From Centralized Disassembly to Life Cycle Management: Status and Progress of E-waste Treatment System in China

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Abstract. China is now facing e-waste problems from both growing domestic generation and illegal imports. Many stakeholders are involved in the e-waste treatment system due to the complexity of e-waste life cycle. Beginning with the state of the e-waste treatment industry in China, this paper summarizes the latest progress in e-waste management from such aspects as the new edition of the China RoHS Directive, new Treatment List, new funding subsidy standard, and eco-design pilots. Thus, a conceptual model for life cycle management of e-waste is generalized. The operating procedure is to first identify the life cycle stages of the e-waste and extract the important life cycle information. Then, life cycle tools can be used to conduct a systematic analysis to help decide how to maximize the benefits from a series of life cycle engineering processes. Meanwhile, life cycle thinking is applied to improve the legislation relating to e-waste so as to continuously improve the sustainability of the e-waste treatment system. By providing an integrative framework, the life cycle management of e-waste should help to realize sustainable management of e-waste in developing countries.

1. Introduction

E-waste (also called WEEE) is one of the fastest growing waste streams [1]. E-waste not only contains abundant amounts of recyclable materials but also hazardous substances, e.g. heavy metals, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs). With the increasing consumption and turnover of e-products, China is now facing the dual pressures of domestic generation and illegal transboundary movement of e-waste [2,3].

E-waste treatment system in China has been through several phases from informal family workshops to licensed plants with specialized subsidy. Prior to 2003, e-waste treatment system was spontaneous family workshops. Early 2004, the National Development and Reform Commission (NDRC) determined Zhejiang province and Qingdao city as the pilot province and city for the construction of a national e-waste treatment system [4]. In June 2009, the Chinese government released the “Household Appliances Old for New Rebate Program” (Old for New Program) in five large cities and four provinces and then extended to most of other provinces. The “Old for New
Program” ended on 31 December 2011. From July 2012, WEEE Treatment Fund Policy (Fund Policy) was implemented, became the new diving force for promoting Chinese e-waste treatment system. Since implementation of the “Old for New Program” and especially the “Fund Policy”, the formal treatment system of e-waste has been improved dramatically.

Life cycle management (LCM) refers to the comprehensive management of the whole of the life cycle of products and service for the purpose of realizing sustainable production and consumption [5]. Apart from enterprise and business development, its concepts and methods can also be used to guide the management of solid waste [6–8]. As the largest country exporting e-products and illegally importing e-waste, China plays an important role in the life cycle management of the global electronic industry [9, 10].

Beginning with the state of the e-waste treatment industry in China, this paper first analyzes the industry’s scale, treatment capacity, formal plant types, informal sector transition, etc. Then, the latest development in e-waste management are analyzed (including the new edition of the China RoHS Directive, new Treatment List, new funding subsidy standard, and eco-design pilots for e-products). Finally, from the perspective of the whole process, this paper proposes a conceptual model for the life cycle management of e-waste. Moreover, the research elaborates the specific strategies and prospects for performing LCM, and attempts to provide a new methodology for optimizing e-waste treatment in China so as to realize sustainable management.

2. Development of e-waste treatment industry

2.1. Treatment capacity of e-waste

Large quantities of e-products in China have been discarded in recent years. With progress in technology and growth in living standards, the trend in e-products discard is an indication of the rapid increase in consumption and speed of update. As a consequence, the quantity of e-waste discarded increases year-on-year. As an example, the number of televisions, refrigerators, washing machines, air conditioners, and personal computers discarded has grown from 51.48 million in 2009 to 113.78 million in 2014 [11], corresponding to an average annual growth rate of 24.2%.

With the implementation of its “Fund Policy”, the Ministry of Environmental Protection (MEP) has begun to count up the numbers of televisions, refrigerators, washing machines, air conditioners, and personal computers treated by licensed plants since July 2012. According to these statistics, 7.68, 39.87, and 70.2 million of these five kinds of e-waste have been formally treated in consecutive years from 2012 to 2014. Correspondingly, the formal treatment rate has risen from 10.13% to 61.7% (Figure 1).

![Figure 1. Generation and treatment of typical e-waste in China (2009–2014).](image)

Among the five kinds of e-waste, it is the discarded televisions that are mainly disassembled by the licensed plants at present. For instance, in 2013, 92.0% of the total amount of the e-waste formally disassembled by licensed plants comprised of discarded televisions, while the other four kinds made
up 8.0% in total [12]. In 2014, the proportion attributable to discarded televisions decreased slightly. Televisions, refrigerators, air conditioners, washing machines, and personal computers disassembled occupied 81.8%, 2.4%, 0.2%, 4.7%, and 11.1% of the total disassembled amount, respectively. The reasons why discarded televisions are the main kind of object treated are as follows. On the one hand, licensed plants are enthusiastic about disassembling televisions due to the high subsidy involved. On the other, the other kinds of e-waste, e.g. air conditioners and washing machines, have relatively high collection costs and so it is uneconomical for licensed plants to purchase them from collectors. As a result, most of them are processed in informal sector.

