.17	52.43	2.57	7.92	8.81	18.46	0.50	0.32	1.58	3.15	0.09
2006	5.32	58.11	1.22	8.62	6.67	16.59	0.33	0.27	1.17	1.62	0.08
2007	3.43	52.33	1.68	9.00	10.35	10.35	0.95	0.38	1.15	2.04	0.09
2008	2.55	52.49	1.15	9.22	8.72	8.72	0.87	0.25	1.38	2.11	0.03
2009	2.20	54.66	1.12	8.39	10.28	10.28	0.77	0.33	1.34	1.69	0.03

*Source: Guidebook of MSW Classification in Guangzhou

Organics are not considered as recyclables in China but are s classified as food waste that can be e subjected to biochemical treatment,

4. WASTE MANAGEMENT IN GUANGZHOU

4.1 RECYCLING

Earlier waste sorting campaigns were carried out in some selected communities in cities like Beijing and Shanghai as trial projects but were not very successful. To raise public awareness, the government of Guangzhou has considered making recycling mandatory, including penalties for those who did not dispose of their waste properly according to the regulation.

Guangzhou is one of the first cities in China to implement formal recycling starting as of 1998. In this effort, Guangzhou's government released China's first regulation to make waste sorting mandatory. The regulation imposes a fine of at least 50 RMB (7.6 USD) on each personal violator, and at least 500 RMB (76 USD) for every cubic meter, on each organization. This regulation came into effect in April, 2011 and aims to building up a comprehensive waste sorting disposal system. As of now, the only step that residents are expected to do is to separate their MSW into "dry" and "wet"; the municipal sanitation staff is responsible for collecting these two streams and sorting the dry stream into recyclable materials using the appropriate equipment.

Under the new regulation, daily MSW will be sorted into four categories: recyclables, kitchen waste, hazardous waste and other waste respectively. Kitchen waste will be subjected to biochemical treatment; discarded batteries will be disposed in a manner that protects the environment; only garbage that is dry and has a high calorific value will be burned.

As for 2011, Guangzhou has used waste sorting methods to recover about 5,800 tons/day of recyclables; this amount accounts for 33% of the MSW, a recycling rate that is amongst the highest in China (30).

4.2 POST-TECYCLING TREATMENT

Currently the Guangzhou MSW management relies heavily on landfilling (91% of post-recycling MSW). The city has 6 MSW disposal facilities: including one WTE plant--the Likeng WTE plant, and five landfills (Xingfeng Landfills, Panyu Huoshaogang Landfills, Huadu Shiling Landfills, Conghua Tankou Landfills and Zengcheng Tangsha Landfills).

The six MSW disposal facilities' capacity, location and division of work distribution are shown in Table 21. And Figure 21 shows the current disposition of total MSW in Guangzhou City.

Table 21 The Guangzhou MSW disposal facilities

Plant Name	Capacity	Location	Distribution of Work
Likeng WTE Plant	1040 ton/day	Baiyun District	MSW from Yuexiu, Haizhu, Tianhe, Baiyun, Huangpu, Luogang and Nansha
Xingfeng Landfills	5800 ton/day	Guangzhou Northeast Maofeng Mountain	MSW from Yuexiu, Haizhu, Tianhe, Baiyun, Huangpu, Luogang and Nansha
Panyu Huogang Landfills	1900 ton/day	Panyu District	MSW from Panyu district
Huadu Shiling Landfills	1200 ton/day	Huadu District	MSW from Xinhua Street, Shiling Town, Huashan Town, Yayao Town, Chini Town, Timian Town, Huadu Town and local Garrison Force.
Conghua Tankou Landfills	500 ton/day	Conghua District	MSW from Jiekou Street, Jiangpu Street, Chengjiao Street, Wenquan Town, and Mingzhu Industrial Park
Zengcheng Tangsha Landfills	400 ton/day	Zengcheng District	MSW from Zhicheng Street, Zengjiang Street, Paitan Town, Xiaolou Town, Shitan Town, Zhongxin Town and Xintang Town.

