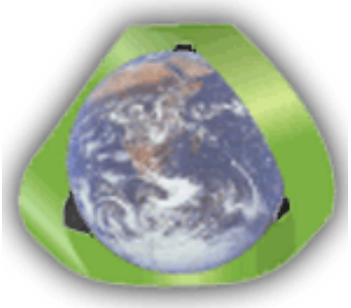
Study of policies and regulations for waste management in China and potential for application in the U.S.

by Zhuo Hao Kevin Cheng

Advisors: Profs. Nickolas J. Themelis and A.C. (Thanos) Bourtsalas

Submitted in fulfillment of the requirements for the Earth Resources Engineering thesis in Department of Earth and Environmental Engineering, Columbia University



EARTH ENGINEERING CENTER
COLUMBIA UNIVERSITY

May 8, 2017

Study of policies and regulations for waste management in China
and potential for application in the U.S.

by Zhuo Hao Kevin Cheng

EXECUTIVE SUMMARY

Chinese cities produce hundreds of millions of tons of solid waste each year, with much still ending up in landfills. In early 2005, China made one of largest state-sponsored commitments toward renewable energy, as the country adopted the Renewable Energy Law which encompassed directives addressed to the management of solid wastes.[1] This Law included a national renewable energy requirement that the use of renewable energy capacity in China be increased appreciably. As a result, in the last decade, China increased its renewable energy production, which now accounts for more than 10% of total energy output. Also, this law recognizes and encourages the use of municipal solid waste (MSW) as a source of renewable energy. This has led to an enormous growth of the Chinese waste to energy (WTE) capacity: In 2005, China had 67 Waste to Energy (WTE) plants converting about 9% of total MSW into energy; by 2013, only eight years after the passage of the Renewable Energy Law, there were166 WTE plants grew to 166, converting over 30% of the nation's MSW to energy.

In comparison, according to the U.S. Energy Information Administration (EIA), renewable energy currently only accounts for 10% of the U.S. total energy output. Currently, there is no federal regulation that encourages or recognizes MSW as a source of renewable energy. Each State government has their definition and regulation of MSW. Only 29 States recognize MSW as a renewable energy source, and only 23 States have WTE plants. As of 2015, there were 79 operating plants in the U.S. combusting with energy recovery about 27 million metric tons of MSW. According to the EIA, the United States converts about 13% of the total MSW into energy. Presently, about 63% of MSW ends up in landfills, 29.5% is

[1] http://www.npc.gov.cn/englishnpc/Special/CombatingClimateChange/2009-08/25/content_1515301.htm

recycled or composted and 7.5% is processed in WTE plants. Without a proper federal framework and legislation to recycle and recover energy from MSW, nearly two thirds of it ends up in landfills.

Using China's Renewable Energy Law, other national and regional regulations, and public information programs as a baseline, this research study aims to analyze and make recommendations as to how the elements of the Chinese waste management framework and laws may be transposed to federal and state legislation for potential application in the United States.

This report concludes that as economic factors and social factors shift the available of essential resource, WTE will eventually become the most economically viable option for MSW disposal. For the WTE sector to grow in the US, it is recommended that US federal and state government adopt policies presented in this report, and use China's WTE development model as a baseline for what can be accomplished here in the US.

Table of Contents

List of Figures and Tables……..6

Acknowledgments…….....7

1. Management of Solid Waste (MSW) in China……8

1.1 Recycling…….9

1.2 Composting……11

1.3 Energy Recovery……11

1.4 Landfilling……..12

1.5 Urbanization in China and Management of Municipal Solid Waste…….14

2. Municipal Solid Waste as a Renewable Energy Source……...15

2.1 MSW as a fuel……15

2.2 The MSW Combustion Process …….……..…….....16

2.3 Development of WTE in China……..17

2.4 Challenges Facing WTE Sector in China……...18

3. National Support and Policies of WTE in China……..20

3.1 Stable and Efficient Policies in Support of WTE in China ……...20

3.2 Support of WTE in China……...21

4. Structured and Planned Approach to WTE Development in China……...22

4.1 Structured approach to WTE development in China……..22

4.2 Planned approach to WTE development in China…….24

5. Laws, Regulations, and Policies……..25

5.1 WTE Laws and Regulations……...25

5.2 Price Policies……..28

5.3 Tax Policies……29

6. MSW Management in the United States…….…..30

7. WTE Development and Policies in the United States……...……34

7.1 WTE development in the United States…….34

7.2 WTE policies in the United States…….37

7.3 Challenges facing WTE development in the United States……...38

8. Analysis on Policies in China and in the United States…….39

9. Conclusions ……..……....41

10. Recommendations ……..…….……42

11. References…….44

List of Figures and Tables

Figure 1: Streets are left covered in rubbish near these high-rise buildings and a children's playground……..8

Figure 2: The Waste Management Hierarchy……...10

Figure 3: A Chinese recycler is sorting through plastic bottles in China. Much of Chin's recycling process is done by hand and is highly ineffective……11

Figure 4: A truck empties garbage that is quickly searched by people at a landfill in Changchun……13

Figure 5: MSW incineration plant, owned by China Everbright International Limited, is located in Suzhou, China……..14

Figure 6: MSW consists of everyday items thrown away by individuals……....15

Figure 7: Fly ash and bottom ash can be reused if treated properly. The ash is used to make construction materials, such as bricks and concrete…….19

Figure 8: The population of China represents 19.48 percent of the world's total population…….21

Figure 9: An example of a BOT structure of an MSW incineration plant project in China……24

Table 1: Policies encouraging WTE projects in China……26

Figure 10: In the late 1800s, public works in America began. The figure illustrates the town of Kearny, Nebraska having sewer pipes installed……..31

Figure 11: Despite solid waste management legislations piles of household garbage is seen at an open dump in present day…….……...33

Figure 12: New York City is dimly seen through the dense smog covering much of the city……33

Table 2: A list of the major federal laws that affect municipal solid waste management…...35

Figure 13: Opened in 1989, the Palm Beach Renewable Energy Facility 1 is an example of waste to energy facility in the United States……36

Figure 14: Opened in 2015, the Pam Beach County Solid Waste Authority's Renewable Energy Facility 2 is the first WTE facility built in the United States in more than 15 years…….38

Acknowledgements

First, I would like to thank my advisor, Professor Nickolas J. Themelis for his guidance, patience, and support during my pursuit of my master's degree. I have been inspired by his diligence and unwavering passion toward research and waste to energy. I am forever grateful for his confidence in me. I would also like to thank Professor A.C. Bourtsalas for his invaluable and generous support on this research. His expertise and knowledge in the field of waste management were an asset to my research.

Secondly, I would like to thank Professor Steven Alan Cohen for mentorship during my studies at the Environmental Science and Policy program at Columbia University's School of International Affairs (SIPA). He taught me innumerable, practical lessons on how to approach research and how to approach problem-solving.

I gratefully acknowledge the financial support of the Global Waste to Energy Research and Technology Council (GWC) of the Earth Engineering Center (EEC) at Columbia University, EEC alumna Dr. Li Wu, and other GWC sponsors . Without them, this academic pursuit would not have been possible.

I would also like to thank my SIPA colleagues who provided a great deal of moral support, including Mohammad (Umar) Ashfaq, Zenia Montero, Iara Vicente, Averill Wickland, Isaac Wilkins, and Lacey McCarthy. Thank you for your comradery and support.

Finally, I cannot thank my family and friends enough for the love and encouragement. I am grateful for my beautiful mother, Nancy, for her unconditional love and unwavering belief in me. Secondly, I am fortunate to have such a loving father, Cliff, whose advice and example has been a positive influence my life. Lastly, I would like to thank my friends, Marissa Sterling, Tiara L. Cunningham, David Lee, Raymond Liang, Ronald Leung, and Alex Liu for their friendship.

Thanks to the universe for all of you.