2.2. Structure of the formal sector
The formal e-waste treatment plants in China can be split into four types. The first one consists of e-waste recyclers that have received WEEE treatment license. E-waste recyclers registered on the e-waste disassembly plant list form the second one. The third consists of recyclers authorized for hazardous e-waste recycling and disposal. The fourth kind is those engaged in the treatment of imported category-seven solid waste. The four categories are not clear-cut: there is crossover between these four kinds of licenses and some formal plants generally present multiple qualifications at the same time.

Since the “Fund Policy” came into effect, the first kind of formal treatment plant has become the main force involved in the formal treatment of e-waste. By the end of 2015, the Ministry of Finance (MF) had announced that 109 formal e-waste treatment plants qualified for funding subsidy. These plants are located in 29 provinces, but are mainly distributed in central and eastern China (Figure 2). With the rapid increase and comprehensive coverage afforded by these licensed treatment plants, the layout of the formal sector for treating e-waste in China has been preliminarily completed.

![Figure 2. Distribution of formal WEEE treatment plants in China.](image)

2.3. Transition of the informal sector
A key issue for China’s e-waste management is how to set up incentives for informal sector so as to reduce improper recycling activities and to divert more e-waste flow into the formal sector [13]. Guiyu, a small town located in southeastern China, is known across the world for polluting the environment as a result of its illegal e-waste disassembly [14]. As a consequence, this region has become a typical representative of the informal sector for recycling e-waste. Since the middle of 1990s, farmers living in Guiyu, initiated e-waste recycling activities [15]. However, these informal workshops adopted primitive methods such as open burning, open dumping, and acid washing, caused serious environment pollution and threatened human health [16].

In October 2005, Guiyu was included in the first group of circular economy pilot projects for recycling waste household appliances. In December 2010, Guiyu established a circular economy park with the theme of e-waste disassembly and treatment, hoping to transform informal recycling activities to formal ones through centralized disassembly and pollution treatment. By 2015, construction of the
park had made substantial progress: of 5,169 disassembly households, 2,028 had been banned. Furthermore, 29 companies (composed of 758 modified disassembly households from the 3,141 rectified households) had entered the zone to perform formal disassembly and treatment [17].

3. Latest progress in e-waste management

In order to deal with the environmental problems of e-waste and improve the e-waste treatment industry, the Chinese government has been issued a variety of environmental laws, regulations, standards, and norms related to e-products production and e-waste management [18].

As the counterpart of the EU’s RoHS and WEEE Directive, China passed the “Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products” in 2006 and the “Administration Regulation for the Collection and Treatment of Waste Electronic and Electrical Equipment” in 2009. Generally, the two documents are unofficially referred to as China RoHS Directive and China WEEE Directive [19].

3.1. China RoHS Directive (2016 edition)

On 6 January 2016, eight ministries and commissions, including the Ministry of Industry and Information Technology (MIIT), published “The Restriction of Hazardous Substances in Electrical and Electronic Equipment”. It supersedes the document “Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products” to be the new and current edition of China RoHS Directive.

The new edition of RoHS Directive proposes the compilation of a management catalogue to restrict the use of hazardous substances. To be more specific, it stipulates the categories of e-products of concern, the types of hazardous substances restricted, and any exceptional requirements.

In addition, the new edition of RoHS Directive adds a system of conformity assessment to the restriction of the use of hazardous substances contained in e-products. For the e-products contained in the compliance management catalogue, the amount of hazardous substances used is supposed to satisfy the national or industry standard and the products have to be managed according to the conformity assessment system.

3.2. WEEE Treatment List (2014 edition)

To help coordinate the implementation of China WEEE Directive, a WEEE Treatment List (first batch) was released in 2011, which included five kinds of e-waste: televisions, refrigerators, washing machines, air conditioners, and personal computers. On this basis, the licensed plants were to mainly disassemble these five kinds of e-waste.

As the e-waste treatment industry in China has developed, an expansion of the scope of the treatment catalogue has become a realistic demand. In 2013, the NDRC and MF jointly evaluated the implementation of the first batch of the treatment catalogue and studied if adjustments to the catalogue were necessary. After extensive consultation and research, the WEEE Treatment List (2014 edition) was officially released in February 2015. In the new edition, e-waste has been extended to 14 categories based on the original 5 types. The added categories are range hood, electric water-heater, gas water-heater, printer, copier, fax machine, monitor, mobile phone and single-machine telephone.

3.3. WEEE fund standard (2016 edition)

According to “Fund Policy”, the e-products that are sold and used in China are the objectives for the fund collection. So the domestic producers and consignees or agents of imported e-products should fulfill their payment obligations of the fund. Moreover, the imported units are included for the fund collection while the exported ones are excluded [20]. Currently, the producer and importer of e-products should pay 13 yuan Renminbi (RMB), 12 RMB, 7 RMB, 7 RMB and 10 RMB, for each television, refrigerator, washing machine, air conditioner and personal computer, respectively.

