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Development potential of e-waste recycling industry in China

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Abstract

Waste electrical and electronic equipment (WEEE or e-waste) recycling industries in China have been through several phases from spontaneous informal family workshops to qualified enterprises with treatment fund. This study attempts to analyse the development potential of the e-waste recycling industry in China from the perspective of both time and scale potential. An estimation and forecast of e-waste quantities in China shows that, the total e-waste amount reached approximately 5.5 million tonnes in 2013, with 83% of air conditioners, refrigerators, washing machines, televisions sand computers. The total quantity is expected to reach ca. 11.7 million tonnes in 2020 and 20 million tonnes in 2040, which indicates a large increase potential. Moreover, the demand for recycling processing facilities, the optimal service radius of e-waste recycling enterprises and estimation of the profitability potential of the e-waste recycling industry were analysed. Results show that, based on the e-waste collection demand, e-waste recycling enterprises therefore have a huge development potential in terms of both quantity and processing capacity, with 144 and 167 e-waste recycling facilities needed, respectively, by 2020 and 2040. In the case that e-waste recycling enterprises set up their own collection points to reduce the collection cost, the optimal collection service radius is estimated to be in the range of 173 km to 239 km. With an e-waste treatment fund subsidy, the e-waste recycling industry has a small economic profit, for example ca. US$2.5/unit for television. The annual profit for the e-waste recycling industry overall was about 90 million dollars in 2013.

Keywords

E-waste, e-waste generation, e-waste recycling, recycling industry, development potential, China

Introduction

The increasingly rapid growth of production and consumption of electrical and electronic equipment (EEE) has led to a sharp rise in the volume of waste electrical and electronic equipment (WEEE or e-waste) at the end of their life, leading as a result to a growing problem of pollution worldwide (Kiddee et al., 2013). E-waste constitutes one of the fastest growing waste fractions generated. An estimation of global e-waste generation by Robinson (2009) gives an annual production of 20–25 million tonnes. As e-waste contains heavy metals (mercury, lead, cadmium, and hexavalent chromium), brominated flame retardants, refrigerants, fluoride foaming agent, etc., it requires safe handling and recycling to avoid environmental contamination and detrimental effects on human health. Contamination associated with e-waste has already caused considerable environmental degradation in poor countries and negatively affected the health of local populations (Robinson, 2009). The burning of insulated wire, which typically occurs in open iron barrels, generates 100 times more dioxins than burning domestic waste (Gullett et al., 2007). It is also reported that up to 0.4 mg L^{-1} lead has been detected in river water downstream of a recycling plant in Guiyu, China – approximately 8 times higher than the local drinking water standard (Wang and Guo, 2006). There are elevated concentrations of polybrominated diphenyl ethers (PBDEs) (Cai and Jiang, 2006) in Chinese agricultural soils nearby the e-waste reprocessing sites. Aerial dioxin contamination at Guiyu has resulted in levels of human exposure approximately 15–56 times the World Health Organization recommended maximum intake (Chatterjee, 2007). E-waste is seen as a problem, it is also important to find effective ways to recover the resources contained in it. The content of iron, copper, aluminium, gold and other metals in e-waste is over 60% (Widmer et al., 2005). Generally, one tonne of printed circuit boards contains 80–2050 g of gold (Duan et al., 2011), that is 20–370 times the grade of mined gold in China, which averages only 4.14 g t^{-1} (China Mining Association, 1996).

Clearly, e-waste is not only an emerging problem, but also a business opportunity, given the volumes of e-waste being

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generated and their content of both toxic and valuable materials. In China, large population and rapid economic development have caused a significant increase in the volume of discarded e-waste, increasing the environmental burden, but also creating new development opportunities for the e-waste industry. In 2001, the National Development and Reform Commission (NDRC) began to implement the legislation on e-waste recycling and disposal in China. Starting on 1 January 2011, the 'Regulations on the Management of the Recovery and Treatment of Waste Electronic and Electrical Products' (referred to as the Chinese WEEE) went into effect, followed by a series of supporting policies at the national level, which regulated the e-waste multi-channel collection system, the centralised treatment system, the planning system, the qualification licensing system, the treatment fund subsidy system, etc.

Prior to 2003, e-waste recycling industries were primarily informal family workshops. On 26 August 2003, regarding e-waste management, the former State Environmental Protection Administration released the first regulatory document 'Announcement on the Strengthening of Environmental Management of E-waste'. Early 2004, the NDRC determined Zhejiang province and Qingdao city as the pilot province and city for the construction of a national e-waste recycling system, which was expected to gather experience that could be promoted throughout the country, but owing to a lack of supporting policies and financial support, the pilot plan came to a premature end (Zhang and Deng, 2012). Since 2008, e-waste recycling enterprises were required to be approved by the local environmental authorities and then disclosed in the e-waste recycling enterprises list according to the 'Administrative Measures for the Prevention and Control of Environmental Pollution by Electronic Waste'. In June 2009, the NDRC and other ministries jointly formulated the 'Implementation Measures on "Old for New" Policy of Home Appliances'. During the 'Old for New' policies for household appliances from 2009 to 2011, the number of designated dismantling enterprises, selected from the enterprises listed in the e-waste treatment enterprises list, increased rapidly. Since the implementation the Chinese WEEE in 2011, e-waste enterprises are required to obtain a qualified licensing according to the Chinese WEEE, with most of these qualifying for treatment subsidies when that WEEE treatment fund policy was implemented in 2012. What are the future prospects for the e-waste recycling industry in China? This study aimed to research the development potential of the e-waste recycling industry in China, from the perspective of both time and scale potential, to determine the industrial business opportunities. Such information could help policy makers to develop plans for e-waste industries, and investors to direct their resources to viable recycling facilities.