1. Management of Solid Waste (MSW) in China

Before the 1980s, there was no formal treatment or disposal of municipal solid waste (MSW) in China. At that time, MSW was collected and transported to rural areas to be used as fertilizer because its quantity was small and it consisted of mostly food. However, as China's economic development took off, China's use of MSW as fertilizer declined and farmers replaced MSW with chemical fertilizers. As a result, a significant amount of MSW was dumped in streams, ponds, and roadsides at the outskirts of cities. By the late 1980s,

Source: dailymail.co.uk

Figure 1 An extreme example: A photograph of streets covered in rubbish near high-rise buildings and a children's playground.

major cities, like Shanghai and Beijing, became surrounded by MSW creating a hazardous environmental situation that drew the attention of many local governments (Dong 2011). Of the 688 cities in China, it is estimated that two-thirds are surrounded by landfill sites (Zhang et al. 2015). Figure 1 is an extreme example of a trash-filled street in a Chinese city. Data

from 2007 showed that China surpassed the United States of America (USA) as the world's largest producer of MSW (Song et al. 2013). It has been estimated that China will produce over 480 million tons of MSW by 2030 (Asian Development Bank. 2009).

The first regulation that was passed to address MSW disposal management was the City Appearance and Environmental Sanitary Management Ordinance in 1992 by the State Council of the People's Republic of China. This legislation is the principal guideline to which municipal governments look to for MSW disposal practices. Since then, other laws on waste management have passed. One of the most influential is the Law on Prevention and Control of Environmental Pollution Caused by Solid Waste of People's Republic of China (PRC). According to the legislative and regulatory framework for disposal of solid waste, local government has its role and responsibility. In a sense, like in most developed nations, the Central government set laws and guidelines for solid waste management for local government to follow. It is up to each of the municipal governments to then set up its requirements and practices for MSW disposal.

Currently, there is no single solution to waste management. Instead, there is a mixture of treatments and disposal options for municipalities to employ to address the MSW problem in China. Under the general guidance of the Hierarchy of Waste Management system (Figure 2), several solutions have already been implemented, such as recycling, composting, combustion with energy recovery and finally, sanitary disposal landfilling. However, waste management facilities in China are not equipped to deal with the amount of MSW collected and in many cities, these facilities are not sufficient to treat and disposal the MSW (Song et al. 2013). The lack of waste management facilities has resulted to most of the MSW still being landfilled throughout China..

1.1 Recycling

Recycling is a critical cornerstone of the waste management. Currently, in China, there is a significant amount of formal and informal recycling taking place in the main cities. In 2005, an estimated over one million people worked in the formal recycling system,

Figure 2 The Waste Management Hierarchy (US EPA).

employed by local government or local business, with the primary task of collecting and transporting waste to recycling centers. Another 2.5 million people are estimated to work in the informal recycling system, which is made up of private citizens selling collected materials, who are not associated with any local government or business entities (World Bank 2005).

China's recycling numbers are hard to obtain, due to the significant amount of informal recycling taking place in the country. Many materials are already recovered by informal recyclers before formal recyclers can collect the waste for processing. An example of recycling can be seen in Figure 3. In some major cities in China, there is a mandatory recycling quota that is put in place to limit the amount of waste going to landfills. Cities like Beijing, Shanghai, and Guangzhou already recycle a fraction of the MSW they generate (Dong 2011). However, it is hard to know the actual amount of materials that are recycled.

Source: irrawaddy.com

Figure 3 A Chinese recycler is sorting through plastic bottles in China. Much of China's recycling process is done by hand and is highly ineffective.

1.2 Composting

Composting is seen as another form of recycling. China's MSW has a high moisture content, which is especially suited for composting. Although as much as 60% of China's MSW is biodegradable organic matter and contains a high moisture content, composting accounts for only 2% of the total MSW treated in China (Dong 2011).

1.3 Combustion with Energy Recovery

Waste incineration technology was introduced to China in the late 1980s and developed rapidly in the 1990s. In 2003, there were only 47 waste incineration plants, with a capacity of 3.7 million tons a year. By 2013, China had 166 waste incineration plants, with a capacity of 46.3 million tons a year (Zhang et al. 2015). Seen as the best solution for managing post-recycling MSW, combustion of MSW with energy recovery, commonly called waste-to-energy or WTE, , has several advantages over landfills, such as significant volume and mass reduction of waste and energy recovery during the process (Cheng, Hu. 2010). As such, waste to energy plants are becoming more and more important in addressing the issue of China's growing MSW generation. However, because of their relatively high capital investment, most waste incineration plants are located in economically developed cities in China.

To further encourage waste to energy (WTE) sector in China, the Central government has issued several favorable policies toward the industry. These include prioritized commercial bank loans, low loan interest, guaranteed subsidized price for the purchase of electricity, carbon financing and low or no tax on revenues (Dong 2011). Through the encouragement of the Central government of China, in 2009 waste to energy accounted for a nearly 20% of the total MSW treated in China (Dong 2011). The WTE fraction has increased since then, due to the construction of nearly thirty new WTE plants each year.

1.4 Landfilling

Currently, many cities in China have no suitable places for landfills and are addressing the problem of garbage siege, which is leading to serious environmental, underground water, soil, and health contamination (Song et al. 2013). The management of MSW can impact public health, and it is critical for the government to devote resources and attention to MSW treatment.

The management MSW did not exist before the 1980s. Before the 1980s, waste was openly dumped anywhere, away from populated areas. It was estimated that only 2% of MSW was properly disposed before the 1990s. The rate of disposal gradually increased in the 1990s, and by 2013, 89.3% of MSW was disposed of properly (Song et al. 2013).

In 2009, it was estimated that 80% of MSW in China ended up in landfills (Dong 2011). Being the least attractive option for MSW treatment and disposal, there are many shortcomings when it comes to landfills in China. For example, even well-designed landfills, with methane capture technology to use for energy recovery, cannot capture all the biogas generated within the landfill. Also, improperly constructed landfills with the passage of time can result in environmental damages and degradation. Other issues revolve around the presence of waste pickers and inadequate collection and treatment of waste. Though China is looking to improve on these matters, landfills are being heavily used as the primary disposal option for MSW in China.

The problem is much worse for illegal waste dumping sites, which are not sanctioned by the government for business. Illegal dumping sites are under no environmental control and can have a serious effect on public health or human health control that would limit the effects of waste on human bodies. Landfills in China are often opening fields; this can be seen in Figure 4.

Figure 4 A truck empties garbage that is quickly searched by people at a landfill in Changchun.

In 2005, it was estimated that in a major city like Beijing or Shanghai, there were about fifty illegal dump sites, with at least five with immediate attention (World Bank 2005). With efforts in place to clean up these illegal dump sites, China is on its way to adequately addressing the MSW disposal issue.

1.5 Urbanization in China and Management of Municipal Solid Waste

In 1978, China initiated market reforms that shifted the economy from a centrally planned to a market-based economy and began the rapid economic development we see today. China's urbanization is characteristic by the mass migration of the rural population into cities. Due to China's rapid urbanization and population growth, MSW generation has rapidly risen as well. In 2013, estimates put China's total MSW generation at 172 million tons (Song et al. 2013), thus making it one of the highest generators of MSW in the world. China's rapid economic growth have accompanied by a sharp increase in waste generation. With development comes improved standard of living, but also significant amount solid waste. For the past thirty years, municipal solid waste (MSW) collection increased from 31 million tons in 1980 to 157 million tons in 2009. Estimates put one-third of Chinese cities are facing the problem of MSW disposal (Dong 2011). An example of a modern WTE facility in China is seen in Figure 5.

Figure 5 MSW incineration plant, owned by China Everbright International Limited, is located in Suzhou, China.

2. Municipal Solid Waste as a Renewable Energy Source

2.1 MSW as a fuel

The term “renewable energy” has traditionally been referred to energy that is replaceable or inexhaustible in nature, such as water, the wind, solar and bio-organic materials. MSW consists of mainly paper, food, wood, cotton, leather waste, and also times fossil fuel-based materials, like plastics and other artificial fabrics (Zhang et al. 2015). The conversion of MSW to energy has a significant potential to reduce greenhouse gasses, and the United States Environmental Protection Agency (US EPA) listed MSW as a renewable resource for energy production (EPA). The composition of U.S. MSW is shown in Figure 6.

The US EPA defines MSW as any "durable goods, nondurable goods, containers and packaging, food waste and yard trimming, and miscellaneous inorganic waste" (EPA).

