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The recycling and disposal of electrical and electronic waste in China—legislative and market responses

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Abstract

The development of new legislation on collection, recycling and disposal of waste electrical and electronic equipment (WEEE) as well as the scaling-up and privatisation of the WEEE processing industry, are indications of major changes for WEEE management in China. However, China's attempts to regulate the industry and establish a financially viable, environmentally benign and safe WEEE management system are facing significant challenges. The existence of an extensive informal sector, combined with a lack of environmental awareness among WEEE collectors, recyclers and consumers, are contributing to China's difficulties in developing a financially and environmentally sound recycling and disposal system. This paper discusses the current status of WEEE recycling and disposal in China, and its impacts on the environment, human health, and the economy. It also examines the legislative and market responses to the WEEE issue, and how these will be affected by Chinese attitudes and practices towards WEEE recycling.

Keywords: WEEE; E-waste; Waste management; Informal sector; Recycling; China

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1. Introduction

In response to the growing concern over how China will manage its increasing piles of waste electrical and electronic equipment (WEEE), central government departments have drafted a number of interrelated legislations. A national pilot program has also been initiated by the National Development and Reform Commission (NDRC) to determine the most suitable model for a Chinese WEEE management system. Growing interest in the WEEE recycling business from the private sector is another indicator of the significant changes in store for China's largely unregulated and environmentally unsound WEEE processing industry. The rationale behind these legislative and market developments is clear, driven by factors such as the environmental and health impacts of WEEE recycling and disposal, and the incentive of complying with international environmental standards.

However, the reform of China's WEEE recycling and disposal system is facing a number of significant challenges. First, China's extensive informal waste sector collects, recycles and disposes of the major part of the country's WEEE before it can reach officially sanctioned recycling and disposal enterprises. There are a number of reasons for the existence of such a large and effective informal WEEE processing sector. In China, as in other developing and industrialising countries, waste is viewed as a resource and income-generating opportunity. There is a general reluctance to pay for waste recycling and disposal services, particularly when consumers can make money by selling their old and broken appliances. In addition, research shows that waste collection and disposal services in developing countries cost a higher proportion of the average income than in developed countries (Cointreau, 2005). Another challenge for the reform of China's WEEE recycling and disposal practices is a lack of awareness among consumers, collectors and recyclers of the potential hazards of WEEE. Although the informal sector and the understanding of waste as a resource encourage the collection and recycling of WEEE, these will also have a decisive impact on attempts in China to apply the principles of existing models of WEEE management from abroad.

2. The environmental, health and economic aspects of WEEE recycling and disposal

2.1. Environmental and health impacts

In China, WEEE is becoming an important waste stream, both in terms of quantity and toxicity. WEEE refers to discarded appliances, such as televisions and refrigerators, as well as a variety of associated waste products, such as electrical wiring, printed wiring boards (PWBs), and batteries. WEEE also contains a myriad of toxic components and materials that can cause significant damage to the environment and human health if recycling and disposal is unregulated.

China's WEEE can be sourced both to domestically produced and discarded products and imported waste. China is the destination for a substantial proportion of WEEE from developed countries, ostensibly exported to developing countries for 'reutilisation'. For example, representatives within the United States' recycling industry have indicated that around 80% of the WEEE they receive is exported to Asia, and 90% of this goes to China

(BAN et al., 2002). Although figures on the actual quantity of WEEE imports are unavailable, certain news reports in China claim that imports are an increasing problem, and have spread from Guangdong to Hunan, Zhejiang, Shanghai, Tianjin, Fujian and Shangdong (for example; The People's Daily, June 21, 2004). In response to this influx of WEEE imports, the Chinese government announced a ban on the import of the seventh category of waste in China's waste catalogue, including waste appliances and electronic products, which came into effect on February 1, 2000 (SEPA, 2000).

Although the long-term generation of WEEE has yet to be determined, with rapid industrialisation since the 1980s, a peak period in both the ownership and dumping of household and office appliances is also expected in China. China will see the additional purchase of an estimated 5 million new computers, 4 million refrigerators, 5 million clothes washers, and 10 million televisions every year after 2003 (Xinhuanet, May 23, 2004). Moreover, the majority of WEEE in China is processed in small workshops using basic methods such as manual disassembly and open incineration. The appliances are stripped of their most valuable and easily extracted components and materials, while the remainder is dumped.