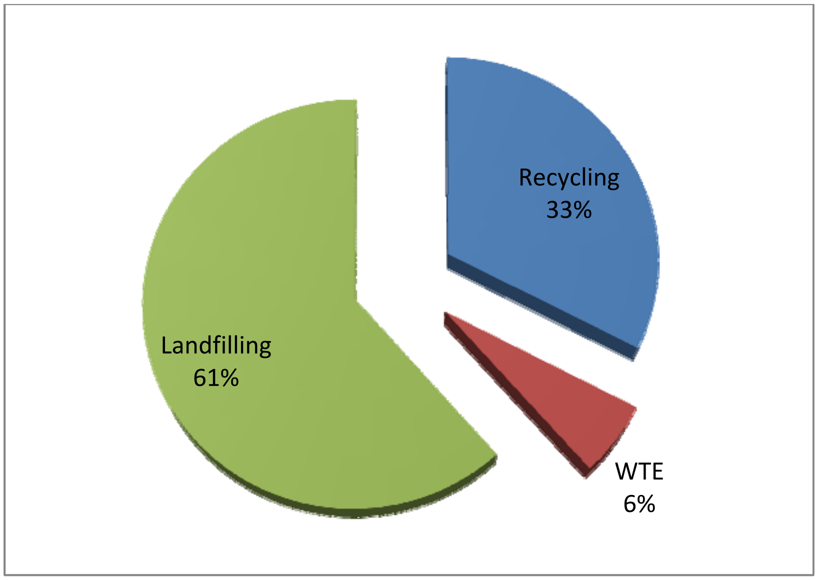


Figure 21 Management of MSW in Guangzhou City, 2011

According to the 11th Five-Year Plan, China will construct 60 refuse-fired power plants, and under the National Waste Disposal Plan, China is planning to increase by 2030 waste-derived energy to 30% of the MSW disposed. Guangzhou will be a leader in this effort. The Guangzhou municipality is committed to environmental protection, especially in the municipal solid waste treatment area, encouraging the cooperation with multinational enterprises in this field. In 2005, the city advocated for the "Construction of an Environment-Friendly Model City", to create an environmental-friendly and harmonious environment for people and business.

The Likeng WTE plant (started in Jan. 2006) has a design daily capacity of 1,040 metric tons and generates 130,000 MWh of electricity a year, by treating 10% of the post-recycling MSW of Guangzhou central city. The rest of the MSW (6,800 tons/day)is landfilled in the Xingfeng sanitary landfill that is provided with landfill gas recovery and electricity generation.

The Xingfeng Landfill of Guangzhou City is in operation since August 2002. By March 2005, the deposited waste was reached about 4.4 million tons. At present, it is the major landfill site in Guangzhou, receiving about 6,800 tons of MSW per day. The Xingfeng Landfill site has carried out landfill gas recovery and electricity generation CDM project since 2006. It is projected that this landfill will reach full capacity by the year 2012. In order to tackle the MSW treatment capacity gap after 2012, the city management committee has carried out internal capacity extension methods within Xingfeng Landfills to add another 7 million cubic meters of landfill capacity, which is projected to put into use in February 2012, and extend the life of Xingfeng Landfills to the end of 2014.

Because that all the major landfills plants in Guangzhou are scheduled to be filled within the next three years, and also of the high cost of land, the City of Guangzhou has been seeking to increase their WTE capacity that will convert more of Guangzhou's waste into energy and alleviate power shortages as well as strengthen environmental protection. The first WTE plant--Likeng WTE plant phase 1 (Capacity: 1040 tons/day) has been in commercial operation since January, 2006. The Likeng WTE plant phase 2 (Capacity: 2000 tons/day) is under construction and is scheduled to start by March 2012. With the third and fourth WTE plant design plans under discussion, the Director General of the Guangzhou Environment and Sanitation Bureau, Lu Zhiyi, has announced that Guangzhou will incinerate all residential garbage to generate electricity by 2015 (31).

