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Measuring treatment costs of typical waste electrical and electronic equipment: A pre-research for Chinese policy making

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ABSTRACT

Waste Electrical and Electronic Equipment (WEEE) volume is increasing, worldwide. In 2011, the Chinese government issued new regulations on WEEE recycling and disposal, establishing a WEEE treatment subsidy funded by a levy on producers of electrical and electronic equipment. In order to evaluate WEEE recycling treatment costs and revenue possibilities under the new regulations, and to propose suggestions for cost-effective WEEE management, a comprehensive revenue-expenditure model (REM), were established for this study, including 7 types of costs, 4 types of fees, and one type of revenue. Since TV sets dominated the volume of WEEE treated from 2013 to 2014, with a contribution rate of 87.3%, TV sets were taken as a representative case. Results showed that the treatment cost varied from 46.4 RMB/unit to 82.5 RMB/unit, with a treatment quantity of 130,000 units to 1,200,000 units per year in China. Collection cost accounted for the largest portion (about 70.0%), while taxes and fees (about 11.0 %) and labor cost (about 7.0 %) contributed less. The average costs for disposal, sales, and taxes had no influence on treatment quantity (TQ). TQ might have an adverse effect on average labor and management costs; while average collection and purchase fees, and financing costs, would vary with purchase price, and the average sales fees and taxes would vary with the sales of dismantled materials and other recycled products. Recycling enterprises could reduce their costs by setting up online and offline collection platforms, cooperating with individual collectors, creating door-to-door collection channels, improving production efficiency and reducing administrative expenditures. The government could provide economic incentives—such as subsidies, low-cost loans, tax cuts and credits—and could also raise public awareness of waste management and environmental protection, in order to capture some of the WEEE currently discarded into the general waste stream. Foreign companies with advanced WEEE utilization technology could invest or participate in this area, producing profits for themselves while helping to develop and implement environmentally friendly and energy-saving technologies applicable to the Chinese market.

1. Introduction

Waste Electrical and Electronic Equipment (WEEE) is one of the fastest-growing sustainability problems throughout the world, as the variety of toxic substances contained therein can contaminate the environment and threaten human health, if disposal protocols are not meticulously managed (Kiddee et al., 2013). Intensive uncontrolled processing of WEEE in China has resulted in the release of large amounts of heavy metals into the local environment, and created high concentrations of metals in the surrounding air, dust, soil, sediment and plants (Song and Li, 2014). As a result of the increased consumption and continual turnover of EEE, not only nationally but worldwide, China is now facing serious WEEE problems from both growing domestic generation and foreign imports. Because of the environmental and social concerns surrounding WEEE recycling, the Chinese government has established domestic collection and recycling systems in order to promote environmentally sound WEEE treatment (Li et al., 2011). Implemented on 1 January 2011, the Chinese Management Regulation for WEEE Recycling and Disposal can be regarded as the counterpart of the EU's WEEE Directive (2012/19/EU), and is a pivotal piece of national WEEE management legislation in China. To implement the regulation, the Chinese government established a "specialized fund" to subsidize the formal collection and recycling activities of WEEE in China. Since September 2010, 5 types of home appliances (TV sets, refrigerators, washing machines, air

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conditioners and personal computers) have been regulated, and producers must pay fees for their products, to the WEEE treatment fund. Based on their volume of processed WEEE, WEEE recycling enterprises can then apply for a subsidy, to ensure the safe and responsible processing of WEEE. Tang and Wan (2014) found that 5 types of WEEE, with a total amount of 42.35 million units, were treated in an environmentally sound way by permitted enterprises in 2013. Beginning in March 2016, another 9 types of WEEE will be included in the subsidy lists, according to the "WEEE Treatment Catalogue (2014)." The exact subsidy amounts for these 9 types of products will be specified in the near future.

Several different models have been reported in the literature, for estimating WEEE treatment and recycling costs. Achillasa et al. (2013) used a cost–benefit approach to analyze the appropriate manual dismantling extent required in order to maximize profitability and minimize the end-of-life management costs. Moussiopoulos et al. (2012) provided guidelines for facility locations for WEEE collection, and calculated the transportation costs for WEEE management, and Ahluwalia and Nema (2009) presented an approach to achieving the multiple objectives of economy, perceived risk, and health and environmental risk, over the entire life cycle of waste computers. However, it is still difficult to gather specific details involved in WEEE treatment research.

This study focused on the cost of the entire WEEE recycling process, to develop a cost structure and model that could be used as a reference for WEEE treatment in China. Since about 90% of WEEEs are TV sets, this study took TV sets as an example, to calculate the treatment cost and determine the contributions of the multiple factors influencing those costs.