The most prominent areas for the small-scale, unlicensed processing of WEEE are in southern Guangdong Province, and around the city of Taizhou, in eastern Zhejiang Province. The town of Guiyu, in Guangdong, attracted international attention after a report by non-governmental organisations, including the Basel Action Network (BAN) and Greenpeace China, on WEEE trading and processing in Asia.

Guiyu is an established WEEE recycling centre, made up of many small-scale enterprises. Investigations carried out in December 2001 by BAN and Greenpeace personnel indicated that the growth of this industry has lead to serious environmental and health impacts in the area (BAN et al., 2002). The potentially hazardous recycling practices witnessed in Guiyu included the manual and unprotected removal of printer cartridge toner, the open incineration of wires to recover copper, the de-soldering of printed wiring boards, and the use of acid baths to retrieve gold from chips and other components. Children were also seen employed in sorting plastic chips for recycling. In addition, the report states that large amounts of materials and residues were being dumped in fields, rivers, and irrigation ditches. Water samples taken by BAN and by Eastweek Magazine at the same locations on the Lijiang River show cadmium content in the range of 0.01–0.033 mg/L, compared to the WHO guideline of 0.003 mg/L, and lead content varying between 1.9 and 24 mg/L, higher than the WHO guideline of 0.01 mg/L (see Table 1). Due to groundwater pollution, Guiyu's drinking water has been delivered from a nearby town since approximately 1 year after the appearance of the WEEE industry.

Table 1
Water samples taken at the Lijiang River (BAN et al., 2002)

Substance	Lijiang River sample A (mg/L)	Lijiang River sample B (mg/L)	WHO guideline values (mg/L)
Lead	1.9	24	0.01
Cadmium	0.01	0.033	0.003
Mercury	<0.001	<0.001	0.001
Copper	1.3	2.6	2

Further, the report claims that a large proportion of the WEEE found in Guiyu originated in the USA, Japan and Europe.

In September 2003, the Shantou University Anthropology Department and Greenpeace China, followed up on this report with a survey of the anthropological aspects of WEEE processing in Guiyu. The survey details the social and health effects of Guiyu's WEEE processing industry, which is now more than a decade old and involves approximately 80% of the families in the area. Guiyu residents have made substantial profits from the industry, which is organised and controlled by local family groups. Actual recycling and treatment, however, is carried out by poorly paid migrant workers from outside the area who are willing to put up with the inferior conditions and the hazards of WEEE processing. These workers numbered more than 100,000 at the time of the survey. Interviews at the local hospital show that Guiyu suffers from many cases of respiratory tract infection and kidney stones, and that the incidence of these health problems is higher among migrant workers. The report also concludes that WEEE processing is increasingly industrialised and now a fundamental part of Guiyu's economy and society.

The international and domestic attention given to the processing of WEEE in southern and eastern China has drawn responses from the central and local authorities in China. In Taizhou, the city government has attempted to regulate and control its WEEE processing enterprises, and asserts that it has made significant progress in controlling the illegal import of WEEE. According to a report by the Pollution Control Division of the Taizhou Environmental Protection Bureau (EPB) (Shen, 2005), the processing of imported waste and domestically produced WEEE is moving towards a system of "fixed-point processing parks". These are government-established industrial parks, where processing enterprises can set up regulated recycling and disposal businesses. The Taizhou EPB states that Taizhou now has 42 fixed-point waste processing enterprises capable of processing waste including WEEE.

2.2. Economic considerations

China also faces incentives to comply with international environmental standards. Of particular concern to China's electrical and electronic equipment producers are the EU's two new directives. The Waste Electrical Electronic Equipment (WEEE) Directive requires EU member countries to have mandatory recycling systems for WEEE in place by August 13, 2005. The Restriction of Hazardous Substances (RoHS) Directive bans the use of six hazardous substances in electric and electronic products put on the market after July 1, 2006. According to statistical data presented in Guo et al. (2005, draft), exports from the electrical and electronic equipment sector earned China US$227.46 billion in 2003, accounting for 51.9% of the country's total export value. Of these exports, approximately 25% went to the EU. Around 70% of the China Electronics Import and Export Corporation's exports to the EU, for example, fall under the WEEE and RoHS directives, and unless full compliance with the new standards can be achieved, there is a risk these will be reduced by 30–50% (Business Weekly, October 13th, 2004). The economic imperative of complying with WEEE standards overseas is therefore an encouraging factor in the development of a domestic WEEE management system.