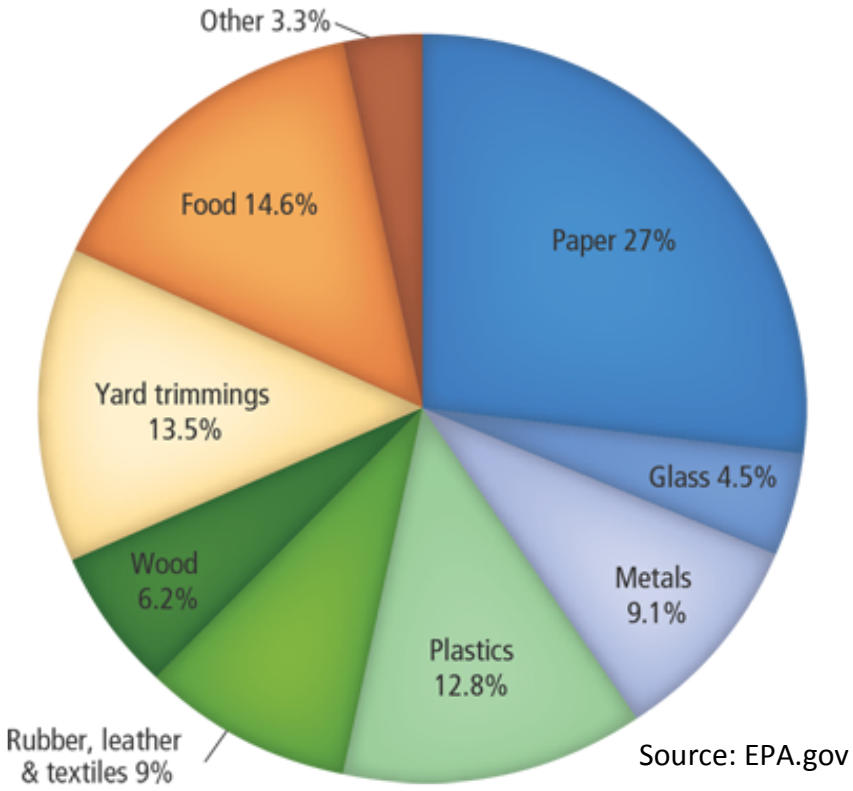


Figure 6 MSW consists of everyday items thrown away by individuals such as product packaging, garden clippings, newspapers, bottles, food waste, clothing, paint, and batteries.

However, MSW does not cover all forms of solid waste, such as construction waste, industrial or sewage waste. MSW can also refer to the collection and disposal of urban waste. In 2005, China's Renewable Energy Law, passed, recognizing MSW as a renewable source of energy. Since then, MSW incineration plants have been categorized as renewable energy sources and are treated and benefited from renewable energy tax credits, loans, and subsidies. The appeal of MSW incineration technology is the dramatic reduction of the need for landfills and the conservation of land resources.

2.2 The MSW Combustion Process

Waste incineration technology utilizes MSW as a fuel to burn, instead of using coal or fossil fuel; i.e., MSW is used as the primary fuel. The controlled combustion of MSW is a fundamental part of the waste management hierarchy, as MSW can be fully utilized to generate energy for the public. MSW combustion replaces coal, or other types of fossil fuel as the primary source of chemical energy to the combustion process. MSW is unloaded from collection vehicles and placed in storage bunker. Then an overhead crane sorts the waste, which then will lift the sorted MSW into a combustion chamber to be burned. The heat from the burning MSW is recovered in heat exchangers to convert water into steam, which is then sent to a turbine generator to produce electricity. The most important part of modern WTE plants is the Air Pollution Control (APC) system in which chlorine and sulfur compounds in the furnace gas are removed by chemical reaction with calcium oxide, nitrogen oxides are removed by reduction with ammonia or urea, and dioxins and volatile metal molecules are adsorbed on activated carbon particles. The gas then passes though a fabric filter baghouse where the articulate matter is removed by filtration. The cleaned gas is then conveyed to the stack.

The bottom ash from the combustion process is collected and subjected to ferrous and non-ferrous metal recovery and can then be disposed in ash monomials or used as a construction material in highway construction or other civil work application.

2.3 Development of WTE in China

The increase in MSW generation has to lead to environmental damages due to pressure on existing landfills. The pressure on landfills is why the need for smart waste management has led to the adoption of a concept known as "hierarchy of waste management." The United States Environmental Protection Agency developed the tiered waste management system to guide waste management decision-making, with the aim of reducing the amount of disposable waste and preserve valuable, limited landfill space. The system places emphasis on reducing, reusing, and recycling to the cornerstone to sustainable practices (EPA).

The hierarchical system of management prioritizes minimizing and reusing waste, however, after all, possible recycling and composting, there is only two options for post-recycling waste: waste to energy (WTE) or landfilling. Seen as a better solution than landfilling, WTE can reduce the volume of waste by 90% and lessen the mass of waste by 70%, along with energy recovery (Cheng, Hu. 2010). The reduction in waste is the reason for WTE facilities are constructed across China, despite the large initial capital investment and substantial operating cost associated with WTE facilities (Dong 2011).

When compared to landfilling, WTE has a substantial capital investment and high operating expenses. At the core of WTE is the boiler, which accounts for 50% of the cost of investment (Zhang et al. 2015). For example, the Shanghai Pudong Waste Incineration Power Plant has an investment of 110 million USD, and the Shanghai Jiangqiao Waste Incineration Power Plant has an investment of 144 million USD (Zhang et al. 2015). The cost associated with WTE facilities are not sustainable for most Chinese cities; hence the majority of WTE

facilities are located in economically developed regions of China and majority of the premises are mainly funded by local governments (Zhang et al. 2015).

Driven by a national target for WTE development and low carbon objectives. China's WTE sector has experienced rapid growth. However, China's WTE industry is experiencing challenges in recent years. Not only do problems come in forms of technological, but also environmental, social, health and other types as well. As China moves into the "13th Five Year Plan", challenges facing the WTE sector are addressed, but the question remain; how effectively can the government address the challenges facing WTE industry in China?

2.4 Challenges Facing WTE Sector in China

China's WTE sector is mainly based off technology that is mature and simpler than other MSW treatment options, excluding landfilling. In 1988, China established its first WTE facilities, and since then much more followed. As the demand for MSW incineration increase, China will need to develop more WTE facilities to keep up demand. However, WTE are capital intensive projects; they require much financial support from an early stage of development to long-term operation cost. WTE facilities require high cost is one of the biggest challenges facing the sector. Most of the expense of a WTE facility comes from the core or the boiler when combustion is taken place. The core can account for 50% of the total cost for a WTE facility (Zhang et al. 2015). With most WTE plants cost hundreds of millions of dollars, these costs are unsustainable for many Chinese cities. Although, the government has turned to Public Private Partnership (PPP) models to encourage private investment into WTE (Song et al. 2013).

The low heat of MSW in China is another challenge facing China. When compared to developed countries, China’s MSW separation is less developed (Zhang et al. 2015). As a result, the MSW has a low heat value because of its high bio-organic composition and moisture content, making the MSW less energy efficient when incinerated. In turn, a lot of

renewable materials are destroyed during the incineration process, and a significant amount of fly ash is created.

Fly ash is a light form of ash that is the remains of MSW when incinerated and is light enough to suspend in the air (Cheng, Hu. 2010). Fly ash is light than bottom ash, which is a heavier form ash that is left from MSW incineration (NRDC 2015). When it comes to fly ash, many regions in China have yet to address this environmental problem. Fly ash is hazardous, containing dioxin and heavy metals harmful to the environment and well as to the human body. Like dioxin emission, which has a national standard to meet, fly ash, and bottom ash also has requirements regarding proper treatment. However, few municipalities in China have the special facilities for treating fly ash, and instead illegally dump the fly ash in open dumping sites (Zhang et al. 2015). Bricks created out of fly ash can be seen in Figure 7.

Figure 7 Fly ash and bottom ash can be reused if treated properly. The ash is used to make construction materials, such as bricks and concrete.

As living standards improve, so does the expectation for the living environment. The expectation for a better living environment is why, as new WTE facilities are planned, the public opposition have been a significant challenge for WTE development. In a report measuring Chinese WTE facilities, dioxin emission found that many incineration plants do not meet the national standard for dioxin emission (Ni et al. 2009). This substandard

performance has led to strong public opposition to the construction of waste incineration plants in communities across China.

The growing green movement in China is increasing the awareness of the need to protect the environment, and hence public opposition has become the most challenging aspect of WTE development in China (Qiu et al. 2012). With inappropriate site selection for many WTE facilities, there is a growing amount resistance to waste incineration in many Chinese communities. The resistance to waste incineration in China have resulted in a social movement in China known as the "Not in My Backyard," which is an organized opposition to planned industrial or commercial land near residential communities (Herszenhorn 2000). One of the main reasons why there is such an opposition towards WTE is the lack of public participation during the planning stage of WTE development.

