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ScienceDirect

Procedia CIRP 61 (2017) 166 – 171

www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

A collaborative End of Life platform to favour the reuse of electronic components

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Abstract

Electronics plays an essential role in many products and this leads to a larger production of e-wastes, currently recovered through impactful recycling processes. This paper proposes a web-based platform to implement reuse scenarios for electronic components. The objective is to create a structured portal where all the stakeholders can collaborate to extend the components lifespan and implement new circular business models. The final goal is to "close the gap" between the beginning and the end of life. The case study (industrial application) shows relevant benefits for the involved electronics manufacturer both in terms of environmental impact and economic savings.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: EoL mangement; Electronics reuse; Collaborative platform; Decsion support system

1. Introduction

The continuous growth of the world population (9.3 billion estimated in 2050 by United Nations) and the increment of the product discard rate, lead to an over-consumption of resources. An accurate management of the product End-of-Life (EoL) and wastes is the univocal effective solution to decouple economic growth from consumption of resources, according to the basic principles of Circular Economy [1].

Electronic wastes (e-wastes) are one of the most critical flows to manage. Waste of Electrical and Electronic Equipment (WEEE) constituted about 8% of the world municipal wastes in 2004 [2], with an increase of 3-5% per annum [3]. The electronics industry has become one of the world's fastest growing industrial sector [4], but the use of electronic devices leads to rapid obsolescence and decrease of product lifetime, which intensifies the e-wastes problem [5].

Few normative about electronics EoL exist, as the European directives on WEEE and on restricted substances [6][7], aiming to extend the producers responsibility.

Currently, only a very small percentage of e-wastes are properly recovered (about 15-20%), while the majority has a non-traced EoL or are exported to underdeveloped countries where they are processed in unhealthy conditions [8].

Material recycling is the most common EoL scenario for electronics. Recycling treatments are quite simple but not very efficient, due to their high consumption of energy and release of emissions to air and water. To mitigate these problems, while keeping the economic value at EoL, a shift toward reuse or remanufacture of electronic products is needed. These scenarios represent a new business opportunity for manufacturers, thanks to the reduction of costs for virgin materials and components supply.

In this context, this paper proposes a web-based platform to practically implement reuse scenarios for electronic components. On the basis of input information, such as component residual life or disassembly cost, the platform suggests the most convenient EoL scenario for electronic boards. The platform provides a tangible support to guide decision-making strategies aiming at economic profits maximization, as well as, environmental impacts and resources consumption minimization. The final goal is to provide a mean to "close the gap" between the beginning and the end of life, by implementing circular business models.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.169

2. Related works on electronics EoL management

In general, e-wastes contain a mixture of different substances and materials: heavy metals (e.g., lead, cadmium, mercury, barium, etc.), precious and valuable metals (e.g., copper, gold, silver, palladium, etc.), oxides (e.g., SiO_2, Al_2O_3, etc.), rare earths, halogenated compounds, chlorinated compounds, etc. [9]. For this reason, the EoL management of printed circuit boards (PCB) is problematic, but high economic value can be recovered from this mixture [10].

Several literature works are focused on materials recycling, which is the most common EoL scenario for PCB . According to Zhang and Xu [11], the traditional methods to recycle metals are essentially: (i) incineration, where WEEE are burned in a furnace to recover copper, (ii) hydraulic shaking bed separation used to obtain crude copper, and (iii) acid leaching to recover metals by using leaching solvents (e.g., HNO_3, HCl). More advanced and complex technologies are pyrometallurgy [12] and hydrometallurgy [13], also used to recover Rare Earth Elements (REEs) [14]. Electrochemical technologies are emerging methods to recover base and precious metals with high environmental compatibility, high energy efficiency and reduced use of chemicals [15].