WEEE recycling and disposal also has a role in resource reutilisation and income generation. China is often characterised as a resource-poor country, with per capita distribution of natural resources at 58% of the world average (SEPA, 2004). In addition, China's growing appliance manufacturing sector requires large amounts of raw materials and components, and recycled materials are regarded more favourably than they are in Europe or North America. The unregulated processing of WEEE results in the recycling of only the most precious and easily extracted materials, such as copper wiring, lead solder and gold plating. Other more difficult to process or less valuable components, such as toner cartridges and desoldered printed wiring boards, are often discarded. It is therefore viewed by the Chinese government as a waste of useful resources.

The WEEE industry also provides income generating opportunities for both individuals and enterprises, as waste is sold and traded among collectors, processors, second-hand dealers and consumers. For example, the extensive WEEE processing industry in Guiyu has been valued at about RMB 600 million per year, or approximately US$72 million (Dayoo Daily News, October 19, 2004). More formal recycling enterprises are also developing an interest in WEEE recycling and processing in China. Cheap labour and a favourable investment environment have already seen the relocation of recycling business in general from industrialised countries to China. New WEEE recycling and treatment facilities are planned and financed by both governments and private companies for Hangzhou, Wuxi, Nanjing and Beijing, despite the current lack of a regulatory framework for such enterprises.

3. Legislative and market responses: a potential revolution for China's WEEE industry

3.1. Draft legislation

Three major, national-level legislations have been drafted in response to the perceived problem of WEEE management in China. These build upon and strengthen earlier regulations on the prevention of pollution from solid waste and the import of waste, which have proven insufficient for the management of WEEE. For example, SEPA, 2003 "Notice on Strengthening the Environmental management of WEEE" prohibits the non-environmentally sound processing of WEEE and states that provincial-level EPBs may issue hazardous waste processing licenses to enterprises that can meet environmental requirements for WEEE recycling, in accordance with the "Law on the Prevention of Environmental Pollution from Solid Waste" (SEPA, 2003). However, a specific licensing system for waste appliance recycling and treatment does not yet exist. Prepared by different government agencies, the three new legislations focus on different stages of WEEE management, with two draft laws in a similar format to the two EU directives on WEEE and RoHS, and a third technical policy providing guidance for the State Environmental Protection Administration's (SEPA) management of WEEE. The three legislations are summarised below. Please see Table 2 below for an overview of legislation relevant to WEEE management in China.

Table 2
Overview of China's national WEEE management-related legislation[a]

Law or regulation	Major content	Status/date
Law on the prevention of environmental pollution from solid waste (SEPA)	Disposal of municipal and industrial solid waste; use of solid wastes as raw materials.	Effective from April 1, 1996.
Notification on the import of the seventh category of wastes (SEPA)	Ban on the import of the seventh category of waste.	Effective from February 1, 2000.
Notice on strengthening the environmental management of WEEE (SEPA)	WEEE processing to meet the requirements of the "Law on the prevention of environmental pollution from solid waste"; generation of WEEE to be reported to local EPBs.	Issued August 26, 2003.
Ordinance on the management of waste household electrical and electronic products recycling and disposal (Draft, NDRC)	Mandatory recycling of WEEE, based on extended producer responsibility; certification for 2nd hand appliances, and recycling enterprises.	Submitted for approval to the State Council in early 2005.
Management measure for the prevention of pollution from electronic products (Draft, MII)	Restrictions on the use of hazardous substances; 'green' product design; provision of information on the components, hazardous substances, and recycling.	If approved, effective from July 1, 2005; restrictions to be enforced after July 1, 2006.

[a] Sources: BAN et al. (2002); Guo et al. (2005, Draft); NDRC (2004, Draft); SEPA (2003, 2000, 1995); Chen (2004).

