URBAN AND RURAL MUNICIPAL SOLID WASTE IN CHINA AND THE CIRCULAR ECONOMY

A BRIEF OVERVIEW AND OPPORTUNITIES GOING FORWARD

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WORLD BANK GROUP

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BACKGROUND AND ACKNOWLEDGEMENTS

This paper is intended to provide a brief, desk-based overview of the urban and rural municipal solid waste sector in China and the circular economy as it relates to municipal solid wastes. Although it contains some policy recommendations, it is not intended to be a policy document which requires further analysis and consultations with Chinese counterparts. Rather, it aims to provide a baseline of knowledge for the World Bank and its dialogue on waste management and circularity with the Government at a time when the sector in China is evolving rapidly.

The work was led by Francis Ghesquiere. The paper was prepared by Professor Liu Jianguo (Tsinghua University) and Kremena Ionkova (World Bank). The team is grateful for the inputs, comments, guidance and support received from Frank Van Woerden, Nikola Doychinov, Marcus Lee and Ning Yang.

SUMMARY

The concept of the circular economy in China was initially viewed by the Chinese as an alternative development model to respond to resource shortages and pollution challenges. Today, it is considered an important green economy measure to promote sustainable economic practices. Consequently, the legal and regulatory environment is evolving quickly with an emphasis on creating economic and financial incentives for greening and secondary resource utilization. In the field of solid waste,[1] new initiatives - such as *Zero Waste Cities* and a program to introduce separate waste collection in 46 pilot cities - are setting the stage for large-scale recycling programs with active citizen participation as well as improved utilization and treatment rates.

The process of achieving circular economy in the waste sector, however, is still at an early stage. Significant advances have been made in the transition from waste disposal to treatment through incineration and to some extent anaerobic digestion. But with regards to separation at source, despite few years of pilot programs in few major cities, results remain patchy. Recycling and utilization are not sufficiently regulated; they are decentralized with a high degree of informality and are a source of pollution. Rural and county areas lag behind urban and metropolitan areas in all indicators including for safe disposal rate, estimated to be rather low.

China's waste management practices have global impact. Given China's levels of industrialization and urbanization, it is estimated to produce more plastic than any other country, estimated at a third of the world's total; and according to some recent studies[2] may be a significant contributor to ocean plastic litter thought to be originating mostly from rural and county areas. While there is a need for more research to validate these results, advances in the circularity of municipal solid waste (MSW) will have a strongly positive impact on any plastic leakage. Post-consumer plastics are concentrated in the MSW stream, and downstream contamination of water or soils could be reversed sustainably at source by strengthening the MSW systems in place. In this regard, recent changes in institutional responsibilities, where material recycling will now be considered part of MSW management, is a significant positive development that promotes circularity.

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[1] Four major types of solid waste – municipal solid waste, industrial solid waste, hazardous waste, and agricultural waste – affect China's environmental quality and long-term sustainable development. This report discusses urban and rural municipal solid waste, which typically includes residential, institutional, commercial, street cleaning, and non-process waste from industries. In some cases, construction and demolition waste might also be included in the reporting although it can dramatically skew the generation rate, especially in times of high economic growth and related construction activity. Industrial waste such as process by-products like scrap metal, slag, and mine tailings; hazardous waste as a by-product of the manufacturing process; medical waste; and agricultural waste are not discussed here.

[2] Jenna R. Jambeck, Roland Geyer, Chris Wilcox, Theodore R. Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan, Kara Lavender Law, "Plastic Waste Inputs from Land into the Ocean," Science Magazine, February 2015.

This paper lists several opportunities for China to advance MSW policies and practices. In addition to building on lessons learned from countries with decades of experience in implementing separation at source programs, including lessons on dealing with the informal sector, China's extended responsibility systems (EPR) for different waste streams including packaging waste could be tested locally and if successful, could then be prioritized. EPR schemes could be used to introduce incentives for eco-design, create a sustainable production and consumption pattern, reduce landfilling and develop recycling and recovery channels.

China could also more comprehensively test the regional approach for service delivery especially for underserved county and rural areas. There is an opportunity to deepen urban-rural integration, enhance economies of scale, and improve efficiency through regional integration in waste service provision. This would not only improve the quality of service provision, but support financial sustainability and help offset some of the increased financial costs for circularity. Ensuring sustainable operational financing is important to provide for public-private partnerships, a stated priority of the government; sustain earlier and current investments; and permit future development of facilities.

The legacy of waste dumps, especially in rural areas, is a serious issue and needs attention. Global experience demonstrates that China's dumpsites need to be operated in a manner that protects groundwater resources as well as protects against leakage of plastic waste into rivers and the ocean. In almost all cases of brownfield site redevelopment, the costs of amelioration are higher than the amortized costs of not creating the pollution in the first place – especially for landfills which are relatively inexpensive to operate properly once they have been constructed. The closure of waste dumps will also reduce any plastic leakage into water bodies.

As international experience shows, achieving well-performing waste management systems is not easy and requires considerable effort to design and establish formal recycling channels. It also requires working with the public towards a 'social contract' where the society has endorsed and embraced the objectives of circularity and has agreed to be an active contributor and adjust its behavior. Internationally, various models to involve the civil society and establish permanent platform for dialogue with stakeholders and professional associations exist and could be explored.

Finally, reliable and near real-time data on generation, collection, recycling and disposal are the basis for decision-making, planning, and effective management of MSW. However, such data – especially from rural and county areas – is currently incomplete and not of high quality; there is also insufficient tracking of waste destinations. Waste captured through the informal sector remains largely outside official reporting and statistics. Modern, integrated, web-based waste information systems could be introduced easily and improve sector planning, management, and monitoring.

China has committed to fight against pollution and address climate change; adequate MSW management can support this agenda, since it is integral to the circular economy agenda and key to reducing greenhouse gas emissions, pollution including ocean plastic debris, and enhanced resource utilization. China's leadership on the international stage in this regard is important and sought after.

CONTENTS

URBAN AND RURAL MUNICIPAL SOLID WASTE IN CHINA

China has made very significant progress in the waste management sector over the last ten years. Waste collection is universal in urban areas, and most large cities have successfully moved away from unsanitary landfilling and are adopting advanced treatment technologies. China is in the process of improving the environmental performance of its waste incinerators and is making advances in the clean-up of legacy sites. Increased access to information and public monitoring of performance have been adopted and are encouraged. Important initiatives setting the stage for large-scale recycling and recovery programs to improve utilization and treatment rates have also been adopted and include:

- Since 2016, China has started to vigorously promote source separation of MSW, a practice of circular economy policy. Waste sorting was piloted about 20 years ago; however, it was not until 2016 when the top leadership embraced the ecological civilization principles, which gave a significant push to the development of the sector. Given the high-level political engagement, sorting and recycling are starting to progress rapidly from policy, regulation, and physical intervention ends.
- In March 2017, the National Development and Reform Commission (NDRC) and the Ministry of Housing and Urban-Rural Development (MOHURD) issued an implementation plan that required 46 cities to pioneer compulsory sorting, and this initial effort is intended for replication.
- Under the Zero Waste Cities initiative from December 2018, approximately ten cities will pilot comprehensive programs to improve management of all types of solid waste, including municipal solid waste as well as industrial, hazardous, agricultural, and construction and demolition wastes. Beyond the central level of government, lower levels of government have also started implementation of related policies and interventions. Separation at source and increased recycling are currently being undertaken by Beijing, Shanghai, Shenzhen, Ningbo, and other large cities, and will be expanded to about 200 medium-sized cities. The construction of treatment facilities for kitchen waste is also progressing rapidly across the country.
- In June 2019, nine Chinese departments and ministries, including MOHURD, issued the Notice on Fully Carrying out Domestic Waste Separation in Cities at and above the Prefecture Level on the basis of the pilot programs in 46 key cities. Separation at source into four streams is therefore planned to start in 2019 along with the development of increased capacities for handling the wet/kitchen fraction of waste and capacities for recycling.

Despite this significant progress challenges remain. These relate to the low safe disposal rate (47%) in rural areas that is thought to contribute to ocean plastic waste; not yet satisfactory results in separation at source in cities; insufficient public awareness and growing waste generation rates; and the continuing legacies of old disposal sites and dumps. In addition, waste management operations are expensive and have high marginal operating costs. Upgrading the sector further through construction of mechanical biological plants and digestors will put additional financial pressure on local budgets. The cost of service is already estimated at around 1% of disposable income - in line with the international benchmark, but leaving little room for further increases.

Given that it has been only a few years since the country fully embraced the circularity agenda, a lot remains to be done also in terms of regulation and implementation. The existing legal framework does not appear to create adequate conditions for material circularity. China captures around 16% of dry household recyclables, which does not compare with the much higher dry recycling rates of leading economies. The rest of China's recycling potential is lost and thus, replaced with virgin materials. Virgin plastics on average remain cheaper than recycled plastics, while EPR for packaging materials has not been regulated or implemented. The recycling efficiency of other municipal streams such as electronic waste with an EPR system in place is low. Going forward, the global market for recyclables is expected to become more important and exceed $50bn by 2022; it will also be increasingly better regulated resulting in cleaner, less contaminated, sorted material. This will present an industrial and market opportunity for China. The recent ban on many single-use plastic items in Europe, requirements for minimum recycled content in certain items, and higher recycling targets will influence the market for both plastic producers and recyclers, including in China, which is the largest producer, consumer, and exporter of plastics.