Research methodology

In order to perform a comprehensive study on the development potential of the e-waste recycling industry in China, literature review, report analysis, market investigation, and visits to typical e-waste processing enterprises were conducted to gather basic information on e-waste generation, collection and recycling status, processing cost, industrial problems, etc. This study was conducted from the following aspects.

Estimation of e-waste generation

First, an estimation and forecast of e-waste quantities in China at present and in the mid- and long-term future were conducted. Wilkinson et al. (2001) reported that, seven different models are used in world-wide studies to calculate WEEE amount, including the Market Supply Model, Market Supply A Model, Stanford Model, Carnegie Mellon Model, Time Step Model, Estimate Model, and Industry Council for Electronic Equipment Recycling (ICER) Model. The United Nations Environment Programme (2007) also introduced five globally used methods to determine e-waste inventory including the Market Supply Method, Time Step Model, Carnegie Mellon Method, and two Approximate Methods. The Market Supply Method is based on sales data, together with typical lifespan. The Market Supply A Method is similar to the Market Supply Method, but the lifespan uses distributed value. The Stanford Method is similar to the Market Supply A Method, but considered the variation of distributed lifespan with time. The Carnegie Mellon Method is a variation of the Market Supply Method, where the calculation of WEEE is made from sales data, assumptions about typical lifetimes, recycling, and storage. The model considers consumer behaviour when disposing of end-of-life WEEE. The Time Step Method is on the basis of private and industrial stock and sales. One of the Approximate Methods is on the basis of stock and average lifetime data. The other Approximate Method is based on the assumption, that with the sale of a new appliance, an old appliance has to be disposed of (United Nations Environment Programme, 2007).

This study will review and comparative analyse studies on e-waste generation in China by previous researches, and then also conduct an estimation of e-waste both in the current, medium, and long-term by authors. First, representative e-waste in China was selected. The WEEE Directive of European Union has 10 categories of WEEE, containing most all WEEE types. It is noticed that, in the European Union, large household electrical appliances account for 49% of the total e-waste amount by weight, while small household electrical appliances 7%, information and communication equipment 16.3%, consumer equipment 21.1%, lighting equipment with the exception of luminaires in household about 2.4%, and others account for 4.2% (United Nations University, 2007). Categories 1–4, namely the large and small household electrical appliances, information and communications equipment, and consumer equipment, are the most commonly researched ones throughout the literature, while the remaining categories have not received much interest from researchers (Pérez-Belis et al., 2015). The e-waste types in China, along with their reason for selection by authors, are presented below.

- Television, refrigerator, washing machine, air conditioner, and computer – common items in China, also listed in the

first round WEEE management catalogue (the first) in China (NDRC et al., 2010).
- Printers, copiers, mobile phones, common office equipment, and consumer equipment with large increasing production volume, also key products listed in the the WEEE management catalogue (2014 version) (NDRC et al., 2015) in China.

This calculation methodology of e-waste quantities by authors is based on the sales of reprehensive WEEE items. Owing to data limitation, and considering the saturated market and relative stable lifetimes for televisions and refrigerator, the Market Supply Method is used to estimate the generation amount of refrigerators, washing machines, air conditioners, and televisions. But this method is not especially useful in the calculation of WEEE for a dynamic market like computers. So considering distribution of lifespan, the generation volumes of computers, printers/copiers and mobile phones are calculated using the Market Supply A Method. Then by using average weights and an average composition of the waste stream, the total WEEE amount for China can be extrapolated.

Furthermore, given the timelines for statistical data, any long-term forecasts of e-waste generation could only be based on the assumptions. The United Nations University (2007) reported that e-waste volume per capita appears to have a rough correlation with affluence, i.e. gross domestic product per capita, and indeed the e-waste volume in Western Europe is currently 14–24 kg head^{-1} and new members 6–12 kg head^{-1}. According to the modernisation report of China (Chinese Academy of Science, 2010), China would complete the first modernisation phase around 2020, and exceed the world average e-waste volume per capita around 2040. So it is assumed by this study, that the generation volume per capita in 2040 in China could reach an average value of ca. 14 kg head^{-1} of Western Europe and new members. Research results on e-waste generation quantities would indicate whether there would be sufficient materials to support the long-term development of an e-waste recycling industry in China.

Analysis on development of e-waste recycling industry scale

To analyse the development potential of the e-waste recycling industry scale through information gathering on e-waste recycling enterprises, the current distribution and processing capacity of the e-waste recycling industry was gathered and analysed if the current processing capacities met the demand on e-waste treatment in China. Then, the number of e-waste recycling enterprises was then predicted based on the collection rate and processing capacity of the e-waste recycling industry.