Based on literature review, a questionnaire survey, and face-to-face interviews, this study analyzed the WEEE treatment cost structure systematically, embedded all relevant cost elements, and interpreted each constituent explicitly. The results could prove helpful for other types of waste treatment cost calculations.

The remainder of this study is organized as follows: Section 2 is a review of the literature of WEEE treatment cost calculation methods; Section 3 describes the model used here for WEEE treatment cost calculations; Section 4 is a framework to help address the WEEE treatment cost in China (especially TV sets) and give suggestions for WEEE management; and Section 5 presents the main conclusions.

2. Literature review

Kang and Schoenung (2006) identified the costs and revenue drivers by using technical-cost modeling (TCM) for the various techniques used for WEEE processing at material recovery facilities (MRFs) in the state of California, United States. The United Nations University (UNU, 2008) launched an evaluation of the implementation of the WEEE Directive in the EU Member States, focusing on the total environmental, economic and social impacts, and technical, operational and additional costs were defined in an economic and eco-environmental benefits analysis. The United Nations Environment Programme (UNEP, 2007) released their "E-Waste Volume II: E-waste Management Manual", and selected India as a case study, to analyze the technical and economic feasibility of establishing a WEEE treatment facility, with financial analysis carried out by calculating the capital, operational and maintenance costs.

Gregory and Kirchain (2008) proposed a framework for evaluating the economic performance of a recycling system, and used data on the collection, processing, and management costs as a preliminary test of the framework, creating a matrix of several net costs for stakeholders within each system. Dahmus et al. (2008) developed a general model for evaluating the economic and environmental performance of electronics recycling systems, including collection, processing, and system management costs.

The UNEP (2011) also published "E-Waste Volume III: WEEE/E-waste 'Take-Back System'", presenting 5 financing models and funding for supply chains, and, in order to cover every aspect of WEEE management, individual costs, including collection, transportation and treatment costs, were summed mathematically.

The Association for Electrical Home Appliances (AEHA, unpublished data 2009) of Japan analyzed the operational cost of WEEE treatment enterprises, mainly focusing on the costs of management, facilities investment, plant construction, waste disposal, sales revenue of valuable materials, and ongoing maintenance charges. The China Household Electrical Appliances Association (CHEAA), the China Association of Circular Economy (CACE), and the China Resources Recycling Association (CRRA) also carried out research on WEEE recycling and treatment costs in 2010, and their treatment cost evaluation included collection fees, treatment expenditures, and sales revenue. In the Taiwan region of China, the fees for the collection and treatment were estimated according to the ratified rates, the calculation of which included sales revenue and the costs of collection (including transportation), equipment, marketing, construction, land, operations, and administration. The specified WEEE treatment enterprises used their own financial methods to calculate the costs and profits, calculating the net profits as revenues minus expenses, which included corporate income taxes.

The Stiftung Elektro-Altgeräteregister (Foundation EAR, German clearing house, 2011) compiled the logistics, storage and treatment costs of WEEE, starting with the pickup of the containers at the municipal collection points, to evaluate the WEEE treatment cost; their analysis did not therefore include the public waste management authority (PuWaMA)'s cost for the WEEE collection. In 2012, the Regional Environmental Center (REC) in Turkey developed cost-benefit models based on several scenarios using different projection tools, to estimate WEEE (cooling & freezing appliances) logistics and treatment costs.

Blaser and Schluep (2012) conducted research on the economic feasibility of building a WEEE treatment facility in Dar es Salaam, Tanzania, and their model considered three main processes: collection, recycling and refurbishment. Other researchers have investigated costs in other fields, using cost-effectiveness analyses of chemical risk control policies (Oka, 2003), and input–output energy analysis in Pistachio production (Külekci and Aksoy, 2013); both of these researches were based on cost-benefit analysis (CBA). Song et al. (2013) used life cycle assessment (LCA) to discuss a typical e-waste treatment enterprise in China.

A literature review shows that the WEEE treatment cost comes mainly from collection, transportation, dismantling, recycling, and final disposal. Each of these can be calculated separately and independently, and summed to produce the total cost.

Comparing WEEE collection prices and dismantled material values (Xu and Qiu, 2011), the bigger the gap between price and value, the lower the quantity of a particular type of WEEE treated by permitted enterprises (Table 1), leading to a suspicion that some unregulated WEEE treatment enterprises may still exist in China. Countermeasures, such as raising the standard subsidy for high-value WEEE, could be implemented, in order to regulate and optimize the recycling and treatment activities.

The WEEE recycling and disposal process consists of three major activities: collection, treatment and management. Table 2 lists the detailed components, divided into these three categories, and indicates which ones have been found to be concerns. According to reports in the literature, the logistics cost is of the most concern, followed by dismantling and pretreatment fees, disposal fees, sales revenue, and labor costs; fund audit and collection costs, and labor and temporary storage costs in the collection stage, are of

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