WASTE GENERATION, COLLECTION, AND DISPOSAL

Solid waste service levels vary across Chinese cities. As with other municipal services, waste service levels tend to decrease geographically from the eastern coastal cities to the west.

China is estimated to produce more than 400 million tons of MSW per year. With urbanization and improving living standards waste generation is expected to increase. In 2017, according to China's Statistical Yearbook, 215 million tons of MSW were collected and transported from 660 Chinese cities, up from 190 million tons in 2004, and representing about 1.1kg of waste generated per capita per day in urban area.[3] Of the 215 million tons, 210 million tons were treated and disposed of in facilities that meet Chinese national standards, with a safe disposal ratio of 97.7% *(see Figure 1 below)*. For rural areas, official statistics are scarce since services for the collection, transportation and treatment of MSW are not well established and thus, reliable data is not available. Estimates on the basis of rural population (about 600 million) and the average MSW generation rate (about 0.8kg per capita per day[4]) suggest that China's rural domestic waste generation in 2017 is about 175 million tons, of which at least 70 million tons is estimated to be illegally dumped or burnt. The safe disposal ratio may be as low as 47% for rural areas nationally.[5] A national plan that's been put forward envisages that by 2020 the rural MSW collection and disposal system will be fully present in the eastern regions of China and 90% of the villages in the central and western regions. However, challenges to implement this plan within the set timeframe remain and relate to insufficient financing, lack of facilities, and low baseline.

By 2050, global waste generation is expected to grow by 70%. The anticipated waste generation growth rate is more than double the estimated population growth rate over the same period. The increase in per capita waste generated in East Asia is expected to be around 44%.[6] In China, the increase is expected to be higher in the less developed central and western areas of the country. While the rate of growth is generally correlated with economic betterment and GDP/capita increase, some countries have managed to decouple waste generation from growth. In Japan, total municipal quantities declined after the year 2000 reflecting the development of a comprehensive policy for a resource-circulation society, including recycling regulations targeting specific products and adoption of the concept of Extended Producer Responsibility (EPR). Consequently, the amount of

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3 It should be noted that the per capita daily generation rate may be higher since content for recycling is in many cases extracted before the waste is collected and transported.

4 As reported by a national survey implemented by Chinese Academy of Environmental Sciences in 2014 (Yue Bo, et.al., Characteristics of Rural Household Waste in China, Environmental Science & Technology (in Chinese), 37(6): 129-134, 2014.).

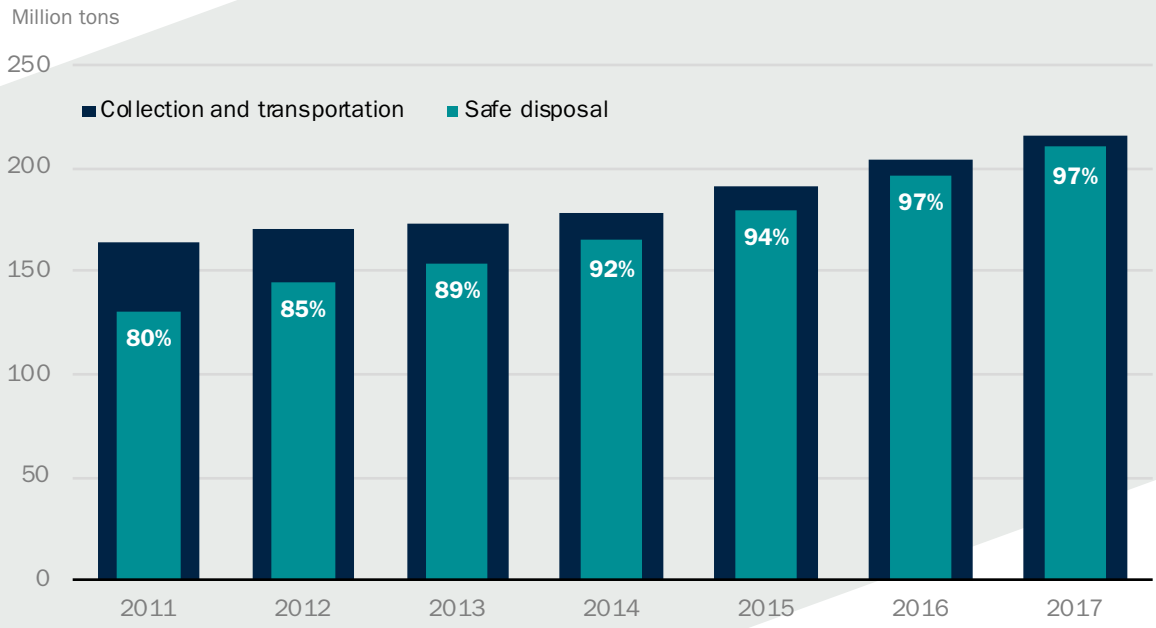
5 China Association of Urban Environmental Sanitation, *The China Municipal Waste Development Report*, October 2017.

6 World Bank, *What a Waste 2.0* (2018).

waste produced daily per capita in Japan declined from 1.18kg in 2000 to 0.94kg in 2014, a 20% reduction over 14 years. For China, a decline or increase of around 0.5kg in its per capita daily waste generation correlates to more than 200,000,000 tons of MSW per year. Given this significant difference, even a small reduction in the waste generation rate will have a very significant impact on the need to develop new facilities, requirements for investments, and operating budgets.

FIGURE 1

SAFE DISPOSAL RATIO OF MSW IN 660 CITIES IN CHINA (2011~2017)

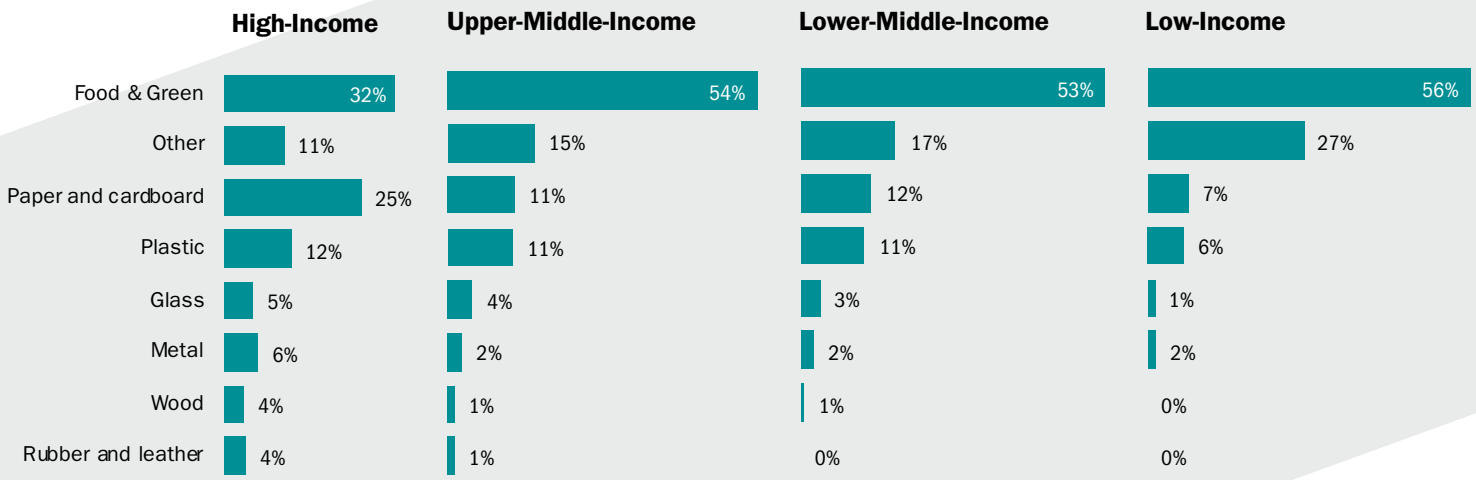


Source: National Bureau of Statistics of China, *China Statistical Yearbook*, October 2018.

Over the past few years, the composition of MSW in China has been relatively stable, of which the proportion of food waste is high at around 60%; this leads to high water content (45~65%) and high organic matter content. Globally, high-income countries have a much lower percentage of organic waste (approximately 30%). The proportion of dry recyclables in China — paper (8.9%), plastic & rubber (11.5%), metal (1.2%), glass (2.6%), and ash (11.6%) — roughly compares to waste composition in upper-middle income countries globally *(see Figure 2 below)*. Within China, MSW composition varies across regions. The more developed eastern region has a higher share of recyclables and food waste while the inner region has more ash components. The composition of the waste influences the choice of waste technology and waste treatment. The high percentage of organic waste, moisture content, and ash have a negative effect on energy recovery through incineration.

FIGURE 2

WASTE COMPOSITION GLOBALLY BY INCOME LEVEL



Source: National Bureau of Statistics of China, *China Statistical Yearbook*, October 2018.