All the technologies described above guarantee economic sustainability. However, they certainly do not represent the best option from an environmental point of view. Despite several researches are focusing on improving the environmental performances of these processes, they are still impactful for the natural environment and hazardous for the humanity. Several studies confirmed that the regions where an intensive processing of e-wastes is carried out are characterized by consistent environmental impacts [16] and present a high concentration of heavy metals in surrounding air, dust, soils, sediments and plants [10]. In addition, the pond water used for irrigation is often seriously acidified and contaminated by heavy metals [17]. These polluted environments can lead to an increment of sex ratio deviations of offspring [18] and male genital diseases [19].

A possible solution to these issues is the reuse or remanufacture of post-consumer e-wastes. Ludois et al. [20] developed a medium voltage distribution system to electrify rural areas in developing nations, starting from transformers repurposed from discarded microwave ovens. Bovea et al. [21] proposed a general methodology to estimate the potential reuse of small WEEE, with the final aim to create a specific protocol to identify the potentially reusable appliances.

Although electronics reuse is recognized as the best approach for conserving resources and reducing environmental toxicity, so far none similar concept of business can be found in reality. Companies can find new electronic components in general purpose (e.g., Alibaba, etc.) or sectorial (e.g., Mouser Electronics, All Electronics, Premier Farnell, etc.) e-commerce platforms. Electronic marketplaces for second-life products exist, but they are only dedicated to consumer goods (e.g., Second Life Marketplace, etc.). An interesting Business-to-Business cloud-based platform is the US Materials Marketplace developed by the US Business Council for Sustainable Development, but it focuses on favouring the reuse of second-hand materials.

In order to mitigate barriers to reuse, more incisive national and international regulations are needed, as well as collaborative systems to support the decision-making process [22]. Only few literature works are focused on this topic. Jin et al. [23] defined a systematic EoL management approach to handle WEEE considering economic and environmental aspects. The final aim is to choose the best EoL option which allows maximizing revenues and minimizing the environmental load. Shrivastava et al. [24] proposed a decision support system to take informed decisions about the electronics EoL. However, these research works are only focused on single companies and not on the collaboration between lifecycle stakeholders.

In conclusion, the presented review highlights a lack of dedicated tools to support the implementation of sustainable business models in the electronics sector. In this context, the objective of this paper is to create a collaborative web portal dedicated to all the stakeholders involved in the whole lifecycle of electronic products. The proposed platform wants to go beyond the traditional e-commerce platforms by offering a shared environment for an efficient collaboration, as well as services for the implementation of the best EoL scenario, from the economic and environmental perspectives. The main innovations in comparison with the state of the art are essentially:

- the creation of a collaborative environment, where relevant stakeholders can share useful information and materials and collaborate to extend the components lifespan;
- the integration within the platform of a decision-making algorithm to support companies in evaluating the convenience of the shift toward circular business models.

3. Collaborative EoL platform

"Close the loop" for electronic products means to close the gap between producers and the other stakeholders involved in the electronics life. The general idea of this work, illustrated in Fig. 1, is to consider not only classical material flows (black arrows), but also additional flows of materials and useful information (red dotted arrows) collected and shared by the implementation of the proposed platform.

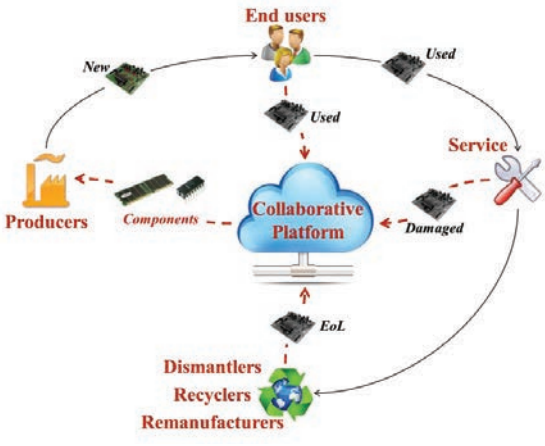

Fig. 1. Electronics EoL framework.