As citizens in China are becoming more and more environmentally conscious, the public has begun to worry about the negative health effects of WTE incineration may have on the human body. Currently, there is limited public participation in the planning process. Whatever participation is there is seen as a form of goodwill, which is far from fully involving the public in WTE development (Zhang et al. 2015).

3. National Support and Policies of WTE in China

3.1 Stable and Efficient Policies in Support of WTE in China

Despite the challenges facing Chinese WTE sector, for the past three decades, the WTE industry in China has experienced a historical growth, unseen before in history. For China's WTE industry, the stable and efficient policies adopted by the Central government are the foundation for the rapid expansion, experienced by the sector. Today, WTE industry is given the special support status of renewable energy to develop the potential of WTE in China further.

The potential of WTE in China comes from the growing population and shortage of land. Figure 8 shows China's population since the 1950s. The extreme difficulties to find land for landfills is driving local municipality authorities to look for other MSW management solutions. Waste incineration can reduce the volume of MSW by 90% (Cheng, Hu. 2010) and can incinerate over a 1000 tons of MSW per day, WTE has great potential to play a larger role in MSW treatment.

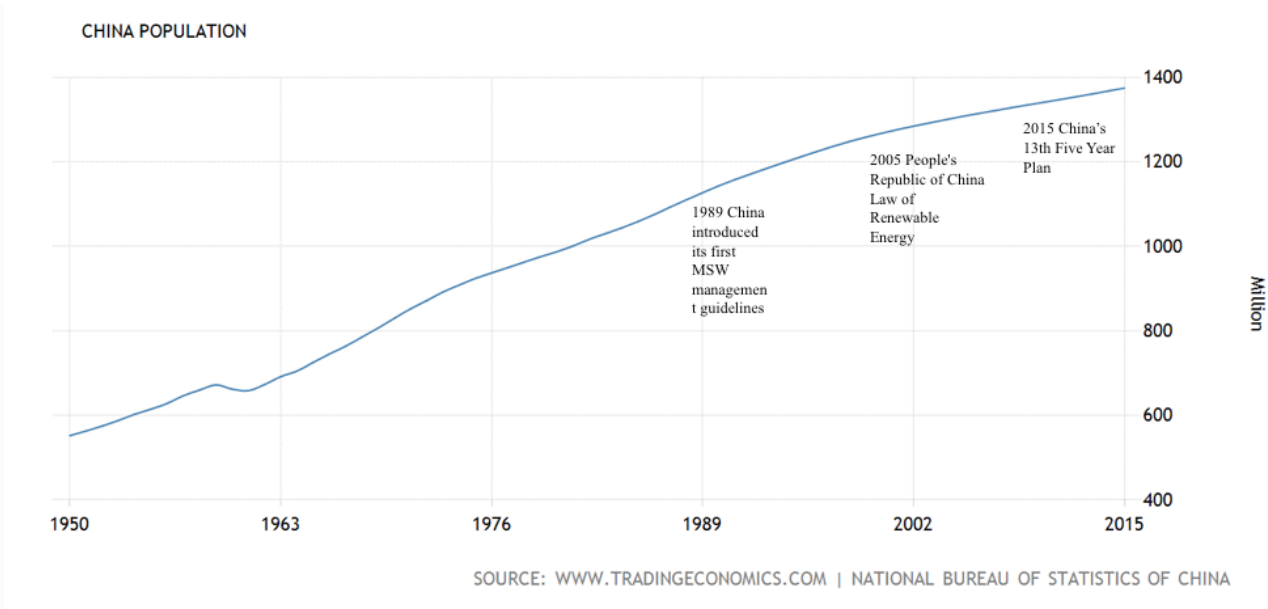


Figure 8 The population of China represents 19.48 percent of the world´s total population which arguably means that one person in every five people on the planet is a resident of China (World Bank).

3.2. Support of WTE in China

The potential of WTE in China can only be achieved by the support of policies and incentives to which then can the WTE sector grow. As a strong foundation, Chinese WTE industry has already experienced a tremendous rate of growth under reliable and efficient policies. In recognizing the problem of MSW generation, the Central government of China adopted solutions to address the issue. Solution mainly involving MSW incineration were supported by several national policies. In China's "12th Five Year Plan", a Soviet-style

economic plan published by the Chinese every five years, outlining the targets and goals for the nation. Chinese national government planned on investing 12.3 billion dollars into WTE development (Zhang et al. 2015), in the period from 2011 to 2015, hoping to introduce the MSW solution to more regions in China.

Along with direct investment from the government, the support for WTE in China is far more significant than compared to the United States. Regarding funding policy for large environmental protection projects, the government requires a private investor provide 30% of the initial capital (Zhang et al. 2015), and remaining capital can be provided by local, provincial, or Central governments. In much WTE development, the local government will provide much of the initial capital investment and look for private investors to buy into the project, to meet the national government requirements. The Central government often provide revenue policies, making WTE an attractive industry for private investment. By establishing favorable tax incentives, high energy purchase price, and tax exemption on 5% of earned revenue (Zhang et al. 2015), the Central government has made WTE sector in China a safe investment, eliminating as much risk as possible for potential investors.

Part of the Central government's plan toward codifying environmental legislation and regulation, many policies have been enacted to address the MSW problem and utilize MSW as a source of renewable energy (Zheng et al. 2014). Since 2000, Chinese WTE industry has experienced an incredible rate of growth, in part driven my progressive policies and regulations list above.

China has an extensive list of rules and regulation on MSW that stretches back to 1992 with China’s first law regarding the treatment of MSW, the “City Appearance, and Environmental Sanitary Management Ordinance." However, the WTE sector only recently experienced a rapid growth in the 2000s.

4. Structured and Planned Approach to WTE development in China

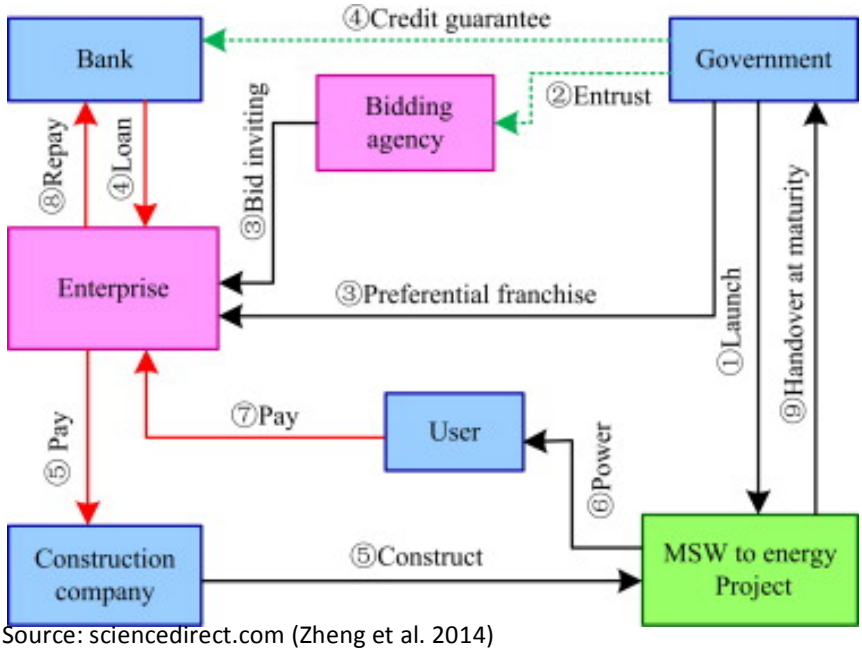
4.1 Structured approach to WTE development in China

The success experienced by the WTE sector in China can be attributed to the approach the Central government adopted over the years. When it comes to high capital and high-risk projects, very few private investors would want to be attached to such projects. The high risk involved with waste incineration plants, the Central government set mechanisms in place to address the high-risk factor associated with the WTE industry. Along with supportive policies and tax incentives, there are market tools; the Central government has employed to support WTE sector growth.

The financial structure of funding WTE projects are the primary market device, the Central government in China, have adopted to foster WTE industry development. The three most common types of financial structure are Build-Operate-Transfer (BOT), Transfer-Operate-Transfer (TOT) and Public-Private Partnership (PPP). Each of these structures has advantages and disadvantages (Xin-gang et al. 2016), but by far the most common structure, out of the three, is BOT.