China is transitioning from disposing most of its waste in landfills to waste treatment through incineration and composting/anaerobic digestion. Currently, landfilling and incineration remain the main waste disposal methods. There are a total of 1,013 treatment and disposal facilities with a total capacity of 680 thousand tons per day: 360 thousand tons for sanitary landfill, 300 thousand tons for incineration, and 20 thousand tons for others *(see Table 1 below)*. Notably, incineration accounts for 40% of the total, which is double the share in 2011. Incineration has been adopted as the major solution for MSW management. According to the 13th National Five-Year Plan (FYP), the capacity of MSW for disposal will be increased from 758.3 thousand tons per day to 1.1049 million tons per day, while the capacity for incineration is to be more than 50% of the MSW disposal mix in cities of China and more than 60% in cities in the east of China. Incineration as a means of MSW treatment is therefore expected to continue to grow in the next few years.

TABLE 1

COLLECTION, TRANSPORTATION AND DISPOSAL OF MSW IN CHINA (2017)

Consumption waste collected and transported (ton)	215 million
Number of facilities for MSW treatment and disposal (unit)	1013
Landfill	654
Incineration	286
Others	73
Safe disposal capacity (ton/day)	680,000
Landfill	360,000
Incineration	300,000
Others	20,000
Safe disposal amount (ton)	210,000,000
Landfill	120,000,000
Incineration	85,000,000
Others	5,000,000
Safe disposal ratio	97.7%

Source: National Bureau of Statistics of China, *China Statistical Yearbook*, October 2018.

Initially the majority of incineration plants in China were fluidized bed incinerators because of the lower capital investment required and the fact that China already possessed the technology. But with the more stringent emission standards enacted in 2014, the technical limitations of the fluidized bed reactor became obvious, and moving grate technology gradually gained prominence. Still, while there is a decreasing number of fluidized bed incinerators in China today, and therefore their capacity is declining, they are still significant in the MSW treatment mix. In addition, the high moisture content of the waste delivered to incinerators inhibits the combustion process and thus, heat utilization is impacted. The government has recognized the adverse environmental impacts that MSW incinerators cause and is in the process of establishing technical protocols including public disclosure of emission data. Capacity building projects in a few demonstration cities are ongoing and intended for replication *(see Box 1)*.

BOX 1

BEST AVAILABLE TECHNIQUES (BAT)

For waste incineration include the appropriate selection of site; waste input and control; and techniques for combustion, flue gas, solid residue and effluent treatment. Best environmental practices (BEP) for waste incineration include appropriate offsite procedures (such as overall waste management and consideration of environmental impacts of siting) and appropriate onsite procedures (such as waste inspection, proper waste handling, incinerator operation and management practices, and handling of residues). To achieve best results for environmental protection as a whole it is essential to coordinate the waste incineration process with upstream activities (e.g., waste management techniques, including, notably, waste reduction, reuse and recycling (3R)) and downstream activities (e.g., disposal of solid residues from waste incineration).

Source: Stockholm Conventi1on BAT/BEP Guidelines
(http://chm.pops.int/Implementation/BATBEP/Guidelines/tabid/187/Default.aspx)

MUNICIPAL WASTE RECYCLING

Waste recycling plays a significant role in MSW minimization in China although the data is not precisely recorded. In fact, the low level of recyclables such as paper, plastic, and metal in the MSW stream is a result of waste recycling taking place mostly through the informal sector, comprised by waste pickers, cleaners, and waste dealers not well regulated by local authorities. Recyclable wastes usually flow at source from the residents or cleaners to waste dealers, or from waste pickers to waste dealers; only very small portion of these actors participate in the formal collection and transportation system established by the government in some cities. Separation at source through the informal sector explains the high content of kitchen waste and low level of recyclables in the collected MSW. It is estimated that there are about 6 million waste pickers and dealers in China, which is the largest waste informal recycling sector in the world.[7] However its numbers have been declining due to rising living standards and falling prices for recyclable wastes in recent years.

It is estimated that China achieved a recycling rate of 15.8% in 2011 because of the informal sector.[8] In 2017, the total amount of waste recycling reached 282 million tons, comprising 52.85 million tons of paper, 6.93 million tons of plastics, 3.74 million tons of E-waste, 3.5 million tons of textiles, and 10.7 million tons of glass.[9] It should be noted, however, that only a part of the recycled waste totals were from household sources. According to a rough survey by China Resource Recycling Association, the recycling rate of MSW in 2017 (the ratio of re-utilized recyclable wastes to the sum of collected MSW and recycled waste) reached approximately 27.8% due to the contribution of the informal sector. Given that separation at source in China has not yet taken place at scale, this percentage is quite high. The recycling rate is expected to increase above its current levels as a result of the promotion of MSW source separation, since some low-value recyclables like glass, and clothes, which are not separated and collected by the informal sector, will be included in the planned recycling chains and supported with public subsidies. According to the national target for implementation of the MSW separation system, the recycling rate of MSW is to reach 35% by 2020 in the cities where mandatory separation of MSW is implemented.[10] Per the definition of waste recycling rate in China, the biological treatment of organic fractions (mainly food waste) of MSW is considered a recycling operation; therefore, it will not be difficult for these cities to realize the recycling rate target of 35%.

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7 M. Medina, "The informal recycling sector in developing countries: organizing waste pickers to enhance their impact," *PPIAF*, 2016.

8 World Bank, *What a Waste 2.0* (2018).

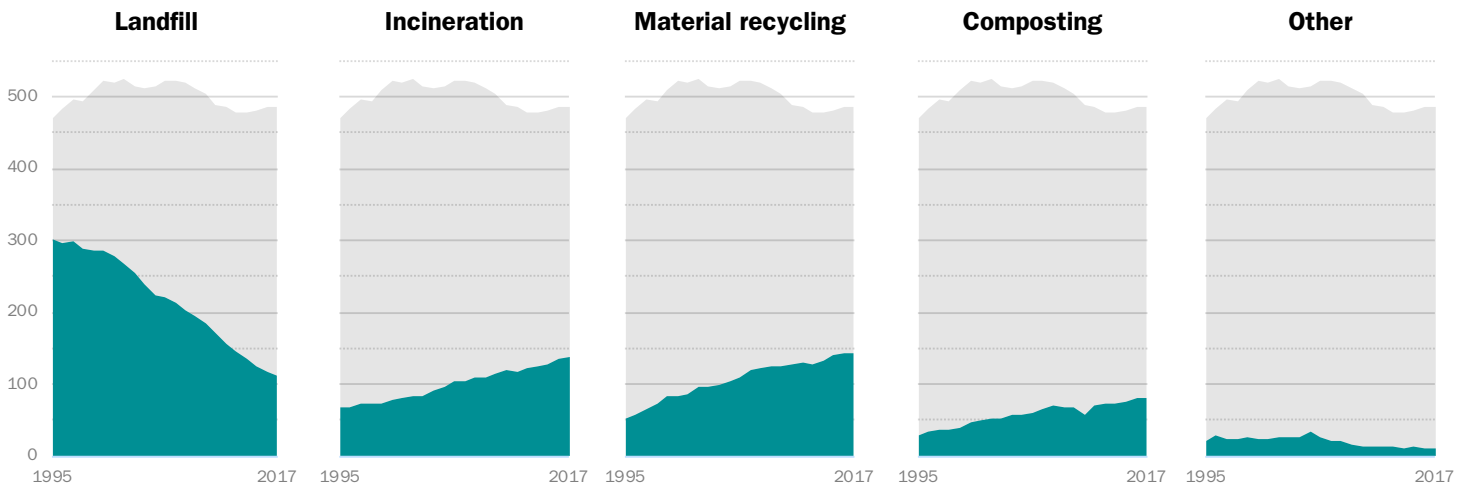
9 Ministry of Commerce of China, *Resource Recycling Industry Development Report*, June 2018.

10 NDRC and MOHURD, *Implementation Plan of MSW Separation System*, March 2017.

The legal and regulatory environment of the sector dictates its behavior. *Figure 3* presents the mix of municipal waste treatment in the countries of the European Union (EU). It shows how policies enforcing the waste hierarchy[11] principle have led to a gradual decrease in landfilling and an increase in recycling and other treatments. The performance among EU countries varies greatly; Germany, for instance, has one of the highest recycling rates (approximately 65%) and has practically eliminated landfilling. Following recent legislative changes under the European circular economy initiative, the shares of landfilling and incineration across the EU are expected to reduce steadily by 2035, and the rate of recycling is expected to increase significantly. The most notable driver of these improvements are mandatory targets, including a 65% recycling target by 2035 and a 70% recycling target for all packaging. Landfilling is considerably restricted such that by 2035 the amount of municipal waste landfilled must be reduced to 10% or less of the total amount of municipal waste generated. By comparison, the target for recycling in China is 35% of MSW by 2020. It should be noted, however, that the definition and calculation of recycling targets varies among countries.

FIGURE 3

MUNICIPAL WASTE TREATMENT IN THE EU 27 (KG/CAPITA/YEAR)



Source: Based on data from Eurostat Municipal Waste Statistics website.

[11] The *waste hierarchy* principle promotes waste prevention, reuse, recycling, and recovery, in this order, over waste disposal, which is seen as loss of economic value of waste. Moving up in the waste hierarchy implies reintroduction of resources into the economy.