3.1.1. The draft ordinance on the management of waste household electrical and electronic products recycling and disposal

The NDRC began preparation of this law in 2001, including research, workshops, and the initiation of a pilot program to trial WEEE management measures. The major content of the draft include:

- The establishment of a special fund to assist in the financing of WEEE recycling and disposal.
- The use of positive measures to encourage the establishment of WEEE recycling and disposal enterprises, as well as support the development of relevant technology, methods and education.
- The implementation of 'extended producer responsibility' (EPR), obliging producers to cover the costs of collection, recycling and disposal. Their responsibilities will include using designs beneficial to recycling, choosing non-toxic, non-hazardous substances and recyclable materials, and providing information to aid recycling. Appliance retailers and service providers will also be obliged to collect WEEE from consumers.

- The establishment of standards and a certification system for second hand appliances, and recycling and disposal enterprises, to ensure safety and the environmentally-sound processing of WEEE.

A draft for comments was released in September 2004, and has now been submitted to the State Council (The People's Daily, February 7, 2005). However, the actual date for the official issuance of the legislation remains a matter of speculation.

3.1.2. The draft management measure for the prevention of pollution from electronic products

The national Ministry of Information Industry (MII) began drafting this law in 2002. It aims to reduce the hazardous and toxic substances and materials present in electronic appliances, and to reduce the pollution caused by the production, recycling and disposal of these products. This draft legislation is a counterpart to the EU RoHS directive, including:

- Restrictions on the use of six hazardous substances in electrical and electronic products: lead, mercury, chromium IV, cadmium, PBBs[1] and PBDE[2].
- Requirements for 'green' product design.
- Requirement for producers to provide information on the components and hazardous substances present in their products, as well as on safe use and recycling.

According to representatives from the MII Economic Systems Reform and Economic Operations Department, it will also involve a component on standards and testing, and a catalogue of products covered by the law (Huang, 2004; Gao, 2004). If passed this year, it will come into effect on July 1, 2005 with the restrictions on hazardous substances to be enforced after July 1, 2006, corresponding with the EU's RoHS Directive.

3.1.3. The technical policy for the prevention of pollution from waste electrical and electronic products

Drafted by SEPA, this technical policy was approved at an expert meeting in September 2004. The goal of this policy is to reduce the overall volume of WEEE, to increase the reutilisation rate and standard of WEEE recycling, and to reduce negative environmental impacts. It includes content on: green product design and green product labels; the management of WEEE collection, storage, recycling and disposal; the encouragement of research and development of technology and equipment; and the formulation of associated national policies and standards (Guo et al., 2005, draft).

China's draft WEEE and hazardous substances legislations have drawn cautious responses from stakeholders, such as the electrical and electronic equipment manufacturing industry. Although the improvement of environmental standards is recognised as an opportunity to promote the technological advancement and competitiveness of Chinese industries, there are major concerns about how the future WEEE management system will be financed and enforced. The manufacturing sector

[1] PBB: Polybrominated biphenyls.
[2] PBDE: Polybrominated diphenyl ethers.

claims to have too small a profit margin to bear the increasing costs of 'green' design, testing and recycling. Recyclers are also worried about the high costs of purchasing WEEE in China, and the lack of preferential policies for recycling and disposal companies (for example: Southern Daily, November 4, 2004). In addition, enforcement of legislation is already a contentious issue in China, where government departments have limited resources for monitoring and control.

3.2. Pilot programs

The NDRC is currently implementing a national pilot program, with the goal of addressing the problems in the draft legislation and the difficulties in establishing a WEEE recycling system. In 2003, the city of Qingdao and the Province of Zhejiang were selected to implement pilot WEEE management systems and explore different models for WEEE recycling and treatment. In addition, the NDRC (2003) asked that the pilots make use of technology and processes suited to China's circumstances, carry out analysis of recycling costs, and develop relevant technical standards.

Qingdao is host to China's largest appliance manufacturers, such as Hai'er, Aucma and Haixin. The Qingdao Economic and Trade Commission directs the pilot, and will trial a producer-owned recycling plant model, aiming to establish a plant with the capacity to process 600,000 items[3] of WEEE per year. According to the China Business Herald (January 4, 2005), the Hai'er Group is implementing the project, and a total of RMB 80 million (approx. US$10 million) will be invested in establishing the WEEE treatment plant. Of this investment, approximately 15% will be contributed by the government. At this stage, the project has reportedly been put on hold, as it is not clear how the investment will be recouped, and no local WEEE management regulations have been prepared.