Furthermore, for the case that e-waste recycling enterprises set up their own collection points to reduce the collection cost, the optimal collection radius of e-waste recycling enterprises was estimated based on an affordable transportation cost, based on the current Chinese situation, and also referred to the situation in Japan under certain assumptions, to evaluate the optimal service areas of the recycling industries.

Finally, a profitability estimate of the e-waste recycling industry is made, based on the anticipated recycling costs and income, which will indicate whether e-waste recycling industries have a business development potential.

Results and discussion

E-waste generation amounts in China

There is no any official statistical data on e-waste volume in China yet. Previous research has been conducted on the estimation of the e-waste generation volume in China using various estimation methods (e.g. He et al., 2010; Li et al., 2009; Zhang et al., 2013). Results indicate that the studies of previous researchers mainly consider five major types of e-waste, namely televisions, washing machines, refrigerators, room air conditioners, and computers. In addition to the five main e-wastes, this study estimated also the generation volume of printers/copiers and mobile phones, which have attracted the attention of managers and researchers recently. A previous study by the author has already made predictions of waste fluorescent lamp generation in mainland China (Tan and Li, 2014). The total e-waste volume in weight was calculated with average weights: 25 kg unit^{-1} for televisions and 15 kg unit^{-1} for personal computers (Liu et al., 2006), 35 kg unit^{-1} for refrigerators (Cobbing, 2008), 25 kg unit-1 for washing machines, 51 kg unit^{-1} for air-conditioners (Yang et al., 2008), 10 kg unit^{-1} for printers, and 0.12 kg unit^{-1} for mobile phones. This weight conversion was also applied to estimation results in units by previous researches.

Results (Figure 1) show that, owing to differences in product scope, data sources like sales quantities, life span, and methods, etc., the estimated results vary from one method to another, especially for computers and air conditioners. But all results indicate an increasing trend of e-waste amount. The Estimate Method and the Social Ownership Coefficient Method are all based on the social ownership and average life span of EEE. The Social Ownership Coefficient Method used by the China Household Electric Appliance Research Institute (He et al., 2010) considered the discard peak period of the waste products and multiplied by a coefficient, which made the predictive value lower than the results of the Estimate Method. Among five research results of computers, the estimated waste computer amount by the Market Supply Method was much higher than the other four results. This may verify that this method is not especially useful in the calculation of e-waste for a dynamic market like computers.

Summing up all the types of representative e-waste estimated by authors, the total weight of generated e-waste reached approximately 5.52 million tonnes in 2013. It is worth noting that, the five main items of air conditioners, refrigerators, washing machines, televisions, and computers account for 83% (Figure 2), while printers/copiers and mobile phones account for 8%. The total quantities are expected to reach ca. 11.7 million tonnes in 2020 and 20 million tonnes in 2040, which indicate a large increasing potential amount of e-waste in the future. The areas generating the highest amount of e-waste are concentrated mainly in the south-eastern coastal developed areas and in populous

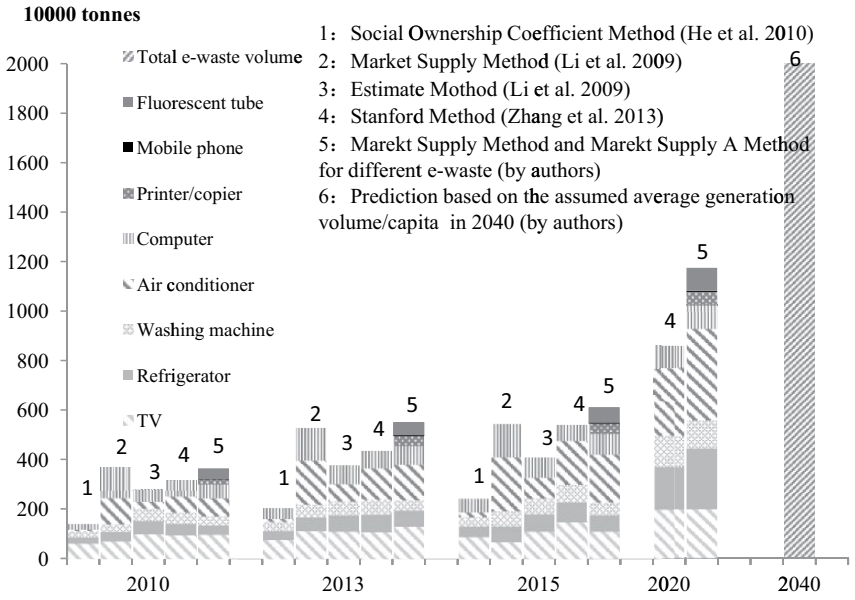

Figure 1. Estimation and forecast of domestic e-waste volumes in China.