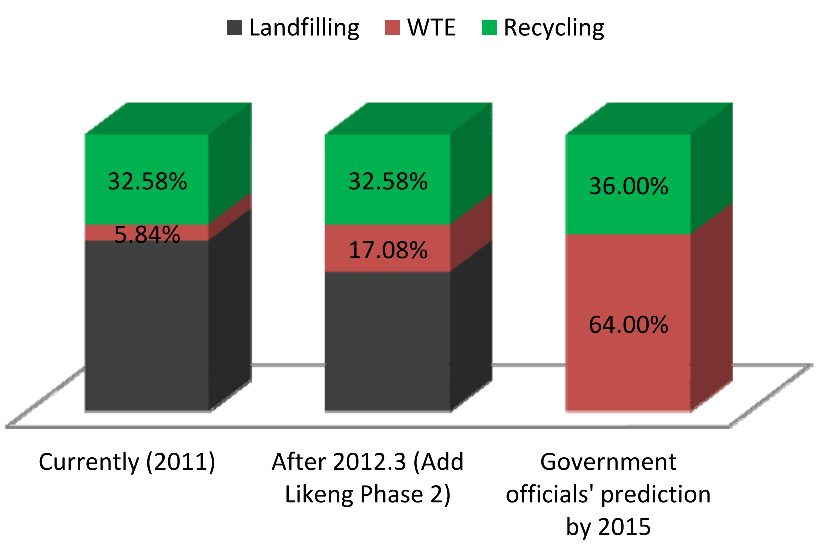


Figure 22 Prediction of Waste Management in Guangzhou

5. THE LIKENG WTE PLANT IN GUANGZHOU

5.1 GENERAL INFORMATION ABOUT LIKENG WTE PLANT

The Likeng Waste-To-Energy plant (Phase I) is the first WTE in Guangzhou and is also the first WTE plant in China to use an elevated temperature and pressure boiler (450oC, 6.5 Mpa). The plant was funded by Guangzhou government with a total investment of RMB 750 million (approximately US$110 million, i.e., US318/ton of annual capacity) it was built by Mitsubisji Heavy Industries using the Martin grate and is operated by Veolia Environmental Service.

Picture 4_a Likeng WTE Plant

Picture 4_b Likeng WTE Plant

The Guangzhou Likeng WTE plant used the following business model:

Government Investing and Building—Government Owned—Private Company Operations and Management—Transfer. During the design, tendering and construction period,, Veolia-ES has provided technical support to Guangzhou. In June, 2005, Veolia Environmental Service was awarded by Bureau of City Appearance Environmental and Sanitation of Guangzhou Municipality the contract for operating and maintaining the WTE plant for a period of 10 years. After a two-year construction period, the commissioning of the plant started in June 2005, and lasted for 6 months before its full time operation started in January, 2006. Table 18 provides the basic facts about this WTE plant.

Table 22 Basic Facts about Likeng WTE (31)

Likeng Waste-To-Energy Plant	
Location	Yongxing District, Baiyun Town, GZ
Total Investment	RMB 750 million (US$ 110 million)
Site Area	32,200 M2
Capacity (2 lines)	1040 tons/day, 325000/year
Boiler Evaporation Capacity	48 tons/hour
Turbine Generation Capacity	22MW
Waste Heat Value Design	4 to 7.5 MJ/kg
Steam Parameters	450^{o}C ,6.5 mpa,
Plant availability	7500 hours/year
Waste Type	MSW
Commissioning	June - December, 2005
Operation	Jan, 2006
Nethermal efficiency)	24%
Total Power Output	158000 MWh/year
Plant Power Consumption	32000 MWh/year
Electricity to Grid	1260000 MWh/year 0.39 MWh/ton
Life	30 years

The Likeng WTE plant components are based on advanced, imported technology. . Furnaces, boilers and the SNCR system for denitrification were supplied by Japan's Mitsubishi Corporation; the emission control system, including dry scrubber, activated carbon injection and bag house were provided by Keppel Seghers Company of Belgium; the feedstock cranes were supplied by KONE Corporation of Finland; and the large shredding machine was provided by SID Company of Switzerland. In addition, the Guangzhou Likeng WTE plant is the first in China to use the following four technologies in China (32): (1) Mid-temperature and pressure boiler; (2) Selective non-catalytic reduction denitrification technology (SNCR); (3) Leachate from waste bunker treated in

WTE furnace; (4) fly ash solidification for fixing volatile metals. The use of advanced technology has resulted in a high thermal efficiency of the plant (24%); and the average revenue from the sale of electricity is US$26.8 (170 Yuan), which is rare in China because of the very low heating value of Chinese MSW.