The amount and value of recycled waste plastics, paper, and textiles in China are shown in *Table 2*. In 2017, there were more than 90,000 enterprises and 12 million people employed in the waste recycling industry in the country. Overall, however, the waste recycling sector - especially numerous small-scale facilities - is not well-regulated, is decentralized, and is a source of pollution. More recently, in 2018, these factors caused the government to close a large number of small-scale waste recycling facilities, especially waste plastic recycling facilities whose operations were linked to water and air pollution. Given its size and scale, the waste recycling industry should be transformed and upgraded to meet the government's new initiatives aimed at higher value-added economic development and higher standards of environmental protection.

Waste recycling in China is market-oriented, and its operations and efficiency depend on the price of recyclable wastes. In recent years, the prices of recyclable wastes fluctuated sharply in response to the price fluctuation of global primary materials as well as national policies such as the foreign waste import ban and enhanced environmental supervision.

TABLE 2

RECYCLING AMOUNT AND VALUE OF WASTE PLASTICS, PAPER AND TEXTILES IN CHINA (2017)

Variety	Recycling amount (million tons)			Recycling value (billion RMB)		
	2016	2017	Growth rate	2016	2017	Growth rate
Waste plastics	18.8	16.9	-9.9%	95.8	108.1	12.9%
Waste paper	49.6	52.9	6.5%	74.5	97.8	31.3%
Waste textiles	2.7	3.5	29.6%	0.9	1.4	62.8%

Source: Ministry of Commerce of China, *Resource Recycling Industry Development Report*, June 2018.

Food waste (from restaurants and households) is an important part of MSW in China. The annual output of restaurant food waste in China's major cities is more than 60 million tons. By 2017, 172 food waste treatment facilities had been completed with a total planned capacity of 35.4 million tons per year. Of that number, 87 facilities have been put into operation with a capacity of 18.7 million tons per year. The most prevalent (>80%) treatment process for restaurant food waste is anaerobic digestion. Household food waste treatment is expected to be the key focus of the MSW management sector in the next few years. Both anaerobic digestion and aerobic composting will be the option for household food waste treatment, and distributed small-scale composting is expected to share part of the market.

PLASTIC WASTE POLLUTION

For decades, China has been one of the world's main destinations for the recycling and disposal of solid waste, including from developed countries. As China has become the world's second largest economy, it has been gradually shifting its focus towards improving the quality of its industries and curbing practices that pollute. The desire for sustainable development and a better environment has in part motivated the ban on imports of waste for recycling in China without strict environmental control. At the same time, China's demand for raw materials for certain industries has slowed after decades of rapid growth. Finally, recycled materials from domestic wastes have grown and replaced the need for imported wastes.

In 2016, over 15 million tons of waste plastics, 16 million tons of scrap paper, and 2 million tons of discarded textile materials were exported globally, a significant portion of which went to China[12]. In July 2017, the Chinese government announced a comprehensive plan to ban the import of 24 types of solid waste in four categories, including waste plastics, unsorted scrap papers, discarded textile materials, and vanadium slags. Bans on additional types of solid waste were also issued to take effect by the end of 2018, including bans on scrap metals, scrap ships, compressed pieces of scrap automobiles, waste plastics from industrial sources, and wood waste and scrap. Since 2019, China has completely banned the import of waste plastics, and it appears that waste imports will be largely banned in their entirety after 2020.

Judging from the timing and content of the bans, China's changes to its waste import policy is an important part of its campaign for sustainable development. In the short run, the ban will likely cause a shortage of recycled materials, thus increasing prices of relevant products throughout the supply chain. Companies relying on imported waste as their primary materials will need to switch to raw materials or domestic waste. Some small businesses without diversified sources of materials thus will likely face significant challenges due to increased material costs. In the long term, banning imported waste can help stimulate recycling of domestic solid waste, thereby stimulating the growth of the domestic recycling industry. Eventually, domestic solid waste could be utilized more efficiently in China. Additionally, China might itself become an exporter of solid waste in the future, as Japan did in 1980s. More broadly, the foreign waste ban can be seen as part of China's overall effort to move itself up in the global value chain from specializing in low-end, labor- and resource-intensive manufacturing to high-end, high-value industries.

China is also the largest plastic producer in the world and has faced serious challenges in managing its own plastic waste. Globally, 400 million tons of plastic are produced every year[13], with approximately 40% utilized by the packaging industry, i.e., products for single

[12] UN Comtrade, 2018. Database. https://comtrade.un.org.
[13] UNEP (2018).

use. The growth in consumption of plastic materials is estimated at 50% over the current ten-year period to 2025. Similar trends are observed in China where the food delivery industry's consumption of plastics has been growing exponentially. Globally, only about 10% of plastic packaging is being recycled. In 2016, the EU recycled on average 30% of its plastic waste (with very significant fluctuations across countries) and has set a target of 55% for 2030 for plastic packaging. The high plastic recycling rate in OECD countries does not necessarily mean that plastic wastes are indeed recycled or that environmental controls are always followed in the recycling process. China has been the primary destination of most of the separately collected plastic waste in developed countries. In 2016, 26.15 million tons of plastic waste were recycled in China, comprising 18.8 million tons of domestic plastic waste and 7.35 million tons of imported plastic waste.[14]

In 2008 an administrative order to restrict plastic bag production and sales was put into effect in China. The order prohibited the production, sale, or use of ultra-thin plastic bags (thickness <0.025mm), while other plastic bags had to be purchased in supermarkets, department stores, and retail shops. More than ten years later, the goals defined in the order have been partly achieved. Ultra-thin plastic bags have generally disappeared from China, and a pay-for-use system for plastic bags is applied. However, the increasing consumption of plastic bags is not well controlled because of rapid economic development and expanding consumption. The NDRC called for proposals on-line from the public concerning the control of plastic wastes, and a new policy for plastic waste prevention and control is under development. The main orientation of the policy is to restrict and regulate the use of plastic packaging in e-commerce, express delivery, and take-out services. Single-use plastic commodities such as plastic straws and plastic hotel supplies are likely to be restricted. Some regions will introduce additional measures; Hainan Province, for instance, released a draft policy to completely prohibit the production, sale, and use of non-degradable disposable plastics in the province.

Global contamination from plastic waste is of recent but rapidly increasing concern; in addition to impacts on land to public health, soil contamination, and impacts on air quality, millions of tons of waste are washed into rivers and the oceans, causing serious ecological and economic impacts. Because of its longevity, ubiquity, and sheer volume, plastic debris is now emerging as a new, truly global challenge. It is estimated that some plastic products retain their original recognizable form 400 years after discharge into the ocean. Recent research, such as a 2015 article in the journal Science, has highlighted the urgency of preventing unmanaged plastic waste from reaching the ocean, a problem known as plastic-waste leakage.

A significant amount of plastic waste that ends up in the oceans is from land-based activities; it is estimated at 70-80% of the total volumes reaching the oceans. The majority of this enters the marine environment through three primary pathways: (i) riverine systems, (ii) along the coastlines, or (iii) by wind-induced transport via the atmosphere with the balance derived directly at sea.[15] As a result, marine ecosystems globally suffer an estimated US$13 billion a year in damages caused by plastic waste. APEC estimates the annual costs to

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[14] Ministry of Commerce of China, R*esource Recycling Industry Development Report*, June 2018.

[15] Kershaw, P.J., and C.M. Rochman, eds., "Sources, fate and effects of microplastics in the marine environment: part two of a global assessment," IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, Rep. Stud. GESAMP No. 93 (2016): 220.

tourism, fishing, and shipping industries to be US$1.3 billion for the East Asia region. There are additional adverse impacts on health, food chains, and jobs as well as threats to a wide range of marine life that ingests it or becomes entangled in plastic debris.[16]

Asia's river systems and waterways are considered to be major conduits for this plastic pollution. It has been estimated that more than a quarter of all global marine waste could be transported by 10 rivers, eight of them in Asia.[17] While there is a need for more research to validate the conclusions which may be overestimated as a result of the methodology followed (and are also questioned by Chinese researchers), the Yangtze River is estimated to contribute significant volumes of plastic waste deposited into the ocean by rivers each year. This reflects the fact that the catchment of the Yangtze River drains 40% of mainland China, an area roughly the same size as Western Europe or equivalent to the land area of Indonesia and with twice as many inhabitants. It should be noted that marine plastic waste discharged by each country was calculated based on the population and MSW generation of coastal regions. Since the population density is quite high and the economic scale is quite large in the coastal regions of China, the marine plastic waste calculated as discharged by China may be high and may need further verification. In the meantime, China started a Clean-up Action in the Yangtze River Basin; a large number of waste dumping sites along the river have already been cleaned up and more will be cleaned up over the next few years. In January 2019, the Ministry of Environment and Ecology (MEE) and NDRC jointly issued the Plan of Action for Yangtze River Conservation and Restoration, and waste clean-up was listed as an important task. The enforcement of the new Environmental Protection Law, the regular environmental supervision from central government and local government on urban-rural solid waste management; and the ban on foreign plastic waste imports further lower the risk of plastic waste discharging into the rivers and the seas.

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[16] Frias, J. P. G. L., and Roisin Nash, "Microplastics: Finding a consensus on the definition," *Marine Pollution Bulletin* 138 (2019): 145-147.