The WEEE management pilot in Zhejiang will follow a "specialised" disposal plant model, with the establishment of a WEEE treatment facility by a specialised company. The agency responsible for the management of the pilot is the Zhejiang Provincial Economic and Trade Commission (ZETC). According to the ZETC (2004), the Hangzhou-based company, DADI Environmental Protection Co. Ltd, has been commissioned to construct a centralised disposal centre, which will make use of a network of collection and recycling points across the province. After its establishment, Zhejiang Province aims to recycle 800,000 units of WEEE each year. At this stage, DADI's recycling and disposal facility will process major appliances, including air-conditioners, washers, refrigerators, televisions, and computers, as well as printed wiring boards. Together with the China Home Appliance Research Institute and the China Home Appliance Association, DADI has invested RMB 2 million (US$250 000) in the establishment of an R & D centre. Approximately RMB 100 million (US$12.5 million) will be invested in the centralised treatment facility, which has already obtained approval and begun collecting WEEE. The ZETC has also formulated standards for the certification of second-hand appliances for resale, and a provisional WEEE Management Measure, which came into effect on January 1, 2005. The Measure is broad and temporary, to allow changes once national regulations are in place.

[3] Quantities of WEEE in China are often provided in items rather than tons.

Both pilot programs have experienced difficulties in collecting WEEE and covering the costs of environmentally sound processing. According to a representative from Hai'er, environmentally sound processing measures account for fully one half of recycling costs, and if the company pays more for waste to compete with collectors, it will make a loss of tens of millions of yuan (China Business Herald, January 4, 2005). Similarly, DADI collected a relatively small amount in 2004, including 35.6 t of waste appliances, 4.6 t of waste computer products, and 10.2 t of light bulbs and tubes. According to Mr. Hong Liang (2005), DADI's vice general manager, the company has slowed down its collection activities due to the high cost of paying for WEEE, which averages RMB 110 (US$13) per item, not including transport and personnel costs.

As well as the national pilot program, local government WEEE management initiatives are being developed in Tianjin, Shijiazhuang and Shanghai. Tianjin, for example, is currently attempting to revive the state-owned recycling network that existed from 1955 to 1990. The Economic Observer (November 17, 2004) reports that the Tianjin Green Angel Co. Ltd. is setting up the '1931' system, referring to 1000 neighbourhood recycling stations, 9 transfer stations, 3 exchange centres for recycled materials, and one WEEE treatment plant. The Shanghai city government is also planning to establish its own facility, with a capacity to treat 500,000 items per year (Shanghai Star, August 26, 2004). As in Zhejiang and Qingdao, these initiatives are facing collection difficulties, as appliances are stripped of valuable components and dumped or sold to second-hand dealers and workshops.

3.3. Industry and market developments

The demand for recycled materials and the potential new regulatory framework are contributing to industrial scaling-up and increased interest among companies in investing in WEEE processing. In addition, large international electronics companies are extending their corporate responsibility programs to China. Instead of relying on the Chinese regulatory system, a number of companies are developing their own initiatives, and sending external auditors to check compliance with corporate social responsibility principles.

As well as the development of WEEE facilities in the pilot programs in Qingdao and Zhejiang, China's Huaxing Group is currently choosing a site in Beijing for a pilot WEEE recycling and treatment plant (The People's Daily, February 7, 2005). New, large-scale recycling and treatment plants are also being set up in Nanjing and Wuxi. Nanjing's Jinze Co. Ltd. has invested RMB 10 million (US$1.25 million) in a plant that became technically operational in October 2004, but remains idle: the plant can process all the printed wiring boards collected over a long period in approximately one hour (China Business Herald, January 4, 2005). The industry news service, Computer Business Information (November 6, 2004) also reports that a new facility with a total investment reportedly of US$65 million is being established in Wuxi, Jiangsu Province, by the Singaporean WEEE recycling firm Citiraya, and expects to begin operations in March 2005.