6. PROCESS FLOW OF LIKENG WTE PLANT

6.1 MSW SUPPLY

After entering into the plant area, waste trucks are weighed at the computerized weighbridge, they then drive to the waste tipping hall to dispose waste into the waste bunker. To prevent odor from spilling, waste bunker is airproof and depressurized, the storage volume is 10000 m^3 with capacity to hold 6000-8000 tons of waste.

6.2 COMBUSTION

Two 8-cubic meter waste grapples are used in the waste bunker to supply waste to the feed hoppers of the two furnaces. Bottom ash generated during combustion of the MSW drops from the grate to the slag bunker from where it is retrieved by vibration conveyers and can be recycled into road building or construction materials after additional processing. Scrap metals mixed in the waste are collected for recycling to steel plants. The high temperature flue gas generated in the combustion chamber process generates steam and then superheated steam in the boiler and then the superheated steam are transmitted to the turbine for electrical power generation.

6.3 FLUE GAS TREATMENT

After the boiler, the combustion gas enters into the semi-dry spraying reactor, where a calcium hydroxide solution is sprayed to neutralize the acid compounds in the gas, while heavy metals and dioxins contained in the gas are trapped and removed by the injection of activated carbon power. The flue gas then enters into the bag house where particulate matter is trapped in fabric filter bags. The purified flue gas is then conveyed to the stack for discharge. Un-reacted chemical materials, fly ash and reactants generated from the flue gas treatment process are trapped in the bag house and conveyed to one of two silos for storage before the stabilization treatment. Fly ash undergoes chemical solidification process to avoid leaching of deleterious materials before disposal for landfilling. As noted earlier, the NOx content of the combustion gases is treated by means of the Selective Non-Catalytic Reduction (SNCR) process.

7. ENVIRONMENTAL PERFORMANCE OF THE LIKENG WTE PLANT

This study showed that when it comes to the environmental performance of many WTE plants in China, one is likely to hear two stories, one from the company side with technical testing data, and the other from local residents or the press reporting personal experience and stories. These two stories in many cases can be completely contradictory. The Likeng WTE is a typical example of this situation.

7.1 THE VOICE OF WTE SUPPORTERS

According to the a brochure describing the Likeng WTE plant by the operator, Guangzhou Veolia ES Likeng Co., Ltd, the Likeng WTE plant has a stringent environmental monitoring system, and the flue gas emission of the Likeng WTE plant meet fully the 1996 European standards (Table 23).

Table 23 Emissions and environmental performance of Likeng WTE Plant (32)

Pollutants	Unit	GWBK-2002 (China Standard)	EU standard (1996)	Actual dischange reported by Likeng WTE	Likeng emission as % of E.U standard for WTEs
Dust	mg/Nm^3	80	30	10	33%
HCI	mg/Nm^3	75	50	50	100%
HF	mg/Nm^3		2	2	100%
NOx	mg/Nm^3	400		200	
Sox	mg/Nm^3	260	300	100	33%
CO	mg/Nm^3	150	100	100	100%
Hg	mg/Nm^3	0.2	0.1	0.1	100%
Cd	mg/Nm^3	0.1	0.1	0.1	100%
Pb	mg/Nm^3	1.6		0.5	
Dioxin &Furan	ngTEQ/Nm^3	1.0	0.1	0.1	100%

7.2 THE VOICE OF WTE OPPONENTS

The information below was compiled by the EEC Investigator from interviews and reports that have appeared in which have been widely used by most of the local website, bbs and newspaper.

"When reporters drove to within 800 meters away from the Likeng WTE plant, they smelled a weird odor like burning bodies in the crematorium. They stopped the car and interviewed several farmers in the field working nearby; they all reported that since the Likeng Plant was running, they had experienced a substantial decline in the production of vegetables, and the drinking water is no long drinkable in this neighborhood." (33)

"Reporters then interviewed a few residents near a local village health clinic where they still smelt the strong and bad odors, residents said that most of the waste burning are at night, and the odors reaches the strongest between 8pm to 10pm. Residents have no other ways but to be at home with their windows closed. The reporters claimed feeling uncomfortable in their throats the next day." (33)

"Reporters reached Yongxing No.1 and 2 villages, which are located only 2 km from Likeng WTE plant. In communication with the village residents, some said "the villages close to the WTE plant has become "the Cancer villages", "People who smells the odor turned to feel dizzy and uncomfortable, but what we can do!" Another lady told reporters "The rich has long moved away from the villages, only the poor has nowhere to go but stay here." (33)