[17] Schmidt, et al., "Export of Plastic Debris by Rivers into the Sea," *Environmental Science & Technology*, Vol. 51, No. 21, November 7, 2017.

LEGISLATIVE PROGRESS TOWARDS THE CIRCULAR ECONOMY

China has embraced the principle of circularity as a green development measure to promote sustainable economic practices. It is clearly outlined and promoted in the 12th and 13th Five-Year Plans with important emphasis on reducing pollution and emissions to achieve better environmental governance. Key laws in this area are discussed below.

The *Circular Economy Law* adopted in 2009 aimed to decouple economic growth from resource consumption and pollution. It introduced mechanisms to control the total quantities of resource consumption and pollution discharge. It also introduced the concept of extended producer responsibility (EPR) and shifted the approach from waste treatment to the idea of a circular loop for material flows. An index system was introduced covering the aspects of resource productivity, waste discharge, the comprehensive utilization of resources, and waste treatment. The resource productivity or material intensity index refers to GDP produced per unit of resource; the discharge of waste index reflects waste generation per capita; the comprehensive utilization of resources index concerns utilization of wastes; and the waste treatment index describes the treatment of waste. However, revisions to the law are being planned since it is not considered sufficient for creating conditions for circularity. Future amendments are expected to focus on the management of resource conservation and comprehensive resource utilization.

The newly-revised *Environmental Protection Law* has been in place since early 2015. It is considered the most stringent environmental protection law ever adopted by the country. It puts forward the principle of 'responsibility for damage;' defines the 'redline' of ecological protection; defines the joint prevention and treatment system for key regions and river basins; endows the environmental protection department with greater powers and responsibilities; and enhances deterrence with a daily penalty system. The environmental public interest litigation system is also stipulated in the law to improve the public awareness of supervision and participation. On January 1, 2018, the new *Environmental Protection Tax Law* came into effect. The law stipulates that an environmental protection tax should be used to replace the sewage discharge fee; defines air pollutants, water pollutants, solid waste, and noise as taxable pollutants; and clearly defines the object of payment and the amount of tax.

The current Law on Prevention and Control of Environmental Pollution by Solid Waste (*Solid Waste Law*) was issued in 2005. In 2018, the Ministry of Ecology and Environment released a draft amendment to revise the law which seeks to reconcile the provisions on solid waste management with other existing environmental programs and to strengthen waste control

enforcement. It emphasizes the establishment of a permit system for solid waste discharge, the disclosure of information and public participation, and the prohibition of the import of solid waste. Specifically, the draft envisages that citizen groups would be permitted to launch environmental public interest litigation in the solid waste domain and authorizes environmental authorities to seal or seize facilities using solid waste practices that may cause environmental harm. It requires companies that generate, use, or dispose of solid waste to disclose information relating to their activities and to accept oversight by the public.

The draft amendment also requires the establishment of an EPR system for electronic waste "as well as other products," adds a requirement for separation system for MSW, and puts into law the principle of accounting according to producer. The proposed amendment envisions a catalogue management system for products subject to mandatory recycling. Manufacturers, sellers, and importers are required to recycle the products included in the management catalogue. In addition, non-degradable thin film coverings and commodity packaging are prohibited according to the draft law. The draft law addresses the idea of economic incentives for MSW separation. In addition, regulations on the management of food waste have been added. In the field of hazardous waste management, there are new requirements for increasing regional cooperation and improving the management system of hazardous waste.

EPR for packaging waste.

While packaging waste is a rapidly-increasing waste stream, there are no regulations specifically concerned with packaging waste management in China. The externalization of treatment costs leads to excessive packaging and rapid growth of packaging waste, especially from the e-commerce, express delivery, and take-out service industries. International experience shows that regulation specifically targeting packaging waste is advisable. It could be tested in China and, if successful, it could become the central policy tool to influence the use of appropriate packaging, green packaging, and recyclable packaging, and to establish standardized collection, treatment, and recycling systems *(see Box 2 on EPR in Europe)*.

EPR for e-waste.

According to research by Tsinghua University, 11.64 million tons of E-waste (comprising 14 E-waste types listed in *the catalogue of wasted electrical and electronic products treatment*) were produced in China in 2017, with 78% of the waste from TVs, refrigerators, air conditioners, washing machines, and computers.[18] Although the volume of E-waste is much less than the total volume of MSW, the environmental problems caused by illegal disposal are tangible. At the same time, E-waste contains a large number of rare and precious metals, known as urban mines, with high recycling values. At present, the recycling efficiency of E-waste is low, and the recycling channels are very dispersed: indeed, more than half of the E-waste processing falls within small, irregular workshops. These disassembly workshops utilize inadequate technology; they are not only incapable of properly dealing with the complex structure and various types of E-waste, but they also cause secondary pollution as well as the loss of useful resources.

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[18] Zeng Xianlai, et al., "Uncovering the Recycling Potential of 'New' WEEE in China," *Environmental Science & Technology* 50 (3) (2016): 1347-1358.

The establishment of formal recycling channels is considered the most pressing issue for E-waste recovery. Due to the lack of public awareness about environmental issues and the weak competitiveness of the formal recycling system, informal recycling enterprises occupy the majority of the market share of E-waste recycling. The formal disassembly enterprises have advanced production lines, but the supply of goods is constrained. Another reason it is difficult to establish formal channels is that the scale of the enterprises lags behind that of developed countries. There are 109 formal E-waste recycling enterprises in China, mainly distributed in the eastern part of the country, and their processing capacity remains insufficient. In 2012, *Management measures for the collection and use of funds for treatment of waste electrical and electronic products*, a prototype of EPR, was promulgated. In addition, both the subsidy standard for different E-wastes and the scope of the E-wastes were adjusted in 2015 and 2016. The subsidy system was established to ensure the operation of formal recycling enterprises; however, there is currently a serious funding deficit and formal enterprises are experiencing financial difficulties.

BOX 2

TYPES OF EXTENDED PRODUCER RESPONSIBILITY (EPR) SCHEMES IN EUROPE

The European Union (EU) has integrated extended producer responsibility (EPR) principles into its policies for more than 25 years. EU countries have adopted different EPR schemes with various financial and technical configurations which are continually being developed and adjusted. EU legislation governs packaging, end-of-life vehicles, batteries, and electronic equipment.

Under a *collective scheme*, individual legal obligations are outsourced to umbrella-type organizations, such as producer responsibility organizations (PROs). PROs are created to support producers in the handling of the technical, financial, and policy aspects of managing product life cycles. PROs receive financial contributions from industry and members and use these funds to recycle goods, manage data, conduct operations, facilitate contracting, and communicate with stakeholders.

Under an *individual scheme*, producers manage waste directly, such as through a take-back program in which consumers can return used materials to the distributor.

INSTITUTIONAL CHALLENGES

Several ministries have responsibility for MSW management in China. At the national level, MSW management is under the purview of MOHURD, while material recycling management is under the purview of the Ministry of Commerce (MOC). At the same time, the development of the circular economy and policies regarding it are administered by NDRC, while environmental monitoring and supervision of all waste management and material recycling facilities is the responsibility of MEE. The data for MSW generation, collection, and disposal is recorded and released by MOHURD, while the data for recyclable waste collection and recycling is recorded and released by MOC.

Generally speaking, since MSW management is considered as both a livelihood and public welfare issue, it is government-led. Meanwhile, since material recycling is considered to best guided by the market, it is market-oriented. At the municipal level, the Urban Management Bureau (UMB) or Bureau of Housing and Urban-Rural Development are responsible for MSW collection, transportation, and disposal. UMB is also responsible for construction and operation of disposal facilities, including landfills and incineration plants. However, material recycling facilities are financed, constructed and operated by industries, and the role of the local Bureau of Commerce is simply to grant the industries permits. Therefore, the scope of the MSW system in China is not equivalent to that of developed countries; most recyclable components are excluded and handled by a parallel waste recycling system.

Combining or merging the two parallel systems – one for MSW management and the other for material recycling – is a significant trend of institutional reform used to promote MSW separate collection. In fact, the Beijing Municipal Commission of Urban Management was reorganized recently, and the responsibility for material recycling was shifted from the Beijing Bureau of Commerce to the Municipal Commission. It is expected that the material recycling industry, including both the informal and formal sectors, will be regulated and upgraded to meet the stringent requirements for environmental protection. In the future, the two systems will be merged into one system; material recycling will be considered to be a part of MSW management, and a certain subsidy will be provided by the government to material recycling industries to optimize the whole MSW management system.