Government investment can be a strong signal to private investors the willingness and seriousness of government commitment towards certain public projects. Government commitment towards certain public projects is why BOT financial structure is the most common in Chinese WTE development (Xin-gang et al. 2016). BOT structure allows the financial burden be shared among private and public stakeholders.

By introducing professional private companies and staff, it can lower the construction period and reduce the cost, along with improvising efficiency. Not only does the BOT structure benefit large multinational professional firms, but also helps China by bringing a significant amount of foreign capital into the country. The BOT structure is illustrated in Figure 9.



Source: sciencedirect.com (Zheng et al. 2014)

Figure 9 An example of a BOT structure of an MSW incineration plant project in China.

BOT structure is used to attract both foreign and domestic investment. BOT allows the government to share the risk of large projects. The government grants the construction and operation of the facilities to an enterprise, which is then responsible for the investment, financing, design, construction, and operation of the waste incineration plant. After a period of operation, usually 20 to 30 years (Y. Li et al. 2015), the operation is transferred over to the government.

The government in the meantime pays waste disposal fees to the waste incineration plant and ensure the electricity generated by the plant can be sold to the national grid. BOT the policy is key to China's rapid WTE development. Not only do investors obtain a return on investment, but the investors also earn additional revenue (Y. Li et al. 2015). The BOT approach to WTE development key factor lies in the full utilization of social forces and market competition to create an environment of rapid growth and high quality.

4.2 Planned approach to WTE development in China

Every five years, China publish an economic development plan outlining China's economic target to meet in the coming five years. In the "12th Five-Year Plan", which ended in 2015, the Central government promoted resource utilization of MSW. Within the "12th Five-Year Plan", it recognized the relationship of MSW treatment and economic, as well as social, development of China. The "12th Five-Year Plan", also recognized the importance of MSW treatment when it comes to environmental protection and public health (Li et al. 2015). Based on the "12th Five-Year Plan", the Central government planned a vast number of projects for MSW incineration throughout China, showcasing the support the Central government has the technology and the industry. With China moving into the "13th Five-Year Plan", stretching from 2016 to 2020, it is predicted that more MSW incineration projects are in development and that China is looking to add 19,500 tons of MSW processing capacity per day in the next five years (Zheng et al. 2014).

Through a series of policies, preferential tax treatments, and favorable tariffs of MSW incineration, the Chinese government is maintaining a healthy supportive attitude towards WTE development. It is through these active and beneficial policies did the WTE industry grow and continue to grow.

5. Laws, Regulations, and Policies

5.1 WTE Laws and Regulations

A key piece to successful WTE development in China in recent history is the Renewable Energy Law passed in 2005 by the National People's Congress. The law came into effect on January 1, 2006, as part of China's overall shift towards renewable energy, the law is the cornerstone of renewable energy development in the years that followed (Zheng et al. 2014). The passage of the Renewable Energy Law helped boost the development of wind and photovoltaic energy production. However, MSW incineration did not, at first, realize the

potential of the law, until the first amendments were made to the legislation (Zheng et al. 2014). Table 1 lists the policies that encourage the development of WTE in China.

Table 1 Policies encouraging WTE projects in China

No.	Time	Policy File Name	Abstract
1	May 1997	Temporary Regulations on the Basic Construction Projects of New Energy	Specific provisions on construction projects of new energy
2	1998	Notification of approval of new energy construction projects	Includes waste to energy in new energy, and provides a lot of preferential policies to support waste to energy
3	Jan. 1999	Notification from the Planning Commission and the Ministry of Science and technology on further supporting the development of renewable energy	gives clear norms on the aspects of project setting up, financial support, grid combination preferential and pricing method, to accelerate the development of renewable energy **priority of basic construction loans** 2% financial discount for renewable energy project loans **Acquisition of all power** the power grid would share the part that is higher than the average price
4	May. 2000	Municipal solid waste disposal and pollution control technology policy	Specified garbage disposal technology and pollution treatment technology in detail.
5	Sep. 2002	Opinions on promoting the industrialization of urban sewage and garbage treatment	1) Guarantee the operating expenses and investment payback, achieve market-oriented operation of waste collection, transportation, treatment, and recycling 2) For investment in urban sewage and garbage disposal facilities, the project capital should not be less than 20% of the total investment, and operating period not more than 30 years3) Government gives necessary policy support to municipal solid waste treatment enterprises and projects constructions, including discounted power supply for waste treatment; allocation of project construction land for new urban garbage treatment facilities 4) **operating cost compensation policy** Governments should compensate the cost of the construction of waste collection and transportation facilities and garbage disposal fees

6	2002	Notification on the implementation of the municipal solid waste disposal charging system to promote the industrialization of garbage disposal	For waste treatment facilities that are in the construction for supplement waste treatment capacity, with the approval of the city government, household garbage treatment fee is allowed to support the construction. But the construction must complete and operation within three years.
7	Jul. 2004	Decision of the State Council on the reform of investment system	Allowing accesses for social capital to enter the infrastructure, public utilities and other industries and fields within laws and regulations permission.
8	Mar. 2004	No. 126th Document from the Ministry of Construction of the people's Republic of China	Defined franchise period no more than 30 years
9	2005	Industrial structure adjustment Guidance Catalogue	Government supports the Reduction, Recycling, Harmless Treatment and Comprehensive Utilization of Urban Garbage and Other Solid Waste Project
10	2005	People's Republic of China Law of Renewable Energy	1) the nation encourages and supports power generation by renewable energy and its combination with the power grid 2) enterprises on the power grid should sign contracts with those renewable energy power generation companies have legally obtained administrative license or submitted for the record, provide easy accesses to grid combination, and acquire their full generated power 3) Power price should be decided according to local conditions based on economic and reasonable principle, and be published.
11	2006	Trial management of renewable energy power prices and cost sharing	1) the subsidy price standard is 0.1 dollar per kilowatt-hour (equivalent to 0.65 yuan). Power generation projects enjoy the subsidy for 15 years from the date of production at the price of 0.25yuan/kWh 2) the mixed fuel power generation projects consume conventional energy of more than 20% shall be deemed as conventional energy power generation projects and don't enjoy the subsidies
12	Jan. 2006	Regulations on the Administration of renewable energy power generation	For large and medium-sized renewable energy projects, direct accesses to the power grid for hydropower, wind power and biomass power shall be invested by the power grid enterprises
13	May 2010	Notification on printing and distributing "the technical guidelines for the domestic refuse treatment."	Incineration facilities relate to less land use, rapid stabilizing, effective waste reduction, easy odor control and useful waste incineration heat.

14	Apr. 2011	Notification on Further Strengthening the work of municipal solid waste disposal	By 2015, the city garbage harmless treatment rate reaches higher than 80%. Each province builds more than one model city for garbage classification. 50% city achieves kitchen garbage classified collection. Municipal solid waste resource utilization ratio reaches 30%, and important cities plan to reach 50%. Establish improved urban household garbage disposal supervision system. Promotion for waste product recycling, waste incineration for power generation, biological treatment and other solid waste resource utilization.
15	Apr. 2012	Notification of the National garbage disposal facilities construction plan for the 12th Five-Year Plan	By 2015, the country's urban domestic waste incineration treatment facilities capacity reaches more than 35% of the total capacity of harmless treatment, of which the eastern region reaches more than 48%.

The amendments enforced purchase obligation by the national grid and the commitment was incorporated into the overall national framework of renewable energy development. The amendment included WTE into the national framework and recognizing MSW as a renewable resource for energy production. The amendment also created a renewable energy development fund, which is financed by budgetary allocations from the Central government, and a collection framework for renewable energy fees charged throughout China (Zheng et al. 2014). The establishment of a collection framework greatly improved the financing of renewable energy production, including WTE, and created a broad platform for the development of WTE in China.

5.2 Price Policies

When discussing WTE development, the environmental benefits should come before the economic benefits. Financial returns are what most investors are concerned about when considering a potential project. As a result, the Central government enacted two pricing policies, with the latest policy regarding the most important (Zheng et al. 2014). In 2006, the Central government tried to regulate the production price for WTE sector, by passing the "Trial Measures for Price Administration and Costs Sharing of Electricity Generated from

Renewable Energy." The policy looked at the current price for MSW incineration power generation and established the additional US $0.043 per kWh of electricity to be subsidized by the government (Zheng et al. 2014). However, this policy applies to projects after 2006 and will in place for fifteen years. The adoption of the trial price system promoted in a rapid development of WTE on a large scale. However, due to high cost, many WTE projects still were only making ends meet.