"The environmental expert", Zhao Zhangyuan (11), 67, an activist and a leader of the anti-incineration movement in Beijing, believes deeply that the health hazards from these plants outweigh the benefits. Dioxins are dangerous chemicals known as persistent organic pollutants with high toxicity. "They can accumulate in people's bodies and linger for a long time, increasing the chance of getting cancer," he said. "Dioxins can hardly be avoided once burning is chosen as the way to cope with garbage." The Likeng incineration plant in Guangzhou was cited as an example. Zhao said about 200 villagers near the plant contracted cancer within four years of the plant opening (33). "A lot of statistics show that people have a greater risk of cancer when they live near a garbage incineration plant," he said. The national standard for a safe distance from an incineration plant is 300 m. The number of people who get cancer within 1,200 m of an incineration plant is twice the number of people who contract cancer outside that circle, Zhao said. "Some experts argue that as long as garbage is burned at between 360 and 850 degrees Celsius, hazardous emissions, including dioxins, can be destroyed within seconds," he said. "In practice, it is very difficult to control the burning temperature," Zhao said, adding sometimes workers cut costs by not using enough fuel to maintain the proper temperature. "I don't trust burning as a scientific way to treat garbage. I can accept about 10 percent of garbage in Beijing being burned," he said (11).

7.3 AUTHOR'S FIELD TRIP TO LIKENG WTE PLANT

The author travelled to Guangzhou and visited the Likeng WTE plant in the period of December 1 to December 4, 2011. During this field trip, the author had the opportunity to visit the whole plant with a detailed tour, meet with the plant manager; and also drive around several local villages and meet with several local farmers to discuss their experience with the Likeng WTE plant.

According to the author's findings, the Likeng WTE plant is well operated and has in place several effective ways to improve their environmental performance and transparency of their emission data to the general public and the press. For example, at the entrance of the administration building of the Likeng Plant, there is a large electronic board showing all the on-online continuous monitoring of the plant's emission data, as shown in Figure 20 and Table 20. The last column of Table 20 has been inserted by the author and shows the actual emission data as a percentage of the national emission standard. However, no dioxin emission data is shown to the public, and as I interviewed with local residents, they have no access to the dioxin data which is the emissions that they most fear of.

Picture 5 Likeng WTE plant administration building lounge

Table 24 Online emissions data of Likeng WTE plant

Guanghzou Likeng WTE plant			
No.2 boiler Flue Gas Emission online testing data			
Name	Online number, mg/Nm3	Hourly average, mg/Nm3	National Standard, mg/Nm3
HCI	28	29	75
SO2	71	54	260
CO	7	9	150
NOx	161	152	400
Dust	6	7	80
12/01/2011 11:30:42			

Throughout the entire plant visit,, from the plant entrance to the operation room, the author did not smell any strong or peculiar odor. Also, because of the fully enclosed tipping floor and maintenance of tipping area and bunker under negative pressure (building air is used as combustion air, as per standard procedure of WTE plants), there was a very mild smell even within the are where the trucks dispose their MSW load to the bunker.

With regard to the flue gas treatment system, the Likeng Plant uses the currently world accepted advanced technologies, such as S.N.C.R system, semi-dry scrubber, activated carbon injection and fabric filter baghouse. As mentioned by the plant manager, the investment for the flue gas emission control system was about 100 million RMB (Approx. 14.7 million USD).

Picture 6 Likeng WTE plant operation room

According to interviews with local residents, 5 households out of 8 (Here will be add more information) said that they do not smell any strong odor from the Likeng WTE plant; the other 3 households mentioned that they smell bad odors, but mainly from the street due to leachate leakage from the trucks carrying the wet MSW. However, 7 out of 8 household expressed their concern with the environmental performance of the Likeng WTE plant. Even though they have got information from the plant and government reports about the use of advanced technologies and low emissions measured at the plant, they still are worried about the actual operation of the plant, and also the dioxin emission since it is measured periodically and not very transparent, and cannot e monitored continuously as the other emissions.