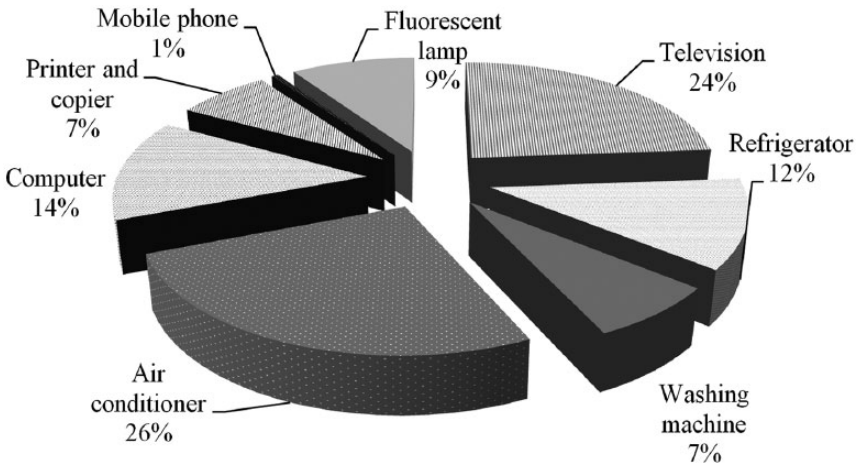

Figure 2. Proportions of e-waste volume in 2013 in China.

provinces, such as Henan and Sichuan (Zhang et al., 2013). In fact, e-waste might be regarded as an essentially inexhaustible source of some valuable minerals. As EEE is the product of the era of science and technology, the types and volumes of e-waste, generated at the end of life of EEE, continue to increase. Hence the e-waste recycling industry may be seen as a source of sustainable business development.

Scale of the e-waste recycling industry

In order to implement the Chinese WEEE, a management catalogue of WEEE was issued in 2010, covering the five main types of e-waste: televisions, washing machines, refrigerators, room air conditioners, and computers. The siting of these facilities to deal with the five e-waste products would be determined by the regional distribution of manufacturing industries, and by the regions' level of economic development, population density, waste volume, etc. By end of 2014, the Ministry of Finance has announced 106 qualified e-waste recycling enterprises qualified for funding subsidies *by four times* (MOF et al., 2012, 2013, 2014). Figures 3 and 4 present an overview of the spatial distribution of these 106 formal recyclers, and the regional distribution of industry processing capacities.

Facilities were sited based on both need and capacity: 34% of the e-waste recyclers, with 39% processing capacity, are distributed mainly in Eastern China, where economic development is more advanced than in the Western areas, while ca.16% are, respectively, distributed in Central and Northeast China, where there are large populations and a thriving electronics manufacturing industry; these have ca. 16% of the total enterprises processing capacity. Provinces with vast land areas, like Inner Mongolia, Tibet, Xinjiang, and Qinghai, having only one or two recyclers, or none at all, would face collection and logistic challenges, and the overall cost would be higher than in other

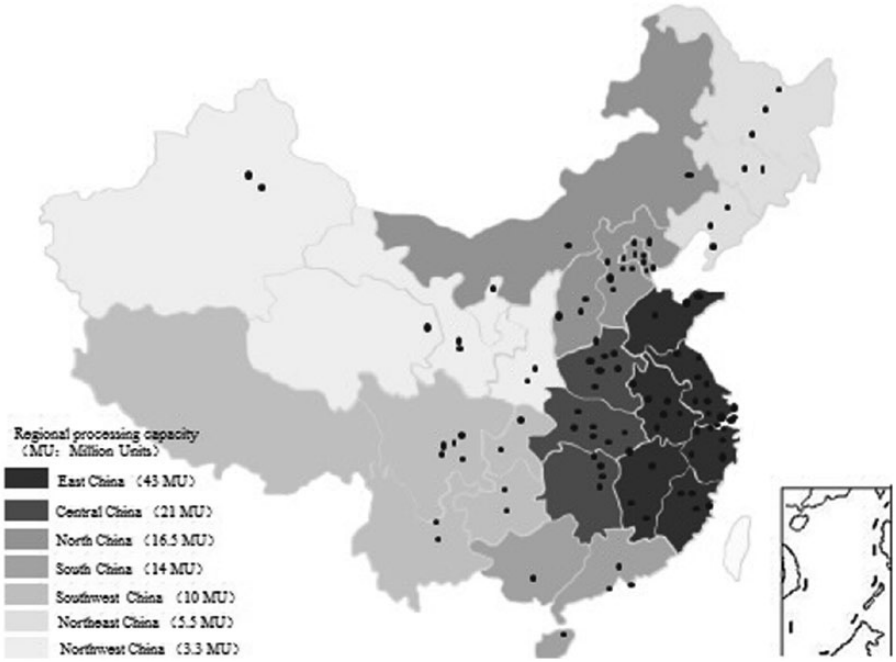

Figure 3. Distribution of e-waste recycling enterprises and processing capacities.

