Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Resource conservation approached with an appropriate collection and upgrade-remanufacturing for used electronic products

Gabriel I. Zlamparet [a,1], Quanyin Tan [a,1], A.B. Stevels [b,2], Jinhui Li [a,*]

[a] State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Tsinghua University, Beijing 100084, China
[b] Design for Sustainability Lab, Delft University of Technology, 3-5655 JL Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 20 May 2017
Revised 7 October 2017
Accepted 29 November 2017
Available online xxxx

Keywords:
E-waste
Remanufacturing
Reuse
Recycling

ABSTRACT

This comparative research represents an example for a better conservation of resources by reducing the amount of waste (kg) and providing it more value under the umbrella of remanufacturing. The three discussed cases will expose three issues already addressed separately in the literature. The generation of waste electrical and electronic equipment (WEEE) interacts with the environmental depletion. In this article, we gave the examples of addressed issues under the concept of remanufacturing. Online collection opportunity eliminating classical collection, a business to business (B2B) implementation for remanufactured servers and medical devices. The material reuse (recycling), component sustainability, reuse (part harvesting), product reuse (after repair/remanufacturing) indicates the recovery potential using remanufacturing tool for a better conservation of resources adding more value to the products. Our findings can provide an overview of new system organization for the general collection, market potential and the technological advantages using remanufacturing instead of recycling of WEEE or used electrical and electronic equipment.

1. Introduction

The most prominent accessories and utilities in our daily life have changed the aspects of living and communication. From the moment when the information and communication technology (ICT) expanded, the world became more interconnected through a diversity of devices. The reflection of Moore law, observed that the updating of packed components from an integrated circuit board is doubling every 18 months, increasing the electronic manufacturing, used/WEEE generation and informal recycling (Mollick, 2006; Xinwen Chi et al., 2011).

According to the UN data, from the released rapport in 2015 for the year of 2014, an approximated amount of 41.8 million metric tons (Mt) of e-waste was generated which consisted 3 Mt small IT devices, 11.8 Mt large equipment, and 7 Mt cooling and freezing equipment(Baldé et al., 2015). In most of the cases, the open dumping areas are related to the informal recycling, dismantling, discharging of hazardous substances from EEE(Abhishek Kumar and Xianlai Zeng, 2016; Rochman and Browne, 2013; Oyuna Tsydenova, 2011; Zeng, 2009).

Because of the chemical and mechanical characteristics e-waste and used electrical and electronic equipment can have another option to be regressed to a new product or raw material with less hazardous environmental effect using remanufacturing procedure.

Different solutions of the WEEE global issue can solve the problem in other manners being more or less efficient as the recycling option (Yi et al., 2016). This article reveals how technology, market potential, and electronic design can contribute to a better collection of the waste and how remanufacturing is implemented, exemplifying of an efficient collection system and internal remanufacturing scheme of used equipment as servers and

Abbreviations: U.N., United Nations; Mt, metric tons; ICT, information and communication technology; MRI, Magnetic Resonance Imaging; CT, Computer Tomography; XRD, X-ray diaphragm; EDX, energy dispersive X-ray; SEM, scanning electron microscope; PCB, printed circuit board; OEM, original equipment manufacturer; ICP-MS, inductively coupled plasma mass spectrometry; BPI, board printed integrate; B2B, business to business; B2C, business to consumer; WEEE, waste electrical and electronic equipment; EEE, electrical and electronic equipment; Pb, lead; Si, silicon; Cd, cadmium; As, arsenic; Al, aluminum; Ti, titanium; Fe, iron; Hg, mercury; IoT, internet of things.

* Corresponding author at: Room 804, Sino-Italian Environmental and Energy-efficient Building, School of Environment, Tsinghua University, Haidian District, Beijing 100084, China.

E-mail addresses: gabi_zlamparet@yahoo.com (G.I. Zlamparet), tqytsinghua@foxmail.com (Q. Tan), stevels@xs4all.nl (A.B. Stevels), jinhui@tsinghua.edu.cn (J. Li).

[1] Room 825, Sino-Italian Environmental and Energy-efficient Building, School of Environment, Tsinghua University, Haidian District, Beijing 100084, China.

[2] Design for Sustainability Lab, Delft University of Technology, 3-5655 JL Eindhoven, The Netherlands.

https://doi.org/10.1016/j.wasman.2017.11.053
0956-053X/

medical devices. In the traditional scheme of electronic collection system the complexity and time duration per transaction of used equipment is too slow and too complicated. A new practice of collection developed in China is "Internet + logistics" collecting waste/used mobile phones, tablets, and monitors. The aim of internet transactions is to build a business to business (B2B), reverse supply chain, not a business to consumer (B2C) standard collection flow, and break through information to a sustainable and fast collection reducing costs and giving more value to the WEEE. This base strengthens the material and fund flow, realizing a breakthrough in the typical industrial chain of the electronic collection. A better collaboration between B2B cuts the corridors of a slow typical collection, helping the user and receiver (remanufacturing company) of used equipment to receive the product in a shorter time and physically diagnose. The case of server remanufacturing in China and healthcare remanufacturing of medical equipment in Europe are proper examples highlighting the availability to maximize the resource value.