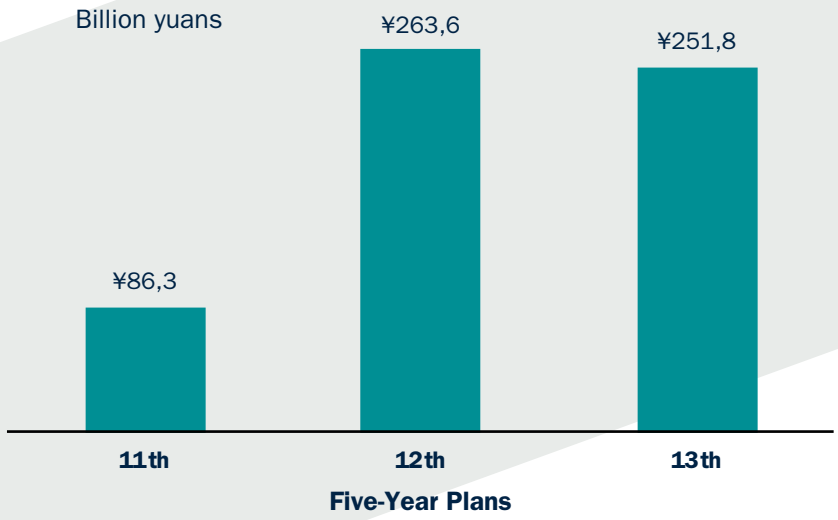
As a country which still has different levels of economic and social development between its urban and rural regions, China likewise has differences in MSW management between its urban and rural regions. In the past, government-funded MSW collection, transportation, and disposal services were focused on urban regions whereas the service and facilities for rural MSW remained insufficient. In the relatively developed regions such as Beijing, Shangdong, Yangtze River Delta, and Pearl (Zhujiang) River Delta, an urban-rural integration model, i.e., “collection by village, transportation by town, disposal by city” has been established. Although location-centered management (where MSW is treated within the local territory) is the generally accepted approach for MSW management, in some plain regions China tried regional integration where one facility is shared by several small and neighbor cities. The objective of the regional approach was to build larger MSW facilities with scaled benefits. However, it did not succeed due to compensation and payment mechanism difficulties.

FINANCING CHALLENGES

China's plan for investment in the construction of safe disposal of MSW during the 11th, 12th, and 13th Five-Year Plan periods is shown in *Figure 4*. Based on the scale of construction and level of investment for the 12th FYP, in terms of annual disposal capacity, the cost of collection and transportation is 210 yuan/ton ($31/ton).
The operating cost of MSW disposal facilities varies greatly in China, and the region, scale, process, and standards are all important influencing factors. On average, the operating cost of landfilling is about 80~120 yuan/ton ($12-18/ton), and that of incineration is about 300~500 yuan/ton ($45-74/ton).[19]

FIGURE 4

CHINA'S PLAN FOR INVESTMENT IN MSW TREATMENT DURING THE 11TH - 13TH FIVE-YEAR PLANS



Source: State Council of China, *Plan for the construction of MSW safe disposal facilities in the 11th/12th/13th FYP*.

[19] Estimation based on interviews.

At present, MSW incineration technology has gradually developed into the main mode of MSW disposal in China. Environmental protection policies and the state's advocacy of public-private partnerships have created opportunities for the MSW incineration industry. Leading enterprises have extended the industrial chain through mergers and acquisitions, seized market share, and entered the subdivision area, which seems to be the trend for future development of MSW disposal in China. The government has issued a large number of policies to encourage the construction of MSW incineration power plants. The contracted companies were paid by local governments based on the amounts of received MSW, and paid by the state grid based on electricity output with a higher purchase price.[20] MSW incineration plants and other plants for centralized treatment of MSW may also be exempted from the environmental protection tax if the pollutants discharged by them do not exceed national and local standards. At the same time, these developments have put pressures on local finances although the total cost of MSW disposal should be expressed by the treatment fee.

Beyond investment costs, waste management operations are expensive and have high marginal operating costs. *Tables 3 and 4* below show the typical costs and user fees globally per income level. Internationally, the accepted affordability benchmark is around 1% of disposable income. In China today, households are typically not charged for waste services and costs are recuperated from general revenue and subsidies. However, when comparing the cost of service as a percentage of disposable income, the costs are similar to the international benchmark of around 1% of disposable income.[21]

In 2018, NDRC proposed to change the charging mechanism for MSW discharges. The goal was to establish a charge system for MSW treatment in cities and towns by 2020 and at the same time explore the establishment of a charge system for rural solid waste treatment. Presently, the new system is not yet clarified, so the standards, means, and allocation of the charges are as yet unknown.

The new treatment facilities that are currently being built – mechanical-biological treatment (MBT) and anaerobic digestors – are expected to increase the financial cost of the sector. On the other hand, incentives to generate less waste and increase efficiency of operations may offer options for cost reductions. Economies of scale may also be achieved through better cooperation between smaller jurisdictions for collection as well as treatment and disposal where several jurisdictions share common facilities – the so-called 'regional approach' – which is not practiced currently in China. The approach could be promoted through incentives set by a higher level of government. In addition to improving the utilization rate of equipment and utilities, the regional approach could improve urban-rural integration towards better service provision and capacity enhancement in semi-urban and rural areas.

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[20] Under 280 kwh/t MSW, payment was at the price of 0.25 RMB plus local purchasing price for coal-fired power plants per kwh of electricity, and for the extra electricity above 280kwh/t MSW, payment was at the local purchasing price for coal-fired power plants per kwh of electricity.

[21] For purposes of this calculation, disposable income per capita between the equivalent of $1,500 – $5,000 was used for rural and urban areas, respectively.

TABLE 3

TYPICAL WASTE MANAGEMENT COSTS BY DISPOSAL TYPE

	(US$/tonne)			
	Low-income Countries	**Lower-Middle Income Countries**	**Upper-Middle Income Countries**	**High-Income Countries**
Collection & Transfer	20-50	30-75	50-100	90-200
Controlled Landfill to Sanitary Landfill	10-20	15-40	25-65	40-100
Open dumping	2-8	3-10	N/A	N/A
Recycling	0-25	5-30	5-50	30-80
Composting	5-30	10-40	20-75	35-90

Source: World Bank, *What a Waste 2.0* (2018).

TABLE 4

WASTE MANAGEMENT USER FEES BY REGION

Region	**Average user dee in selected cities (US$/year, as reported in data)**
East Asia and Pacific	46
Europe and Central Asia	83
Latin America and the Caribbean	80
Middle East and North Africa	55
South Asia	34
Sub-Saharan Africa	10-40 (based on World Bank estimates)

Source: World Bank, *What a Waste 2.0* (2018).

OPPORTUNITIES GOING FORWARD

Some opportunities to advance the implementation of the recent initiative towards circularity in municipal solid waste management, namely the Zero Waste Cities initiative, are listed below. Above all, to allow further utilization of resources, recycling, and recovery, the waste has to be successfully separated at source by the waste generators requiring, among other changes, enhanced public participation and a change in behavior. Second, EPR is a possible mechanism to aid the separation at source for different waste streams as well as EPR as means to deal with packaging waste, which has not yet been implemented in China. EPR systems rely on good data, data flow, and reporting systems which are lagging behind in rural China where the informal sector dominates. Third, since circularity of resources and recycling will increase the financial cost of the sector, cost recovery becomes essential to sustain operational financing. Fourth, in less developed county and rural areas, opportunities for further urban-rural integration exist at the level of service provision. This will facilitate the process of replicating models from Chinese cities into county areas including models for improved utilization of wastes. Finally, GHG emission reduction, plastic waste pollution, and groundwater pollution are all impacted by waste management practices and fall within China's agenda to fight against pollution and climate change. These areas are each briefly discussed below.

Separation at source of MSW

Separation at source of MSW is yet to be rolled out successfully in China. Even though several large cities have attempted to introduce it widely, the results so far are less than satisfactory. Given China's high level commitment to the circularity principle, legislative changes, and ambition to green its economy, there are tremendous opportunities to develop and expand recycling activities through separation at source and sorting of municipal waste. The expectation that in the future material recycling will become part of MSW management will make this process much easier. Lessons from OECD countries that have had separation at source for years show that successful separation and sorting is very sensitive to a number of factors and system design features. The section below lists some of the lessons learned from a review of 28 European countries with separation of source systems – which could be studied further for possible replication in Chinese cities. Introducing separation at source systems also offers an opportunity to begin streamlining the informal recycling channels.

China started to promote source separation of MSW in eight demonstration cities in 2000, but the results were thus far not satisfactory. After President Xi Jinping spoke about promoting MSW separation systems in December 2016, the progress of MSW separation was greatly accelerated. In March 2017, NDRC and the Ministry of Housing

and Urban-Rural Development (MOHURD) issued the implementation plan for MSW separation systems and 46 cities were selected as demonstration cities to promote mandatory MSW separation. A MSW separation system is defined as a complete sequential chain involving separate placement, separate collection, separate transportation, and separate treatment. MSW is required to be separated into four basic types – hazardous waste, recyclables, putrescible waste, and other waste. Hazardous waste must be separated at source and cities can select either recyclables or putrescible waste as the other type that must be separated at source.

By the end of 2018, all 46 cities issued local implementation plans for MSW separation systems, and 28 cities finalized legislation specifically on MSW management. Xiamen, Shenzhen, Ningbo, and Shanghai led the demonstration cities with their strong leadership, large financial input, relatively advanced facilities, and higher public awareness. The most recent local regulation for MSW separation management was issued on February 2019 by the Shanghai Municipality, and an amendment to the regulation for MSW management in Beijing (issued in 2011) is under consideration now. However, even in these leading cities, less than 20% of their residents always separate the MSW at source as required by the government, and the separated waste contains high levels of impurities. The enforcement of the laws and regulations is weak despite relevant legislation and institutions.