As a result, in 2012, the Central government adopted the "Improvement of Feed-in Tariff Policy of MSW Incineration Power Generation." The new policy looked to bolster the already existing subsidies received by the WTE industry by increasing the feed-in tariff for MSW incineration to US$ 0.11 per kWh of electricity, which is much higher than what coal-fired was receiving at US$ 0.005 kWh of electricity (Zheng et al. 2014). Along with an increase in subsidies, there were conditions put on WTE sector to boost energy production. The condition came in the form of how renewable energy price is calculated and how it is defined, regarding power generation.

To encourage the output of WTE generation as well as limit the use of traditional energy the Central government adopted a new way of calculating purchase price. First, the quantity of energy supplied by WTE (Q_1) is calculated; second, comparing Q_1 with the overall traditional power (Q_2), if Q_1 is less than 50% of Q_2, the WTE energy is regarded as traditional energy and is purchased at the price of traditional energy; if Q_1 is more than 50% of Q_2 but less than overall Q_2, the WTE energy is then regarded as renewable energy and is purchased at the price as renewable energy (Song et al. 2013). The Central government believes by implementing new price policies; it will encourage the growth of renewable energy and improve the profit for MSW incineration projects.

5.3 Tax Policies

China's WTE development have been characterized as late-starting, large-scale and rapid growth (Zeng et al. 2013). There is a need for research into WTE technology, management, and policy, as to propyl promote the successful development of WTE in China. As a result, the Central government implemented preferential tax policies toward WTE development, and since, preferential tax policies have been the core principle of which the Central government address WTE development in China.

The "Notice of Policies regarding the Value-Added Tax on Products on Products Made through Comprehensive Utilization of Resources and Other Products," was adopted to refund value-added tax (VAT) to WTE projects on January 1, 2001 (Zheng et al. 2014). VAT is a general base consumption tax assessed on the value added to a good or a service (EY 2016). Since then, the policy has been expired, replaced with a policy that only 80% or more of the total fuel used can be refunded (Zheng et al. 2014).

In 2009, a trail program was lunch, titled "Notice on Promulgation of the Catalogue for Enterprise Income Tax Preference for Environmental Protection and Energy and Water Saving Programs." The trail program exempted WTE sector from paying income tax, for three years, as of January 1, 2010 (Zheng et al. 2014). With the adoption of preferential tax policies, WTE industry profited enormously. Again, these preferential tax policies showcased that the commitment the Chinese government have toward WTE industry.

6. MSW Management in the United States

For the longest, American cities had no organized public works for the waste collection, sewage treatment, and human waste removal. It was in the 1800s, did recurring epidemics forced efforts to improve public works for street cleaning, waste collection, sewage treatment and human waste removal. However, by the time attention turned to solid waste management, funding was not available, and thus, solid waste management

became a local responsibility, centered on local dumps. Public works in late 1800 can be seen in Figure 10.

Source: circleofblue.org

Figure 10 In the late 1800s, public works in America began. The figure above shows , in 1889, the town of Kearny, Nebraska installing sewer pipes for the town.

In the mid-1900s, MSW generation increased as a result of rising American affluence and urbanization accompanied by higher levels of consumption. As local government expanded to cope with new demand in the United States, the federal government became involved with regulation and financing for public works. In 1965, President Lyndon B. Johnson called for "better solutions to the disposal of solid waste" (Louis. 2004). The call for better solutions to the disposal of solid waste focused federal attention on the issue of solid waste.

As a result, the United States Congress passed the Solid Waste Disposal Act, as an amendment to the Clean Air Act. The Solid Waste Disposal Act was intended to do the following:

1. Oversee the implementation of solid waste management and resource recovery system.

2. Provide technical and financial assistance to states, local governments, and interstate agencies in the planning and development of these systems.
3. Accelerate and initiate research programs to develop systems, guidelines, and training for effective implementation.

However, the attempted to deal with the solid waste problem was limited to assessment of the problem. The main focus of the federal government was to improve disposal methods rather than addressing the problem as a whole.

In 1970, five years after the passage of the original Solid Waste Disposal Act, the act was amended again, this time, the amendment was to shift the focus of waste management toward recycling and energy recovery (Louis. 2004). However, the passage of the amendment, known as Resources Recovery Act, raised a strong response from the local and state levels. However, by 1975, almost all of the states had enacted some form of solid waste management laws and most had established state agencies that dealt with solid waste management. Despite, the federal and state laws, the day to day operation remained a local or municipal responsibility. Open dumps continued to operate, and the design, construction, and operation of landfills were ignored and inconsistent from state to state, leading to confusion. An example of an open dump in the United States in the present day can be seen in Figure 11.

Due to industrialization and urbanization of the 1900s, many American cities and industrial centers experienced dense, visible smog prompt the passage the Clean Air Act of 1970 (EPA). An example of the smog in American cities can be seen in Figure 12. The Clean Air Act (CAA) included specific parts to address emissions from incinerators, factories, and landfills, as well as emissions from composting facilities (Louis. 2004). Following the passage of CAA in 1970, in 1976, the Resource Conservation and Recovery Act was passed into law.

The Resource Conservation and Recovery Act (RCRA) became the definitive legislation for solid waste management as we now know today (Louis. 2004). RCRA's intention is to promote the protection of the environment and public health to conserve valuable material and recover energy. The intention of RCRA represented a significant shift in policy and approach, from the evaluate and assess to the direct implementation approach, especially when it comes to hazardous waste management.

Figure 11 Despite solid waste management legislations piles of household garbage, bags of yard waste, appliances, old barrels, used tires, and demolition debris is seen at an open dump in the present day.

Figure 12 November 1953, New York City is dimly seen through the dense smog covering much of the city.

With the passage of RCRA and CAA in the 1970s, landfill declined, while wasting incineration, recycling, and composting increased to offset the drop-in landfilling (Louis. 2004). RCRA effectively became the basic approach to solid waste management as we know it today. RCRA outlined the primary federal guidelines for state and regional governments for the proper disposal of solid waste. However, the federal guidelines and, later, federal directives stop at the planning level. As a result, most regional governments developed but did not implement regional solid waste management plans. Currently, the implementation of solid waste management plans remains, largely, a local or municipal government responsibility.

In the absence of regulation, policy or directive to implement solid waste management plans, or to coordinate solid waste management efforts, solid waste management operations remained a local and municipal responsible, occasionally involving state governments. Currently, at the local and municipal level, the focus is on establishing operational units to address solid waste in the near-term. The failure of RCRA to require more than planning stage, have returned to the contact system, where private corporations are increasingly owning and operating large scale MSW management facilities (Louis. 2004). It is estimated that some regions in America, rely primarily on the private corporation to address their solid waste management. Due to regulations from CAA and RCRA, the cost for MSW management has increased. Hence, many small municipalities are turning to private management organizations for their solid waste solutions. Major federal statutes that affect municipal solid waste management can be seen in Table 2.

Regulation	Year	Notation	MSW impact
Rivers and Harbors Act	1899		US Army Corps of Engineers controls dumping in waterways and on adjoining lands
Solid Waste Disposal Act (SWDA)	1965	PL 89–272	Focus on sanitary disposal of MSW. R&D based.
Resources Recovery Act (RRA)	1970	PL 95–512	Shifts focus to material and energy recovery. Still R&D based.
Clean Air Act (Air Quality Act) (CAA)	1970	PL 91–604	Regulates emissions from MSW treatment/disposal facilities
Resource Conservation and Recovery Act (RCRA)	1976	PL 94–580	Defines MSW, sets standards for landfills, sets guidelines for regional and state management plans
Comprehensive Environmental Response Compensation and Liability Act (CERCLA)	1980	PL 96–510	Provides for clean-up of contaminated sites with costs recovered under strict, joint and several liability to responsible parties.
Superfund Amendment and Reauthorization Act (SARA)	1986	PL 99–499	Increases funding for Superfund and strengthens EPA's power in seeking compensation settlements with PRPs.

Source: Louis. 2004

Table 2 A list of the major federal laws that affect municipal solid waste management.