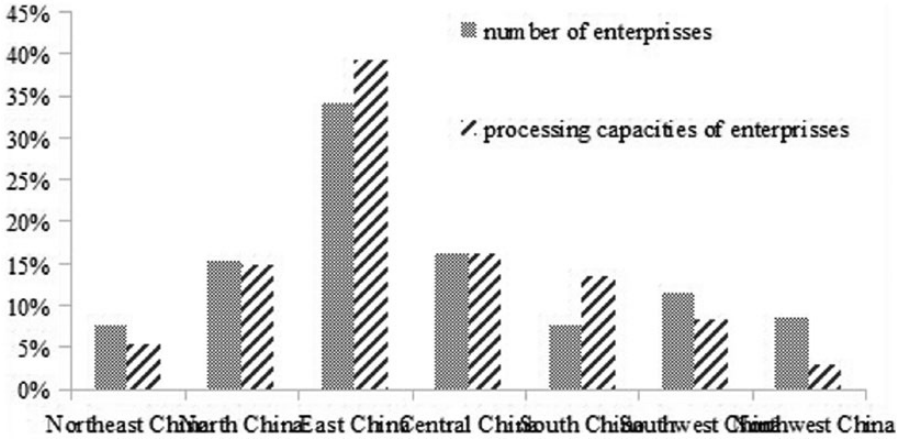

Figure 4. Regional distribution of processing capacities of e-waste recycling industries.

provinces. Also, 8% e-waste recyclers are located in Northwest China, but with only 3% processing capacities. This means the recyclers there have relative small processing capacities. On the contrary, large-scale e-waste recyclers are mainly located in South China, 8% recyclers with 13% processing capacities.

In 2013, approximately 43 million units of e-waste were collected and dismantled by formal e-waste recyclers; 92% of the dismantled e-waste consisted of cathode ray tube (CRT) televisions (Tang and Wan, 2014), that is ca. 1.2 million tonnes. It has been estimated by the author that ca. 1.3 million tonnes of television waste was generated in 2013, so the collection rate of televisions reached more than 90%. From the disproportionate distribution of the recycled e-waste types and the processing capacities of the enterprises (Figure 5), it can be seen that the collected e-waste consists mainly of television, causing the processing line in the recycling enterprises for other items, such as air conditioners and computers, to be in idle mode most of the time. Lindhqvist (2000) noted that administrative instruments (e.g. regulations) and economic instruments (e.g. tax or subsidy and disposal fee systems) are important drivers for a sustainable economy. Since the fund policy went into effect on 1 July 2012 for the dismantling of the five main e-waste products, namely televisions, refrigerators, washing machines, air conditioners, and computers listed in the WEEE management catalogue of China, the recycling enterprises could receive subsidies from government (MOF et al., 2012). The public awareness of e-waste recycling is still low in China, and selling WEEE to individual collectors is the preferred option by Chinese households or companies for e-waste disposal (Zhu et al., 2012). E-waste products like printers/copiers and mobile phones have no fund subsidy for their treatment, so few formal enterprises handle them and there is also no formal collection data yet. Although the dismantling of

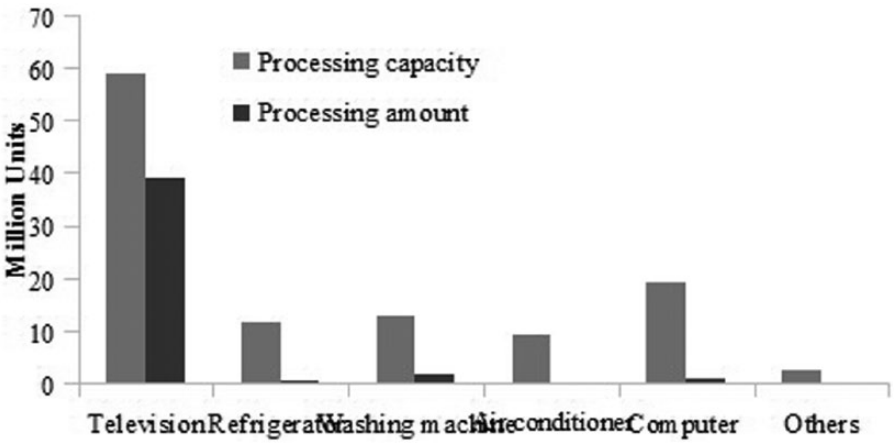

Figure 5. Disproportionate distribution of recycled e-waste types and processing capacities of existing recycling enterprises.

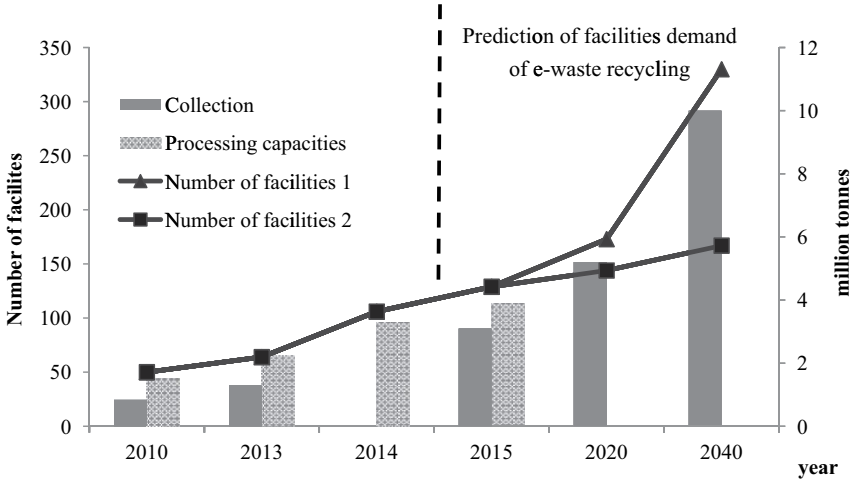

Figure 6. Demand for e-waste recycling enterprises.

e-waste like air conditioners and computers etc. are funded, high reuse and resource recycling value of air conditioners and computers has resulted in a relatively higher collection price. A high collection cost makes it difficult for the formal treatment enterprises to collect these items.