Picture 7 Likeng WTE plant surroundings

8. OTHER WTE PLANTS IN GUANGZHOU

8.1 LIKENG WTE PLANT PHASE II

The Likeng Waste-To-Energy Plant Phase II is Guangzhou's second WTE plant, and will begin operation in March 2012 with a daily MSW intake of 2000 tons, about one-fifth of Guangzhou's total waste generation. This WTE power plant is expected to generate 200000 MWh of electricity annually. With a reported capital investment of RMB 970 million (US$140 million, i.e. $220/annual ton of capacity), this WTE plant will utilize Danish technologies to help reduce waste gas emission (32).

8.2 PANYU WTE PLANT

Panyu, located to the south of Guangzhou, became a district of the metropolis in 2000. Since then, people have been moving here because of the attractive house prices and good living conditions. As of 2011, 2.3 million residents in Panyu district produce 1,600 ton/day MSW. However, the district only has a landfill with a daily capacity of 1,200 ton/day, and that's why building a large capacity WTE plant is high on the government's agenda. The Panyu WTE plant was originally planned to start in 2009, but was delayed because of public protests from local residents due to safety concerns. Hundreds of people took to the streets in November 2009 and protesters argued that three hundred thousand people live in areas three kilometers away around the chosen site and would be affected by the plant emissions. Although the government stated that current WTE technology is able to control the emission of harmful s gas, people living around the projected WTE at Panyu strongly opposed it, claiming that it will cause pollution and cancer. In December 2009, the project was called off temporarily (37). Local authorities promised to the public to have a thorough discussion and solicit their opinions. In April 2012, the local government of Panyu district held a press conference to announce five possible sites for the Panyu WTE plant. Guo Chang'an, chief designer of Guangzhou City Planning Institute, stated "This time, we've chosen five sites carefully, based on comprehensive evaluations of geography, transport, and power supply and other factors." Local residents could vote to decide the final location of the WTE plant, or if they were not satisfied with the options, other suggestions would be welcomed. The local government stated that they will not proceed further until all public opinions have been heard.

Picture 8 Public protests from local residents towards the Panyu WTE Project (37)

9. CONCLUSION TO PART 2 AND RECOMMENDATIONS

The municipal solid waste (MSW) generation in Guangzhou City is 17,800 tons/day and 6.5 million tons/year, accounting for 4.2% of the national MSW generation. The waste production per capita is 0.48 tons/year and is increasing by 5% annually. Since 1995, the MSW generation of Guangzhou has increased from 2,875 tons/day in 1995 to 8,148 tons/day in 2009. The forecast for MSW generation is 3.06 million tons/year in 2015, 3.2 million in 2020, and 3.31 million in 2025.

As one of the first cities in China to implement formal recycling, Guangzhou's MSW management relies heavily on landfilling (91% of post-recycling MSW). The city has 6 MSW disposal facilities: including one WTE plant, and five landfills. The Likeng WTE plant (started in Jan. 2006) has a design daily capacity of 1,040 metric tons and generates 130,000 MWh of electricity a year, by treating 10% of the post-recycling MSW of Guangzhou central city.

The Likeng WTE plant used imported Martin Grate Technology and advanced flue gas treatment systems, incorporating the best of the E.U. and Japanese WTE technologies. Therefore, it was surprising to read in the local press several adverse stories about WTE emissions from the Likeng WTE plant in Guangzhou. In order to understand the true situation in Likeng WTE plant, the author travelled to Guangzhou and visited the Likeng WTE plant in December, 2011. Through visiting the whole plant with a detailed tour, meeting with the plant manager; and also driving around several local villages and interviewing with several local farmers, the Likeng WTE plant, in the author's opinion, is well operated and has in place several effective ways to improve their environmental performance and transparency of their emission data, which the except of dioxins data, to the general public and the press. One of the key findings through the interviews with the local residents is that the unpleasant odors which make the people complain about the WTE plant is not directly from the WTE plant, but from the local streets due to the leachate from the trucks carrying the wet MSW. As been mentioned in numerous studies, the MSW in China has high moisture content in all components, including plastics, paper, etc., and the trucks leak a stream of dirty water on their way to WTE which creates unpleasant odors. One recommendation is for government to provide covered bins where people deposit their wastes and require citizens and businesses to put out waste in closed bags as it is carried out mostly in developing countries and large cities, such as New York. It would help the appearance of the city as well as better collection truck operation.

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