7. WTE Development and Policies in the United States

7.1 WTE development in the United States

Currently, in the United States (US), the most common method of MSW management is landfilling, accounting for 64%; other methods of MSW management, including composting, recycling, biological treatment, and WTE. Composting and WTE combine only accounts for estimated 7% and recycling accounts for an estimated 28% (Psomopoulos et al. 2009). While landfills have declined over the past three decades, the individual landfills itself have been increasing in size. At current capacity, landfills can address the MSW management problems in many regions of the United States. However, in the 1990s, MSW going to landfills dropped by an estimated 11 million tons, and the net per capita discarding rate dropped from 3.19 per capita in the 1990s, to 2.32 per capita in the early 2010s (EPA 2015). The drop of discarding rate can be attributed to several factors, one of which is recycling efforts to reused materials American discard.

The first waste incineration power plant was introduced into the United States in the early 20th century. By the 1970s, the US WTE industry was rapidly expanding, which was in part due to policies that were enacted to address the 1970 energy crisis. The Public Utility Regulatory Policies Act (PURPA) was passed in 1978 to mandate the price of electricity to be "equal to the utility's avoided the cost of energy and capacity" (Williams. 2011). What

PURPA did was to off-set the cost of energy production, so that energy producers' cost of energy production is limited and revenues are maximized. As a result, WTE industry received a higher profit than they usually would. However, by the 1990s, WTE industry began to

Figure 13 Opened in 1989, the Palm Beach Renewable Energy Facility 1 is an example of waste to energy facility in the United States.

stagnate, mainly due to environmental concerns brought on by the public and the end of favorable policies toward WTE. Figure 13 shows the Palm Beach Renewable Energy Facility 1, opened in 1989, is an example of a WTE facility in the United States.

The opposition to WTE as an energy resource or as MSW management solution has been universally adopted by activists and regulators here in the United States. The opposition has been mainly based on the terrible experiences with traditional waste incinerators, which emits high levels of toxic emissions. To address the toxic emission problem, the EPA enacted regulation known as Maximum Achievable Control Technology (MACT) that required WTE facilities to install Air Pollution Control (APC) systems to control the toxic emissions from the facilities. With the enactment of MACT, the operating cost for many WTE facilities increased. On top of the increase in operating cost, the PURPA policies and many tax incentives that followed PURPA, all ended in the 1990s. The convergence of policy and environmental factors affected the profitability of many WTE facilities in the US, resulting in many facilities to be closed down.

In the 2000s, there were efforts for WTE resurgence, given the America Jobs Creation Act of 2004, that expanded the federal tax credit program for renewables. In the following year, the Energy Policy Act was passed that recognized MSW as a renewable energy source, hence, making MSW incineration projects eligible for renewable loan guarantees (Williams. 2011). Despite the recognition as a renewable energy source and eligibility for renewable loan guarantees, there is still little sign for WTE to make a comeback in the US.

7.2 WTE policies in the United States

One of the biggest misconceptions of WTE in the US is that there is no governmental policy on integrated waste management (Themelis. 2014). However, there are several policies and guidelines from the US EPA, on integrated waste management in the US. RCRA, passed in 1976, requires states to design and implement a solid waste management strategy. RCRA tasked the EPA to develop guidelines to which states can then follow and implement their MSW management plans. RCRA also banned open dumps nationwide and created a guideline for the proper treatment of hazardous waste. These guidelines required by RCRA outlined a governmental policy for states to implement an integrated waste management strategy.

Under RCRA, WTE shows a rapid growth in the 1970s and 1980s. The rapid growth of WTE sector was mainly attributed to the tax incentives that was provided by the federal government in response to the 1970 energy crisis. According to estimation, WTE projects receives the less amount of federal support when compared to another source of electricity, which is including coal (EESI. 2009). The lack of support means that WTE projects are less attractive to investors, given the large capital needed, as the risk of the project is too high for private entities. In 2009, there were efforts to make renewable energy more attractive to investors; the federal government passed the America Reinvestment and Recovery Act (ARRA). ARRA gave a tax credit to renewable energy producers for ten years, starting from

the date of service. ARRA however, only applied to renewable energy facilities built after August 2005 and not before October 2004 (EESI. 2009). The tax credit increased the production of renewable energy to an average of US$ 7.42/kWh compared to coal US$ 0.44/kWh (EESI. 2009). Which the incentives and tax credits, there is little development in US WTE sector.

In 2016, Palm Beach County built the first WTE facility in two decades (Dawid. 2015), singling a positive sign to WTE development in the US. The newly finished WTE facility in Palm Beach Country is seen in Figure 14. However, the construction of one WTE in two decades is a modest development for the WTE sector, given the size of the US and the US demand for energy.

Figure 14 The Palm Beach County Solid Waste Authority's Renewable Energy Facility 2 is a $672 million state-of-the-art waste to energy facility. The project, completed in 2015, is the first of its kind in the U.S. nearly 20 years and the most advanced and cleanest waste-to-energy power plant in North America.

7.3 Challenges facing WTE development in the United States

Looking through reports conducted by the US EPA, the US EPA identified three main reasons why MSW combustion facilities are not more common in the US. They are as follow:

1. The US EPA have concluded that regions where populations are dense, and land is limited have greater adoption of WTE compare to the US, which is mainly attributed to the limitation of available spaces.
2. The US EPA have also concluded that a strong factor in slow WTE development in the US is due to public opposition to MSW incineration facilities. Due to a negative experience with unregulated air emissions, incineration facilities have gained a reputation as high polluters. There is also the factor of many communities do not want the increased traffic from trucks handling waste.
3. The US EPA lastly concluded that the upfront capital needed to construct an MSW combustion facility is significant and economic benefits takes years to be fully realized. Large MSW combustion facility cost at US$ 100 million to construct according to EPA estimates, and larger facilities may cost double or triple as much.

The EPA conclusion is correct as to the three factors that have contributed to the lack of development in the WTE industry. However, after analysis, a fourth factor should be added to the factors that contributed to the lack of development for America WTE industry; the lack of a federal plan and approach for the development of WTE in the US. Without a clear and consist target and goal, the WTE sector in the US does not have the drive to further develop itself. As financial and economic factors are against expanding the industry, mainly due to large capital needed and slow returns on investment; there is no incentive to for the industry to develop, resulting in the decline and stagnation we see today.

8. Analysis of Waste Management Policies in China and United States

Government policies play a major role in supporting the development of the waste management and the WTE sectors. In China, there are several government policies designed

to support the WTE industry to address the "waste siege" experienced by many cities. In America, government policies are designed to help the US move away from dependency on fossil fuels and focus on renewable energy production than on addressing any waste problem. The different drivers of policy have drastically shifted the policies of both countries.

In China, WTE is seen as a solution to the growing MSW problem due to its growing population. Whereas in the US, WTE is seen is a renewable energy source that is unlike by Both the public and by politicians. As a result, policies in China and the US have similar characters but drastically different motives and results.

China's WTE development has outpaced the US, leaving the US to catch up. China's successful WTE development can be attributed to the efforts of a strategic nationwide approach that can be broken into two main parts;

1. Structured approach by using market tools to eliminate financial risk associated with WTE development, making the path clear for private investors and firms. The Chinese government has preferred using the BOT structure when it comes to financing WTE projects, as it allows financial risk to be shared among parties.
2. Planned approach with targets set by the Chinese central government for WTE development and amount allocated to WTE growth. The planned approach is associated with China's Five Year Economic Plan. China's Five Year Economic Plan, illustrate China's development path and goals for the next five years. WTE is recognized by the Central government as an integral part of growth, both economically and socially.

The planned approach is critical to WTE development in China, which is due to a combination of favorable tax policies, tax exemptions, loan guarantees, and favorable pricing on energy production.

US's WTE development peaked in the 1980s and 1990s, where most of its currently WTE facilities were built (Hauck et al. 2011). Time since the 1990s, there has not been much WTE development in the US. The reason for lack of WTE development can attribute to the abundance of cheap landfills, opposition from state officials who fear WTE could undercut recycling programs and a negative public perception in the US (Rosenthal. 2010). As a result, WTE regulation, legislation, and policy, on the federal level, have reminded relatively unchanged for more than 20 years. The exception came in 2007, when the Energy Independence and Security Act was passed, recognizing MSW as a renewable fuel source (EESI. 2009). Again, in 2009 when the American Reinvestment and Recovery Act was passed which provided production tax credit to renewable energy production (EESI. 2009). According to Professor Nickolas J. Themelis, the Director of the Earth and Environmental Engineering Center at Columbia University, "America's resistance to constructing new [WTE] plants was economically and environmentally irresponsible." (Rosenthal. 2010).