Demand analysis on facilities development

During the 'Old for New' policy for household appliances, ca. 28 million units (ca. 0.84 million tonnes) were collected in 2010 (Zhu et al., 2012). According to the development plan for e-waste recycling in the provinces (2011–2015), the collection rate for the five major e-wastes are expected to reach approximately 60% in 2015 in most provinces, that is, 3.1 million tonnes of e-waste is expected to be collected. Similar to e-waste generation for the long-term future in China, the collection amount in the mid- and long-term was also estimated according to China's development degree and reference to average collection volumes per capita in European countries. Hence, it assumed that approximately 4 kg per capita (the collection amount required by the old WEEE directive (European Union, 2002) could be collected in 2020, when China completes the first modernisation level, and the collection volume would reach to ca. 8 kg per capita (which is an average collect volume per capita in 28 European countries in 2010) (Eurostat, 2010), when China exceeds the world average development level in 2040. Figure 6 shows that the current recycling enterprises meet the total recycling need for collected e-waste, as the processing capacity of enterprises exceeded, or will exceed, the collection amounts in 2010, 2013, and 2015. According to the development plan of the provinces, the number of e-waste processing enterprises is expected to reach 129 in 2015 (Ministry of Environment Protection of the People`s Republic of China, 2014).

Considering the expected increase in collection demand, it is likely that more recycling enterprises will soon be needed, especially in west and southwest China where the e-waste recycling industry is weak, with limited geographical distribution. In fact, not only will there be an increasing amount of the five main types of e-waste, there will also be more and more new types of e-waste to be managed in China, and new e-waste recycling enterprises will need to be built. The currently qualified 106 e-waste recycling enterprises have a combined e-waste processing capacity of more than 110 million units per year, with an average processing

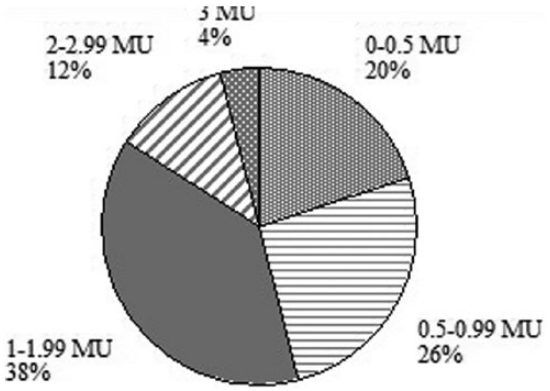

Figure 7. Processing capacities of e-waste recycling enterprises.
MU: million units.

capacity of 1 million units per annum (approximately 3000 tonnes per annum) for one enterprise. In order to meet the recycling target, however, 173 e-waste recycling facilities will be needed by 2020, and 330 by 2040, assuming an average processing capacity of 3000 tonnes.

Under the new policy (MOF et al., 2013), on the other hand, the number of recycling enterprises would be strictly controlled in order to avoid vicious market competition. A qualification exit mechanism for the funding subsidies has been adopted, for example, since 2014 the fund subsidy qualification would be cancelled if the actual dismantling capacity is less than 20% of the licensed processing capacity. Figure 7 shows that close to half of the current enterprises, however, are small- to medium-sized, with processing capacities of less than 1 million units per annum. Moreover, the expected increase in e-waste volume and variety will force enterprises to increase processing capacities if they want to remain competitive. It can be assumed that, with an average mid-scale processing capacity of 120 million units in 2020 and 200 million units in 2040, 144 and 167 e-waste recycling facilities will be required by 2020 and 2040, respectively. Thus, the e-waste recycling industry will tend to develop in the direction of large-scale concentrated enterprises, which would be easier to manage and could take advantage of economies of scale.

Optimal service radius of e-waste recycling enterprises

In most developed countries, e-waste is collected by formal collectors or established municipal waste collection systems, temporarily stored, and then transported to recycling facilities. It indicates that transportation cost plays an important role in the cost structure of the e-waste recycling process. In a reverse logistic network, products to be recovered need to be physically moved throughout the entire recovery process. Thus, in many cases, transportation costs greatly influence economic viability of products recovery (Dat et al., 2012). Reverse logistics is one of the most important parameters in the management of waste equipment, accounting for 50%–70% of the total costs (Achillas et al., 2010). This figure is relatively high, especially when compared with logistics cost elements of a new product that represents only 10%–15% of its price (Nagel, 1996). For example in Japan, e-waste (here mainly referred to the four household appliances) is collected mainly by retailers, who transport them to the over 350 designated stockyards, and then transport them to the 49 designated recycling plants. The distribution of the designated stockyards is based mainly on the cost of transportation from the designated stockyard to the designated recycling plant. Taking CRT television as an example, the storage cost in stockyard and the logistic cost (from the stockyard to the recycling plant) account for ca. 21% and 9.6% of total recycling cost, respectively (Terazono et al., 2013).