Remanufacturing is more sustainable than material recycling offering a new possibility to the product to be reintegrated in the life chain avoiding the transformation of components, parts and assembles in secondary materials and again in a new product (Bernard, 2011; Gutowski et al., 2011; Nabil Nasr and Michael Thurston, 2006). This is giving the possibility to reduce the CO_2 emission, raw material, and energy consumption plus environmental degradation (Gutowski et al., 2011; Miao et al., 2016). However, to support the benefits of reusing for remanufacturing ilustrate the internal composition and physical status of the plastic circuit board (PCB) and plastic cases of two monitors. Overall, the experimental parts uncover the already discussed composition of WEEE products which degrade the environment and avoided raw material consumption. All of this can be avoid by using the proper tools as remanufacturing and reuse of subassemblies via Internet of Things (IoT) upgradability with Banana pi (card sized single-board computer) for a universal range of new and use equipment.

This paper is organized as follows. Section 1 a worldwide introduction of e-waste generation and markets approach and possibilities. In Section 2 is presented the methodology of collection by using new methods as internet application, (B2B) remanufacturing to maximize resource value and physical status for selection of subassembly for reuse and upgradability. In Section 3 we describe the research results which are followed by Section 4 discussion of the study. In particular, shows that IT contributes to increasing the collection and resource conservation.

2. Methodology

The aggregated methods used in this research are shared in three main parts: collection, remanufacturing management and experimental analysis. All the information generated herein has been collected from the field. In the collection section, a Chinese company from Shenzhen called Taolv Iinformation Technology Company is described, from which the data has been collected and processed. They collect, test and sell secondhand mobile phones and tablets. Taolv is a leading third party internet transaction platform for Waste/secondhand mobile phones, which aims to build a B2B reverse supply chain, set up standard collection flow, and break through information, material and fund flow, and realize the green, technical and intelligent collection.

In the second part, the data from the remanufacturing section had been compiled from two remanufacturing companies: A – medical devices manufacturer and remanufacturer in Europe and B – servers in China. Company A had offered their information during the visit at the remanufacturing facility in Europe. At this moment company A doesn't have any kind of remanufacturing activity in China due to the legislative restriction. The data from the company B had been collected on the spot at their facility remanufacturing in Zhejiang Province, China and compared with the data from the company A. All the process of remanufacturing had been explained step by step by both companies, resulting our described analysis for a general understanding of the internal managerial activity of remanufacturing process in case of servers and medical devices. Both companies are leaders in the remanufacturing industry with a high reputation for quality and technical and fiscal sustainability of their products.

For the experimental part, different methods had been used to identify the physical and chemical characteristics of the electronics. Several analyses had been made as XRD, SEM, ICP-MS and leaching. The experimental samples and materials had been gathered from electronic markets in Beijing, China. They represent a description of existent statues – surface, chemical composition, from plastic and PCB to realize that the applied updating and resource conservation thought IT devices applicability can extend the life cycle of existent products postponing the recycling process.

3. Case studies

The investigated companies in this study generate another view regardless to the traditional collection system and the new opportunistic approaches from China and Europe. The waterfall of the manuscript describes a new collection system rather the conventional one (Magalini et al., 2015) and remanufacturing introduction and management for servers and medical devices. This path gave a meaningful approach to conserve the existent equipment and reuse specific parts/components avoiding recycling.

3.1. Collection

Informal recycling and transboundary movements of electronics are one of the key factors in the regression of electronics and open dumping. Considering the informal recycling is having the potential we decided to exemplify the collection system implemented in Shenzhen, China by Taolv which is a leading third-party Internet+ transaction platform for waste/used mobile phones, tablets, aims to build a B2B reverse supply chain. They are one of the 25th specific enterprises with this profile in China, collecting approximately 1/5 (60 million, units) of discharged mobile phones in the country. The company is supervised by the Chinese authorities and requested to give balance reports regarding quantity and product destination. According to Ministry of Industry and Information Technology (MIIT), the discarded mobile phones add up to 250 million in 2016. Their activity unfolds where as in 10 of the biggest cities in China, such as Beijing, Shanghai, Shenzhen, etc., where Guyiu is the direct intermediary between seller and purchaser providing the special services (Table 1) as shown below.

Their implemented methodology of work succeeded to reduce the general cost of several key sectors in the collection and transaction chain (Table 2) as shown below. Among these, the requirements for supply chain and collection are simply eliminating some disadvantages, such as:

- Lack of standards.
- Too many steps in the logistics chain.
- Information asymmetry (imbalance).
- Impossibility of fragmentation of different kinds of items.
- Stable supply and less variety for downstream plants.

The total cost reduction (45%) achieved is specified in this table according to the various cost categories. It is concluded that

Please cite this article in press as: Zlamparet, G.I., et al. Resource conservation approached with an appropriate collection and upgrade-remanufacturing for used electronic products. Waste Management (2017), https://doi.org/10.1016/j.wasman.2017.11.053