The Zero Waste City initiative further enhances the concept of source separation of municipal waste and aims to expand the circularity objective to include industrial, agricultural, construction, and hazardous wastes. It aims to identify 10 cities to pilot develop comprehensive implementation plans that may be further replicated.

While there are a wide variety of ways to collect different waste streams based on geography, size, population, waste composition, etc., some best practices and lessons learned from the multi-year experience of European countries with separate collection are listed below:[22]

- Countries that have introduced mandatory separate collection of certain municipal waste fractions have high municipal waste recycling levels.
- It is crucial to both extend the technical infrastructure as well as to inform and motivate the users of the collection systems.
- The percentage of recyclable materials increases when municipalities introduce door-to-door collection systems. Door-to-door collection systems provide the highest recycling rates and the best quality of recyclables. Collection costs for such schemes are higher than alternatives, but collection rates and revenues are also usually higher, and the resultant rejection rates and treatment costs lower.
- Bring systems with drop-off containers often struggle to encourage the inhabitants to separate their waste and result in a larger percentage of impurities. However, bring systems are a reasonable solution for certain fractions such as glass.
- Co-mingled collection of recyclables is practiced in several European countries and tends to result in lower costs. Two-stream co-mingled collection (e.g., plastics and

[22] BIPRO, *Assessment of separate collection schemes in the 28 capitals of the EU* (2015).

metals) is a reasonable way to reduce costs and maintain good material quality. Mixing several fractions together, however, can result in a higher incidence of cross contamination, and the quality of recyclables tends to be lower and rejection rates higher.

- When separate collection of biodegradables was included in the door-to-door system, the overall sorting of dry recyclables (and other fractions) increased.
- Civic amenity sites have the potential to improve the overall recycling rate, on the condition that they are convenient to use (close by and with suitable opening hours) and that the number of sorted fractions is significant.
- The trend in recycled material markets is likely to be towards requiring higher quality materials.

All of these lessons could be reviewed in more depth against the needs of Chinese cities to inform the design of their separate collection systems.

Extended Producer Responsibility

An EPR system is an economically effective means for MSW management. However, designing and implementing an EPR system can be a lengthy and challenging process. China has embraced the concept of EPR for certain waste streams, but this is in a very early stage of development. Successful EPR schemes allow for the introduction of incentives for eco-design, create a sustainable production and consumption policy through encouraging separate waste collection and recycling, reduce landfilling, and develop recycling and recovery channels.

Other benefits of EPR systems include increased collection and recycling rates; reductions in public spending on waste management by shifting responsibility from local public authorities onto producers (and ultimately to consumers); reduction in overall waste management costs through optimized cost efficiency of collection and recycling operations; and implementing design for environment (DfE) innovations which increase the durability and potential for reuse of products. In addition to these benefits, EPR programs are also believed to generate a range of broader benefits, including increased technological and organizational innovation; a diversification of sources of material supply and therefore a contribution to resource security; and a better organization of supply chains through the emergence of more international operators in the recycling sector *(see Box 3)*.

The EU experience reveals that factors such as population density, citizen awareness, local laws, the informal sector, and legal frameworks affect EPR performance. Designing and implementing an EPR scheme involves a range of technical, financial, institutional, and legal considerations. A recent analysis of EU EPR schemes identified four key pillars of success:

1. *Successful distribution* of financial and operational responsibilities across stakeholders;
2. *Recovery* of true costs;
3. *Fair competition* between PROs and operators;
4. *Transparency* by EPR schemes in reporting and transparency by the government in monitoring.

In 2016, the State Council of China issued *Implementation Plan of the Extended Producer Responsibility System*, and electrical and electronic products, vehicle, lead acid accumulator, and packaging were selected as the four priority products to which to apply EPR systems beginning in 2017. However, progress has been slower than anticipated in the plan. No concrete implementation plan had been made for the four designated wastes by the end of 2018. Given the country's ambition to increase its recycling targets and implementation performance, an EPR for the four designated waste streams could be contemplated. The implementation plan for applying an EPR scheme to paper-based composite packaging for beverages is to be formulated in the first half year of 2019, since the specific industry is highly centralized and a consensus is relatively easier to be reached by the relevant parties.

BOX 3

EPR INSTRUMENTS

EPR is a tool whereby producers take over the responsibility for the end-of-life management of their used products. This can include collection, sorting, and treating these for their recycling and recovery. The policy first appeared in the early 1990s in a few EU Member States, especially concerning packaging waste, and later expanded across the EU and globally. According to the OECD, there are four broad categories of EPR instruments at the disposal of policy makers. These typically address specific aspects of waste management and can be implemented concurrently. These include:

(i) product take-back requirements obliging producer or retailer to collect the product at the post-consumer stage to achieve recycling and collection targets of the product or materials, or providing incentives for consumers to bring the used product back to the selling point;

(ii) economic and market-based instruments, including measures such as deposit-refund schemes, Advanced Disposal Fees (ADF), material taxes, and upstream combination tax/subsidy (UCTS) that incentivize the producer to comply with EPR;

(iii) regulations and performance standards such as minimum recycled content;

(iv) accompanying information-based instruments aiming to indirectly support EPR programs by raising public awareness. Instruments across these four categories can be implemented as mandatory policies or alternatively be applied on a voluntary basis by producers themselves.

Sustainable operational financing

Sustainable operational financing of the MSW sector is important to allow public-private partnerships (PPPs), sustain earlier and current investments, and permit future development of facilities along agreed plans.

Financial performance of waste management, efficiency and sustainability are areas which according to the existing literature are not well studied in China. Some studies suggest that the fee collected, where it exists, covers less than half of total operating costs even though the collection rate is relatively high.[23] While the exact cost numbers may be difficult to identify, investments in recent years in treatment facilities and improved operations have increased the cost of the sector. Normally, if the *polluter pays* principle is followed, corresponding changes in waste fees should be made. There are plans to introduce volumetric waste charges as a means to reduce waste generation and to facilitate source separation. International experience shows that volumetric charges do indeed reduce waste generation, but this requires significant public communication, education campaigns, and environmental awareness. Volumetric waste charges are also more difficult to administer and add to the cost of operations. Although it will be an arduous task for China to adopt a strict volumetric waste charge system, some frontier cities such as Ningbo, Xiamen, Shenzhen, and Shanghai have put it on their agendas.

In 2017, the Ministry of Finance and MOHURD required that MSW treatment projects had to include a PPP plan that integrates the collection, transportation, treatment, and disposal of MSW in order to improve the quality and efficiency of public service. The PPP market is expected to be formed based on policies that encourage expansion of private capital investments, improve the private capital investment environment, and improve the price, cost, and fiscal and taxation systems.

Sustainable operational financing for MSW incineration and anaerobic digestion plants is crucial for the stable development and safe operation of these facilities. Thanks to the electricity price subsidy, MSW incineration developed quickly in China even though in many cities the government payment is rather low. Currently, the electricity price subsidy in China is being considered for cancellation, and it is likely that the subsidy policy will change in the next few years. At the same time, a similar subsidy may be provided to MSW anaerobic digestion in order to accelerate the development of biological treatment of food waste, which is lagging behind current plans for the treatment mix.

Urban-rural integration and the regional approach

China could again attempt a regional approach for service delivery especially for underserved county and rural areas. There is an opportunity to deepen urban-rural integration, enhance economies of scale, and improve efficiency through regional integration in waste service provision. This would not only improve the quality of service provision, but would support financial sustainability and help offset some of the increased financial costs for circularity.

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[23] Ren X., Hu S., *Cost recovery of municipal solid waste management in small cities in inland China* (2014).

The unbalanced development of MSW management between urban and rural areas and between cities and counties is still significant and mirrors unbalanced regional economic development. MSW generation in a city is higher than 500 tons per day, while the MSW generation in an entire county is often 200 to 300 tons per day, which is lower than the economic scale of MSW incineration or other advanced treatment. Often several adjacent counties are served by multiple MSW incineration plants, whereas their load rate is well below capacity. Alternative solutions may also be introduced, such as refuse-derived fuel (RDF) for co-incineration at cement plants. Landfills are the priority for most of the counties, but site selection, leachate treatment, and gas management may be difficult to resolve. In order to improve the MSW management in counties and rural areas, a regionalization approach offers a feasible solution.

'Waste service areas,' or 'waste shed' as they are sometimes called, are territorial areas spanning several jurisdictions serviced by shared facilities or operators. The experience of other countries' indicates that the optimum approach is to designate such areas using scientific modeling (based on distances, geography and terrain, population density, and waste composition, etc.). In some countries, the jurisdictions are left to freely enter into such 'waste shed' agreements; however, this approach may be random, slow, and may not result in an optimum territorial approach. A managed regionalization approach could be supported by a positive incentive structure, where financial incentives are provided to support regionalization. The approach could also be tested, perhaps as part of China's promotion of metropolitan areas that cross jurisdictional boundaries. In 2017, MOHURD and MEE jointly issued a *Notice for Regulating Trans-regional Transportation and Treatment of MSW* where the basic administrative requirement and procedure was defined. Within cities and counties, urban-rural integration has been growing steadily. In 2016 alone, 134 new projects for urban-rural integration were put into operation in China.