In China, however, the e-waste collection system is still not mature, and it is driven by the interests of the various players. Thus consumers are most willing to sell waste products to the collector offering the highest collection prices, causing most e-waste, especially the products containing high-value materials to flow into the informal sector. Different to other developed countries like Japan, e-waste recycling enterprises need to pay for e-waste collection in China. At present, there are mainly two situations. One is that, enterprises purchase e-waste directly from e-waste collectors, which collected e-waste from consumers or sub-collectors; currently most recycling enterprises do so. According to the price guide (China Resources Recycling Association, 2013) and market investigation, the average purchase price of one CRT television from a collector is approximately US$13.7 (exchange rate with Ren Min Bi (RMB) calculated at 6.1). The treatment cost or internal operating cost of e-waste recycling enterprises for each television set varies from US$6.2–8.5 (China Association of Circular Economy, 2010). Since there is no uniform regulated e-waste collection price set by the government, the price varies with market demand and competition, leading to a high collection cost. Hence, compared with Japan (Figure 8), the collection cost constitutes the highest proportion of the total recycling cost at ca. 65%.

The other situation is that some e-waste recycling enterprises set up their own collection channels. To do so, they need to determine their optimal collection service radius. In this study, the transportation (from collection point to treatment enterprise) cost, that needed for the e-waste recycling enterprises to be economically viable, was taken into consideration for the optimisation of transportation radius for the e-waste collection.The authors have used a maximum of 300 km from the recycling enterprises for reference; however, there are no such studies on the optimal collection transportation distance. Situations are different between China and Japan, and e-waste collection and treatment in China have collection fees and fund subsidy. It is interesting that, the collection fee with ca. US$13.7 and fund subsidy with US$13.9 for televisions in China soon offset each other. So considering that Japan has a relatively mature collection system for e-waste, and without consideration of the collection fee and fund subsidy, an average 10% of the transportation cost from collection point to recycling enterprises is referred by the authors to roughly calculate a service radius of e-waste recycling enterprises. Considering China's actual situation, 10% should be acceptable for e-waste recycling enterprises.

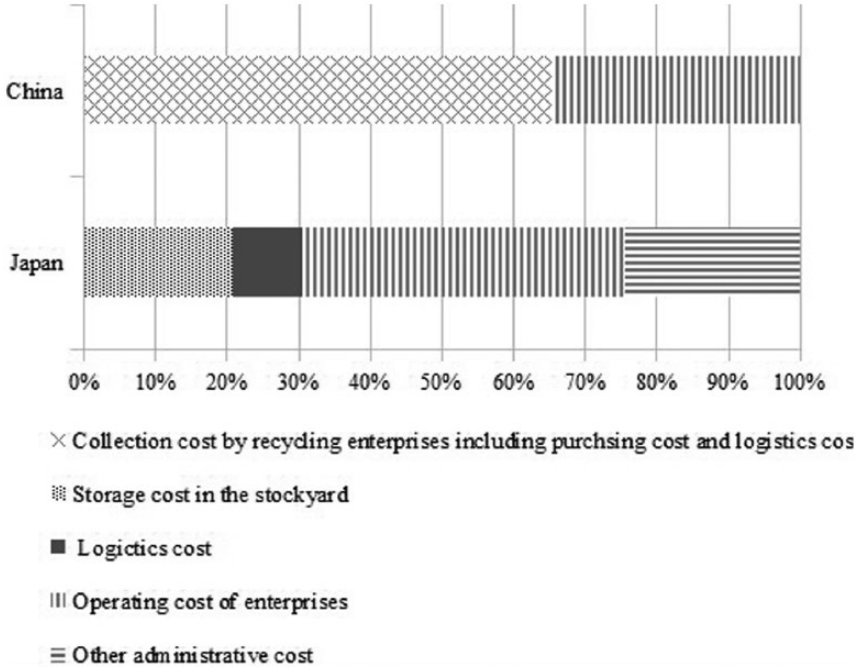

Figure 8. Contrast of recycling costs between China and Japan (for CRT television).

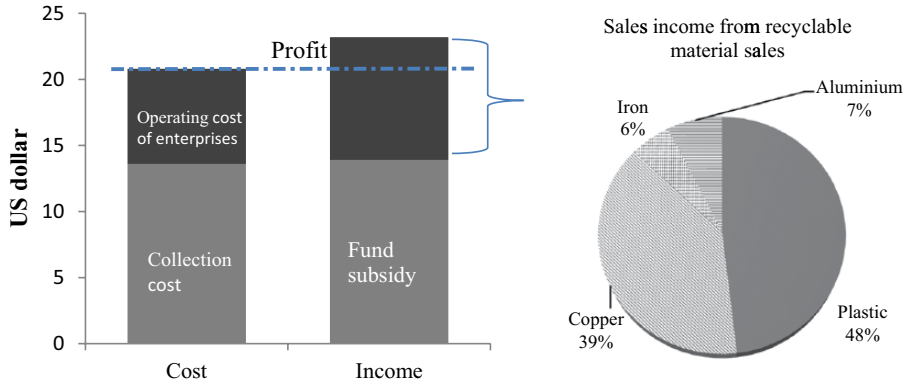

Figure 9. Profit from CRT television recycling in China.