By keeping an audit of e-waste disassembly, the licensed plants can acquire the fund. The MF started to adjust the existing funding subsidy in 2015 according to changes in the treatment costs and...
the profits from e-waste. The newly established subsidy standard was put into force on 1 January 2016. Compared with the old standard (formulated in 2012), the new 2016 standard are predominantly characterized by a reduction in the subsidy available for disassembling televisions and personal computers and an increase in the subsidy for disassembling air conditioners (Table 1).

Table 1. WEEE funding subsidy standard in China.

| Category          | 2012 standard (RMB yuan) | 2016 standard (RMB yuan) |
|-------------------|---------------------------|---------------------------|
| Television        | 85                        | 60-70                     |
| Refrigerator      | 80                        | 80                        |
| Air conditioner   | 35                        | 130                       |
| Washing machine   | 35                        | 35-45                     |
| Personal computer | 85                        | 70                        |

3.4. Eco-design of e-products
Apart from strengthening the supervision of e-waste disassembly and recycling processes, the Chinese government has begun to control the pollution sources and to utilize resources more effectively from the perspective of eco-design. Since July 2014, the MIIT has begun to establish eight demonstration industries to coordinate eco-design of industrial products. The aim is to transform industrial pollution control from end-of-pipe treatment to whole life cycle management.

The first batch of eco-design pilot enterprises was published in June 2015. It included seven e-products producers mainly producing televisions, liquid crystal displays (LCDs), refrigerators, air conditioners, washing machines, personal computers, dust collectors, air cleaners, relays, lead-acid batteries, etc. At present, the second batch of eco-design pilot enterprises is under declaration and more enterprises are supposed to participate in this work.

3.5. Extended producer responsibility in e-products areas
In June 2015, the MIIT launched a pilot scheme on extended producer responsibility (EPR) in electronic industry. The aim was that the producers should play a leading role in the design, production, collection and recycling of e-products.

The pilot work involved household appliances, computers and office electrical appliances, communication and electronic products, lighting electrical appliances, and batteries. In addition, a total of 15 enterprises involved in manufacturing electronic products were considered in this pilot project.

4. Future perspective: life cycle management of e-waste
To improve e-waste recycling efficiency and effectively control environmental risk, a conceptual model for the life cycle management of e-waste is proposed (Figure 3).

When considering the life cycle stages, it is necessary to obtain relevant information about key components, material metabolism, and input/output of materials in the treatment process, starting from its generation to the final disposal of the e-waste. The life cycle implications of e-waste can then be systematically analyzed and diagnosed using appropriate tools including material flow analysis (MFA), LCA, life cycle costing (LCC), and social life cycle assessment (S-LCA). This leads to the decision-making process. In the process, it is helpful to consider life cycle engineering aspects including eco-design, recycling techniques, and prevention and control of pollution. Finally, the life cycle thinking stage is reached wherein consideration is given to laws, regulations, standards, and government policies in place.

Based on life cycle thinking and EPR principle, the “Fund Policy” implemented in China requires the producers and importers of e-products to meet the cost of treat e-waste. At present, the “Fund Policy” is still in its infancy, a lot of endeavor is needed to improve its optimization [20]. Depending
on the effect of the “Fund Policy”, a dynamic regulation mechanism needs to be established in the future to adjust the fund collected and subsidy standard so as to improve the policy performance. The fund collected for treating e-waste inevitably increases the economic burden on producers. For e-products enterprises adopting eco-design or participating in e-waste recycling, the fund collected is meant to be reduced within a certain range from a life cycle perspective. On the pretext of maintaining the stability of the total fund, the funding subsidy standard is supposed to be adjusted according to development in the industry in a timely manner.

**Figure 3.** Life cycle management scheme for e-waste.

5. **Conclusions**

There are large amounts of e-waste generated in China which have a high recycling value. In recent years, the amount of e-waste formally treated has increased at a steady rate. As the number of formal treatment plants for e-waste has increased, the layout of the formal sector has been basically realized providing an increasingly enhanced recycling ability. Meanwhile, by enhancing environmental supervision and effectively controlling illegal disassembly activities, the informal sector have been transformed to formal one.

To implement an LCM scheme for e-waste, four aspects need to be considered simultaneously: the life cycle stages, life cycle tools, life cycle engineering, and life cycle thinking. Our suggestion is to first identify the life cycle stages of the e-waste and extract the important life cycle information. Then, life cycle approaches and tools can be used to conduct a systematic analysis to help decide how to maximize the benefits from a series of life cycle engineering processes. Meanwhile, life cycle thinking is applied to improve the laws and regulations, standards, and policies relating to e-waste so as to continuously improve the sustainability of the e-waste treatment system. This framework should help to realize sustainable management of e-waste in developing countries where legislation surrounding e-waste management is imperfect and the treatment system is relatively immature.

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