Various models exist regarding the structure and ownership of regional facilities. They can be owned by one large municipality that has agreed to provide services to other jurisdictions with conditions codified contractually, or they can be owned jointly. Operational modalities also differ, although international lessons suggest equalized operating costs as a preferred approach given differences in distances and other costs.

Wild dump closure and remediation

The legacy of waste dumps in China is a serious issue and needs attention. Global experience argues strongly that China's dumpsites need to be operated in a manner that protects groundwater resources as well as protects against leakage of plastic waste into rivers and the ocean. In almost all cases of brownfield site redevelopment, the costs of amelioration are higher than the amortized costs of not creating the pollution in the first place – especially for landfills which are relatively inexpensive to operate properly once they have been constructed.

In the history of MSW management in China, uncontrolled or partly-controlled dumping had been the dominant method before 1990. From 1990 to 2000, dozens of sanitary landfills were built in big cities such as Shenzhen, Hangzhou, Beijing, and Shanghai. After 2000, most of the new landfills were built and operated in compliance with local sanitary standards. However, there are a large number of informal landfills or dumping sites with accumulated MSW around cities. Even now, in rural areas without MSW collection and

disposal service, dumping sites or informal landfills are still in operation with little or no environmental controls. In the 12th FYP, governments invested 21.1 billion RMB resulting in 1,182 sites cleaned up or remediated. According to the primary investigation by MOHURD, there were about 27,000 dumping sites or informal landfills in China in 2017. Only about 800 big sites were selected to be cleaned up or remediated in the 13th FYP with a total budget of 24.1 billion RMB. Additionally, MEE implemented a "waste cleanup action" in the Yangtze River economic zone, and more than 1,300 dumping sites with an aggregate of 38 million tons of MSW were cleaned up. These actions are planned to continue and be strengthened in 2019.

In addition to the immediate problems of public health and nuisance, dumps present a long-term liability for cities. Cities in the U.S. and Europe have had hundreds of old dump sites that needed to be ameliorated and costs were enormous. Most of these "brownfield sites" were addressed due to their impact on groundwater. China's groundwater, which in the future will be relatively more valuable than that of European and American cities due to population density and the otherwise relative scarcity of water, needs greater protection. Over the next 50 years China is likely to face an enormous brownfield site clean-up cost. Today, there are probably a few thousand brownfield sites needing cleanup; budgeting adequate funds to do this will be extremely challenging.

Clean-up and remediation of old sites is also a relatively easy way to meet Nationally Determined Contributions towards mitigation and adaptation to climate change under the United Nations Framework Convention on Climate Change (UNFCCC). agreement (Kampala Waste Management 2017) without significant structural changes to the sector. Emissions from solid waste treatment and disposal are primarily driven by disposal in open dumps and landfills without landfill gas collection systems. Globally, they were calculated to account for about 5 percent of total global greenhouse gas (GHG) emissions.[24] According to a UNFCCC report, from 1990 to 2015 the waste sector achieved a decrease in GHG emissions of 20%, the largest relative to other sectors.[25] The emissions decrease can in part be attributed to the growing effort of many cities, including Chinese cities, to undertake mitigation activities in solid waste management through improved waste collection, waste reduction, reuse of products, recycling, organics waste management, and capture of GHGs for flaring or energy recovery.

Incineration pollution control

China should continue its efforts to curb pollution from incineration, especially from the older fluidized bed incinerators.

Because of rapid economic growth, high population density, and limited usable land, China has viewed incineration as the key solution for MSW disposal. Incineration has been the primary cause of *not-in-my-backyard* (NIMBY) events where the main concern is dioxin pollution. According to the *waste hierarchy* principle, incineration is also a lower-benefit option than recycling and thus, will need to be reconciled with the policy on circularity and resource utilization. Japan, where incineration has traditionally been the dominant treatment method (80% of MSW), has more recently adopted the *Material-Cycle Society* policy and

[24] World Bank 2018a; Hausfather 2017.
[25] UNFCCC 2017.

has stepped up efforts to promote and increase recycling. Similarly, the 65% recycling target by 2035 in the EU will probably depend on a reduction in incinerated waste which in 2016 was 28%.

China adopted a new *Standard for Pollution Control of MSW Incineration and the emission* limit of dioxin was lowered from 1 ng TEQ/Nm^3 to 0.1 ng TEQ/Nm^3, which is the same as the EU standard. The flue gas cleaning system has been improved, and the process SNCR (selective non-catalytic reduction) + seeming-dry + activated carbon spraying + bag filter has been widely used as a basic process for air pollution control of MSW incineration. MEE required all MSW incineration plants to install on-line monitoring system, to connect to the monitoring platform of the local Bureau of Environment and Ecology (BEE), and to set up screens for display of real-time air pollutant emissions. However, some relatively old incinerators, especially fluidized bed incinerators, cannot meet the new standard and transformation is needed.

MSW incineration fly ash is classified as a hazardous waste containing both heavy metals and dioxins. In 2017, about 5 million tons of MSW incineration fly ash was generated in China. Currently the safe disposal of fly ash is not satisfactory, and authorized facilities have insufficient capacity to dispose of fly ash. The main approach for fly ash disposal is landfilling in sanitary landfills after solidification and stabilization by chelating agents or cement. Co-disposal in cement kiln is the alternative approach for fly ash disposal. Plasma melting is seen as a promising approach for fly ash disposal, and the specific standard for this approach is under preparation and expected to be issued in 2019.

Enhanced public participation

As the international experience shows, developing waste management and separation systems that perform well is not easy. Rather, it requires considerable effort to design and establish formal recycling channels and to work with the public towards a 'social contract' where society has embraced the objectives of circularity and has agreed to be an active contributor and adjust its behavior. Similarly, public involvement is required to stop illegal dumping of waste, reduce marine pollution, and achieve financial sustainability. Internationally, various modalities exist to involve civil society and establish permanent platforms for dialogue with stakeholders and professional associations, and these can be explored by China.

The latest draft revision of the Solid Waste Law emphasizes public participation in the management of MSW. In the process for site selection, the government should adhere to the principles of science, transparency, and openness, make detailed and thorough statements to the public, and invite professional, third-party organizations for evaluation and input. In the process of construction, the government should improve the construction standards of MSW treatment facilities and strengthen management of implementation and oversight. Regarding operations over the long-term, improving the openness of treatment facilities to the public and establishing an environmental incentive system are very important. In this regard, it should be noted that in 2018, MEE and MOHURD made a joint decision that at least one MSW disposal facility, one waste water treatment plant, one hazardous waste or E-waste treatment facility, and one environmental monitoring facility be opened to the public in each city above the prefectural level before the end of 2020.

Based on the experience of advanced management approaches abroad, citizens and NGOs play an important role in promoting public participation in MSW management. In Japan, not all recyclables are collected by a regular collection system run by municipal governments. Waste paper is usually collected though community activities or entities such as a children's association. In this way, the voluntary efforts of citizens in source separation, as well as citizen participation in group collection systems, contributes not only to increasing the recycling rate, but also to reducing the cost of collection and transportation carried by municipal governments.

Data collection (Waste Information Systems)

Reliable and instant data on generation, collection, recycling, and disposal are the basis of decision-making, planning, and effective management of MSW. Data especially from rural and county areas in China is lagging behind and there is insufficient tracking of waste destinations. Waste captures through the informal sector remain largely outside official statistics.

Unreliable solid waste generation rates and insufficient tracking of solid waste destinations are significant weaknesses of solid waste management in China. In fact, the quality of data for MSW management in China is better than that for other waste streams, such as industrial solid waste, agricultural solid waste, E-waste, and hazardous waste, since MSW management has been affected and effected by the fact of the purchase of service by government; indeed, the MSW data obtained mainly by weighbridge is the reference for payment. However, since the informal recycling sector is independent of MSW management systems, most of the separated household recyclables are not included in the composition and quantity of MSW in China. Furthermore, as collection and disposal service for MSW in rural areas has not been fully developed, there is no data released officially for MSW generation in rural areas in China. The MSW data for county towns is incomplete as well. Therefore, MSW generation in China may be underestimated.

The efficient, instant and accurate data collection, transmission, and processing in e-commerce and express-delivery industries (logistics industry) provides a useful guide for MSW data collection (reverse-logistics industry) in China. "Smart MSW management" based on the Internet of Things (IoT), "Internet +," and big data have become increasingly popular and are expected to be widely promoted in China. Information technologies will be applied in MSW management systems (including household recyclables) to collect the data for generation, collection, recycling, and disposal of different components of MSW, and to monitor recovered material or energy output as well as environmental emissions. Some pioneer cities, such as Suzhou and Lanzhou, have established fundamental MSW intelligent management platforms to monitor and optimize MSW management, and similar platforms are under design in Shenzhen, Beijing, and Shanghai. With these platforms, the generation, collection, transportation, and disposal of MSW could be located and tracked; material recycling could be regulated; and the data could be combined in MSW management systems to evaluate the effectiveness of MSW source separation. Furthermore, operational efficiency and environmental emissions of MSW facilities could be monitored online for better environmental supervision. In the future, more reliable and complete data for MSW management will be obtained through the hierarchical intelligent platform from national to local level.

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