Private sector WEEE take-back schemes are still limited in China, although mobile phone producers have begun to collect waste phones and accessories. Nokia launched its "Future is in Your Hands" campaign in the Asia-Pacific in 2001, and in China in 2002, with more than 200 recycling bins placed in around 100 major cities at Nokia service

centres. At this stage, Nokia China has only collected approximately 0.5 t of batteries and chargers, as consumers prefer to sell old mobile phones on the second-hand market, a common practice in China[4]. Philips has stated it will soon choose a company to recycle its products in China and sponsored the "Sino-Netherlands Electronic Waste Recycling Conference" in November 2004 (Central TV Economic News Broadcast, November 20, 2004). In addition, Fortune Plastic and Metal Inc. won a contract from Motorola to collect and recycle mobile phones in more than 100 Chinese cities, to be processed at the Jinze WEEE plant in Nanjing.

China's changing WEEE processing industry and growing equipment manufacturing sector offers both opportunities and risks for companies. As well as the chance to enter China's WEEE recycling and disposal market at an early stage, the need to comply with environmental and technical standards has created a market opportunity for the provision of consultancy to Chinese companies on 'green' design, design for disassembly and testing for hazardous substances. However, the difficulties of operating in an uncertain regulatory environment and competing with China's large and effective informal sector also demonstrate the risks of investing in this field.

4. Conclusions

An examination of China's fledgling WEEE management system shows that attempts to regulate and industrialise the processing industry are facing a major challenge in terms of financing and collection. The pilot programs in Qingdao and Zhejiang, as well as newly established facilities, are finding it difficult to compete with China's large and unregulated informal sector. Informal collectors and second-hand appliance dealers remove WEEE from the waste stream before formal recycling companies can obtain it, and divert it to informal processing workshops and poorer regions of China.

There is a fundamental difference between the current European models of WEEE management and the reality of WEEE recycling in China. In various European and in the Japanese WEEE recycling system, consumers either pay to return waste appliances or return them free of charge. Recycling companies can generate revenue from selling refurbished appliances, components and recycled raw materials, as well as charging fees to producers or consumers. In China, however, a consumer or company expects to receive payment for their WEEE, which is viewed as a potentially valuable resource. Recycling enterprises must pay for their materials and lose the extra revenue of charging fees. The cost of buying WEEE, combined with the expense of environmentally sound processing, means that official WEEE recycling businesses in China find it very difficult to compete with small, unlicensed collectors and workshops that operate with limited environmental protection measures.

Uncertainty as to how recycling businesses will obtain a return on their investment increases the risk for foreign companies investing in China's WEEE industry. Recycling and treatment facilities require a high initial investment, particularly those fitted with

[4] Personal correspondence with Nokia China, dated March 7 & March 10, 2005.

technologically advanced equipment and processes. The risk of setting up businesses outside China's government-supported WEEE pilot programs is high, and formal, modern recycling and treatment facilities still rely on government co-financing and preferential policies. The reform of China's WEEE industry requires the environmentally-sound and regulated processing of waste, but how this will be paid for requires further research and consideration.

The implementation of China's draft WEEE ordinance aims to significantly reform the framework of the WEEE recycling system. The institution of licensing and a system based on extended producer responsibility, for example, will transfer some of the burden of recycling onto appliance producers, make the arbitrary dumping of WEEE illegal, and institute standards for the sale of second-hand appliances. However, it is a difficult task to reduce the costs of collection and recycling by banning the sale and trade of WEEE in a country where it represents a resource. The draft ordinance does not attempt to do so, with Article 14 stating that "(c)onsumers should sell their waste electric and electronic equipment to appliance distributors, after-sales service organisations, or recycling enterprises" (NDRC, 2004). Further, the ordinance does not state that informal or individual WEEE collection will be banned or restricted. Given the difficulty of controlling China's informal processing sector, new strategies must be sought to develop financially viable, environmentally sound and safe processing. As noted by Darby et al. (2004), new regulatory approaches can have long-term implications for financial, environmental and social sustainability beyond the initial intentions of their designers. Similarly, a lack of attention to the issues of sustainability may result in a new policy unable to effect the desired change in practice and behaviour. Darby et al. (2004) recommend, for example, increased efforts to include all relevant stakeholders and consumers in WEEE recycling systems. Raising awareness among collectors, recyclers and consumers of the potential dangers of recycling and dumping old and broken appliances can contribute to building new attitudes toward WEEE.

How to incorporate the informal sector into a well-regulated WEEE management system, how to transfer the experience and know-how of existing models from abroad, and how to successfully combine this with the reality of current practice in China are therefore important questions for the country's developing WEEE recycling and disposal system.

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