Compared to the US, China publishes new WTE development targets and goals every five years. New targets and goals from the Central government not only push forward the WTE industry by creating competition and innovation but also shows the Central government commitment to the development of WTE. In the US, there is no national target for WTE development or any goal set forth by the federal government. As a result, WTE development in the US has slowed and stagnated over last decade, while developing countries like China have outpaced the US, constructing more WTE facilities than the US have in the last two decades.

9. Conclusions

Municipal solid waste disposal is an increasing issue worldwide. As landfills are still viewed as the best option for developing nations whereas, in developed nations, they employ more advance methods for MSW disposal. The Chinese government recognized

that WTE development is not only is the best option for the disposal of MSW but also associated with the positive economic development of the country. As a result, the Chinese government has employed several policies aiming to encourage WTE development. The US government, however, does not recognize WTE development as the best option for disposal of MSW, it has left the decision to individual States to decide what is best for their jurisdiction. As a result, American WTE development has been in a state of stagnation and decline. With growing population and increasing demand for land, resource, and energy, MSW generation looks to continue to increase over the next decade. As economic factors and social factors shift the available of essential resource, WTE will eventually become the most economically viable option for MSW disposal. For WTE sector to grow in the US, it is recommended that US federal government adopt policies stated within this report, and use China's WTE development model as a baseline for what can be accomplished here in the US.

10. Recommendations

Based on analysis conducted in this paper, there are three recommendations for the US to help restart the development of WTE in the US:

1. The United States should adopt federal legislation that would reduce and limit the production of waste and reduce the amount of MSW being disposed at landfills. The comprehensive strategy can be modeled after the European Union's (EU) directives on limiting landfills and reduction of waste. A directive is a legislative act that sets out a goal that all EU countries must achieve. However, it is up to the individual countries to devise their methods on how to achieve the directive (europa.edu). For example, in 1999, the EU passed the EU Landfill Directive (1999/31/EC), which required a progressive reduction of MSW to 75% of the 1995 disposal level by 2010 and 35% reduction by 2020 (Chang et al. 2010). The

result was some different solid waste management programs being adopted. There was the Pay-Per-Bag scheme in Belgium and Italy; a plastic bag levy in Ireland; a weight based charging scheme in Denmark and Sweden; and many other MSW management schemes throughout the EU. Another example is the European Council Directive (91/156/EC) that urges EU member states to "take appropriate measures to encourage the prevention and reduction of waste production and its harmfulness" (Chang et al. 2010). The directives left to implement to individual EU countries to determine which method is best to achieve set targets and goals. The US federal government should follow by passing regulations that sets targets and goals for WTE development and MSW management.

2. The United States should adopt an approach to that would reduce the financial risk associated with WTE projects, this would great encourage investment and create an economic incentive for WTE development in the US. Upfront capital needed to construct an MSW combustion facility is significant and economic benefits takes years to be fully realized. Based on the Chinese financing model for WTE projects, the US should adopt the same model. When local and municipal share the economic burden along with private investors, it signals to investors that the government is both committed and confident in the project. By adopting the BOT structure of financing, the local government and state government aren't carrying the financial risk by themselves, but rather shared equally among partners.
3. Along with adopting a national target and goal for WTE development, the US federal government should strengthen the renewable energy tax credit and adopt a favorable tax policy that increases the incentives for renewable energy development, including WTE development.

11. References

Castaldi, Marco J., and Nickolas J. Themelis. "The case for increasing the global capacity for waste to energy (WTE)." Waste and Biomass Valorization 1.1 (2010): 91-105.

Chang, Shoou-Yuh, Wanchi Huang, and Shu-Liang Liaw. "Municipal Solid Waste Management: A Comparison between the US and Other Countries." Journal of Solid Waste Technology & Management 36.3 (2010).

Chen, Xudong, Yong Geng, and Tsuyoshi Fujita. "An overview of municipal solid waste management in China." Waste management 30.4 (2010): 716-724.

Cheng, Hefa, and Yuanan Hu. "Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China." Bioresource technology 101.11 (2010): 3816-3824.

Dong, Yani. Development of Waste-To-Energy in China; and Case Study of the Guangzhou Likeng WTE plant. Diss. Department of Earth and Environmental Engineering Columbia University December 2011 Research sponsored by Earth Engineering Center, Columbia University, 2011.

Ernst & Young (EY). "China VAT reform: Are you ready for the last run?" http://www.ey.com/Publication/vwLUAssets/EY-china-vat-reform-are-you-ready-for-the-last-run/$FILE/EY-china-vat-reform-are-you-ready-for-the-last-run.pdf

Glover, Brian, and Justin Mattingly. "Reconsidering Municipal Solid Waste as a Renewable Energy Feedstock." Environmental and Energy Study Institute (EESI), Washington DC (2009).

Hauck, Paul L., Anthony M. LoRe, and Kevin Trytek. "Has the Time Come for More Publicly Operated WTE Facilities in the United States?." 19th Annual North American Waste-to-Energy Conference. American Society of Mechanical Engineers, 2011.

Herszenhorn, David M. "Now It's 'Nothing in My Backyard'; Just About Any Kind of Project Can Rile Homeowners." The New York Times. (2000).

Kiser, Jonathan VL. "The Status of Waste-to-Energy in the US." 13th Annual North American Waste-to-Energy Conference. American Society of Mechanical Engineers, 2005.

Li, Yun, et al. "Waste incineration industry and development policies in China." Waste Management 46 (2015): 234-241.

Louis, Garrick E. "A historical context of municipal solid waste management in the United States." Waste management & research 22.4 (2004): 306-322.

Michaels, Ted. "The 2014 ERC Directory of Waste-To-Energy Facilities." Energy Recovery Council (2014).

Psomopoulos, C. S., A. Bourka, and Nickolas J. Themelis. "Waste-to-energy: A review of the status and benefits in USA." Waste management 29.5 (2009): 1718-1724.

Qiu, Ling, Yani Dong, and Nickolas J. Themelis. "Rapid Growth of WTE in China: Current Performance and Impediments to Future Growth." 20th Annual North American Waste-to-Energy Conference. American Society of Mechanical Engineers, 2012.

Rosenthal, Elizabeth. "Europe finds clean energy in trash, but US lags." The New York Times 12 (2010).

Song, Jinbo, et al. "Risk identification for PPP waste-to-energy incineration projects in China." Energy policy 61 (2013): 953-962.

The World Bank. “China, Overview.” http://www.worldbank.org/en/country/china/overviewCLE

United States Environmental Protection Agency (EPA). “Clean Air Act Requirements and History.” https://www.epa.gov/clean-air-act-overview/clean-air-act-requirements-and-history

United States Environmental Protection Agency (EPA). “Energy recovery from the combustion of municipal solid waste.” https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

United States Environmental Protection Agency (EPA) “RCRA, Superfund & EPCRA Call Center Training Module.” https://www.epa.gov/sites/production/files/2015-09/documents/defsw.pdf (2001)

Van Haaren, Rob, Nickolas Themelis, and Nora Goldstein. "The state of garbage in America." BioCycle 51.10 (2010): 16-23.

Wang, Feng, Haitao Yin, and Shoude Li. "China’s renewable energy policy: commitments and challenges." Energy Policy 38.4 (2010): 1872-1878.

Williams, Matt, and Anna Helm. "Waste-to-energy success factors in Sweden and the United States." Analyzing the Tranferability of the Swedish Waste-to-Energy Model to the United States (2011).

Xin-gang, Zhao, et al. "Technology, cost, a performance of waste-to-energy incineration industry in China." Renewable and Sustainable Energy Reviews 55 (2016): 115-130.

Zeng, Ming, Chen Li, and Lisha Zhou. "Progress and prospective on the police system of renewable energy in China." Renewable and Sustainable Energy Reviews 20 (2013): 36-44.

Zhang, Dongliang, et al. "Waste-to-Energy in China: Key Challenges and Opportunities." Energies 8.12 (2015): 14182-14196.

Zhang, Dong Qing, Soon Keat Tan, and Richard M. Gersberg. "Municipal solid waste management in China: status, problems and challenges." Journal of Environmental Management 91.8 (2010): 1623-1633.

Zheng, Lijun, et al. "Preferential policies promote municipal solid waste (MSW) to energy in China: Current status and prospects." Renewable and Sustainable Energy Reviews 36 (2014): 135-148.