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Perspective

China E-waste management: Struggling for future success

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More than one decade has passed since the Chinese government enacted the legislation system for Waste Electric and Electronic Equipment (WEEE or e-waste): *Bulletin regarding strengthening environmental management of WEEE* (*The Bulletin*) and implemented the *Management Regulation on the Recycling of Waste Electrical and Electronic Products subsequently* (hereinafter "WEEE Regulation") (Li et al., 2015). These policies seem to have transformed the once notoriously polluting e-waste management in China. As of 2017, 109 authorized WEEE recycling enterprises have been established to process approximately 79 million WEEE units, weighing, in total, an estimated 1.7 million tons after enacting changes according to the WEEE Regulation. Guiyu County which was notorious for e-waste mismanagement and extensive environmental pollution, transformed its polluting e-waste mining operations into a relatively cleaner resource recovery establishment. This transformation is responsible in part for the 2016 United Nations Environment Assembly's recognition of the "China model" of e-waste management, which the Assembly deemed worthy of international promotion and replication.

Financial support for the *Home Appliances Trade-in Policy* (Implementation Measures of the 'trade-in' of Automobile and Home Appliances) and *the Fund policy* (Administrative Measures on the Collection and Using of Waste Electrical and Electronic Equipment Treat Fund), (Logan and Rabaey, 2012) spurred the success of the China model of e-waste management particularly. Between June 6, 2009 and May 31, 2011, the Trade-in Policy was responsible for collecting and recycling 57.61 million units of home appliance waste (hereinafter "WHA") (which included mainly air conditioners, TVs, washing machines, computers, and refrigerators)—14% of the total WHA generated in China during that period. Despite this impressive achievement, the Trade-in Policy came to end two years later because it was a tremendous financial burden on the country.

Following the demise of the Trade-in Policy, the Chinese government established the Fund policy, a supplement to the WEEE regulation, similar to the European Union's Extended Producer Responsibility policy. Although the Fund policy did partially inherit its success from the Trade-in Policy, it was far more successful because it offered significant subsidies—5.4 billion Yuan in 2015—to the authorized WEEE recycling and recovery companies.

Just as the financial support of the Fund stimulates the success of WEEE recycling and recovery in China, the *Technical Specifications of Pollution Control for Processing Waste Electrical and Electronic Equipment* (hereinafter "the Specifications") ensure this success by providing detailed requirements for WEEE collection, transportation, storage, disassembly, recycling, and disposal. In other words, the Specifications act as a guideline for conducting these activities. In order to receive a subsidy through the Fund, the recyclers must receive a certification denoting that their company meets the Specifications. Thus, these two policies—the Specifications and the Fund–complement each other, anchoring the success of so-called China Model.

Just as a double-edged sword—the Fund and the Specifications, also lead to their downfall. The e-waste recycling system could not sustain itself, even with the Fund subsidies. In 2015, there was a deficit of nearly 2.6 billion Yuan between the amount paid by the electric and electronic producers (2.8 billion Yuan) and the 5.4 billion Yuan subsidy provided to the WEEE recycling and recovery companies. In addition, because the Chinese model of e-waste management focused on

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recovering valuable materials under a stringent pollution control policy, it failed to implement alternative solutions such as repair, reuse, remanufacture, and neglected to consider the matter of the disposal of the unrecovered materials. For instance, according to the Specifications, around 35% WEEE units in China end up at one of the 109 authorized recycling facilities (Lu et al., 2018). At these facilities, valuable resources, like metals and circuit boards, are separated from waste and sold to the market for profit. However, once the valuable resources are collected, the remaining waste, which includes invaluable waste and hazardous materials, is transferred to other waste management companies outside of WEEE management system and, thus, this waste is reintroduced into the polluting, mismanaged pre-Specifications waste system. As such, although these policies reduce some of the WEEE pollution, they do not address the e-waste problem holistically—failing to incorporate other fundamental waste management methods such as life cycle impact assessment (LCIA), integrated solid waste management (ISWM), and industrial ecology.

The European Union's Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) program aims to shift chemical risk management to risk prevention, globally. This risk prevention approach aligns with the approaches of other related industries that imagine solutions through a broader perspective of industrial ecology. For instance, aspects of the REACH approach can be seen in the ISWM approach as it enlarges WEEE management to incorporate not just material recycling but also production prevention, reuse, recovery, and final disposal. This holistic approach to WEEE management would be the best solution for the current dilemma facing the Chinese model. To implement this approach, the following three inter-related efforts must be effectuated.

First, with respect to linking e-waste management to design-for-the-environment or eco-design approaches, in order to select less-toxic materials, the product designers and manufacturers must be properly trained in alternative analysis methodologies, including life cycle assessment (LCA) with standardized weights for trade-offs on economic cost, performance, carbon footprint, ecological and environmental impacts, and human health (Ogunseitan and Schoenung, 2012; Williams, 2011).

Second, the WEEE management system must incorporate principles from ISWM and industrial ecology. In addition to adopting mechanisms, such as repair, reuse, and remanufacture, to prolong the lifespan of Electrical and Electronic Equipment (EEEs),the recycling and recovery mechanisms should attempt to convert waste not only into marketable materials but also into energy and innovative products. Once these mechanisms have eliminated all valuable and convertible WEEE, the remaining waste should be organized and disposed of properly. These efforts may require tweaking the two anchors, The Fund and The Specifications, in order to encourage these potentially less a profitable ventures.

Finally, a holistic WEEE management system should focus on innovations that can transform waste into valuable products while taking into consideration the potential risks of those innovations. The most effective e-waste management system will maximize the amount of waste that can re-enter the manufacturing process. Therefore, the government should advocate for and increase the application of sustainable and cost-effective technologies in order to enhance the waste-to-products approach. To prevent unintended and harmful outcomes, this approach must also assess the risks of these products. Therefore, to maintain quality and avoid risks to the environment and human health, new criteria should be established for these products made from waste with one clear principle: the risk of the product must be lower than that of the waste.

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