1. The proportions of plastics, aluminium, copper scrap, and iron are, respectively, 23%, 2%, 3%, and 10% (Li et al., 2006).
2. According to the national standard for 'the limit and target value of the utilization rate of waste electrical and electronic products', the utilisation rate limits for metals and single plastics are, respectively, 85% and 80%, taking into consideration the limitations of processing technology and costs.
3. The market prices for waste plastic, aluminium, copper scrap, and iron are based on current market investigations.

If this percentage could be achieved in China, then since the treatment cost for each television set varies from US$6.2–8.5, the logistics cost from stock point to recycling enterprise would be US$0.68–0.94 – a very affordable cost/unit for an enterprise. Market investigation found that each truck can transport approximately 150 units of e-waste, and that the maximal logistic cost of each truck is US$102–141. As the truck maintenance and labour fee are usually contained in the operating cost of the enterprises, the logistic cost in China would be mainly determined by the cost of diesel fuel and highway fees. Taking an average US$0.34/km cost for diesel fuel and US$0.25/km for the highway fee, the optimal transportation radius would vary from 173 km to 239 km. The variation would be based on the sustainable logistics cost, the size of the truck, the amount of e-waste transported, the highway fee for the region, etc., although since an enterprise would still have to collect a certain amount of e-waste to receive the fund subsidies, the collection areas might have to be wider.

Profitability estimates

Since the funding policy went into effect for the five main types of e-waste on 1 July, 2012, the enterprises could receive government subsidies of US$13.9/unit for television sets, US$13.1/unit for refrigerators, US$5.7/unit for washing machines, US$5.7/unit

for air conditioners, and US$13.9/unit for computers (MOF et al., 2012).

At present, the total e-waste recycling cost for enterprises in China mainly covers the purchasing cost and the operating cost within the e-waste recycling enterprise. E-waste dismantling also allows the enterprise to make a profit from the recyclable material sales. Figure 9 shows that the total recycling cost of one CRT television set is estimated at ca. US$20.8/unit. For one set, the enterprise could get US$13.9 subsidy and approximately US$9.3 income by selling waste plastic, waste aluminium, copper scrap, etc., after dismantling. The profit would then be US$2.4 from dismantling one CRT television set.

In 2013, e-waste recyclers received totally ca. 540 million dollar subsidies based on their dismantled e-waste amounts of 39.87 million units, whose dismantling met the requirements of Ministry of Environment Protection (Ministry of Environment Protection, 2014). As more than 90% are televisions, it could be calculated that the annual profit for the e-waste recycling industry overall was about 90 million dollars.

One problem with this system is that the fund subsidies currently require examination of the quantities dismantled and disclosure of the results, a process that takes approximately 6 to 12 months, delaying the receipt of the funds. But improvements in the examination system are gradually decreasing this waiting period.

Currently, the high reuse and resource recycling value of air conditioners and computers has led to a relatively higher collection price, making the recycling enterprises difficult to collect, so more efforts are still needed to improve the e-waste collection.

Conclusion

Considering the increasing volume of e-waste and consequent demands for recycling services, as well as the potential profit, it would be seen that e-waste recycling is a fast-maturing industry in China, which will continue to broaden its scope and present excellent business opportunities.

The total amount of e-waste was estimated to be ca. 3.6 million tonnes in 2010 and 5.5 million tonnes in 2013, and is expected to reach 11.7 million tonnes by 2020 and 20 million tonnes by 2040. In addition to the traditional e-waste, namely televisions (24%), washing machines (7%), refrigerators (12%), room air conditioners (26%), and computers (14%), printers and fluorescent lamps can also produce a significant percentage of e-waste volume with 7% and 9%, respectively.

The current processing capacity of the 106 recycling enterprises with more than 110 million units, not only meets but exceeds the recycling need of collected e-waste, with approximately 43 million units recycled in 2013; the main type being television sets. Large amounts of waste refrigerators, air conditioners, and computers, however, cannot be effectively collected. Increasing e-waste volume and expanding the management scope of e-waste require an effective e-waste collection and processing system. E-waste recycling enterprises, therefore, have a huge development potential in terms of both quantity and processing capacity, with 144 and 167 e-waste recycling facilities needed, respectively, by 2020 and 2040.

In the case that e-waste recycling enterprises in China purchase e-waste directly from e-waste collectors, which collected e-waste from consumers or sub-collectors, the collection cost constitutes the highest proportion of the total recycling cost with ca. 65%. In the case that some e-waste recycling enterprises set up their own collection channels to reduce the collection cost, the optimal collection service radius is estimated to be in the range of 173 km to 239 km, taking into account the transportation cost. In order to collect the vast amounts of e-waste needed to qualify for the fund subsidies, however, the collection areas covered by the enterprises actually may be larger.

With current government policies and funding supports, e-waste recycling enterprises can make a small profit of US$2.5/unit for one television set. The annual profit in 2013 for the e-waste recycling industry overall was about 90 million dollars. With increases in the processing quantities, costs will be lower. Although high collection prices for some types of e-waste have led to low collection rates of other types, improvements in the recycling system, and a standardised collection price – currently the major cost for e-waste processing in China – could lower costs and increase profits, allowing the funding subsidies to be decreased and the e-waste recycling industry to thrive.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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