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ScienceDirect

Procedia Manufacturing 21 (2018) 502–509

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

15th Global Conference on Sustainable Manufacturing

An approach to favor industrial symbiosis: the case of waste electrical and electronic equipment

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Abstract

Waste management, in particular waste electrical and electronic equipment (WEEE), currently represents an important issue for the modern society. A transition toward circular economy and industrial symbiosis models is needed to mitigate the environmental problem and recover value from end of life (EoL) materials/products. This study aims to define an approach and a platform, dedicated to the WEEE sector, to favor the creation of industrial symbiosis opportunities. Through this structured approach, demand of virgin materials and components, and supply of EoL products are linked to find potential collaborations. In this way, EoL components/materials could be reused in different applications, thus closed-loop lifecycles can be created through industrial symbiosis. A case study focused on the reuse of plastics from electrical cables is shown to demonstrate that in the WEEE sector the implementation of industrial symbiosis models can lead to win-win scenarios for all the involved stakeholders.

Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).

Keywords: closed-loop scenarios; industrial symbiosis approach; End of life platform.

1. Introduction

In order to guarantee a livable planet for future generations, the most relevant environmental problems (e.g., water scarcity and pollution, air pollution, noise, etc.) need to be efficiently faced. Waste management is a primary issue for the modern society. Several reasons are behind this aspect, such as the continuous growing of the worldwide population, which is expected to reach 8,5 billion by 2030 [1]. The improvement of the overall economic

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2351-9789
Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).
10.1016/j.promfg.2018.02.150

conditions, together with an increment of the product discard rate, lead to an over-generation of waste and to an over-consumption of resources. The traditional linear consumption pattern ("take-make-dispose") is based on the assumption that "resources are abundant, available, easy to source and cheap to dispose of" [2]. According to this model, we are using more resources than nature can regenerate and we are emitting more carbon dioxide than forests can sequester [3]. This kind of economic model is not sustainable in the long-term perspective.

Among the waste flows, waste electrical and electronic equipment (WEEE) is one of the most critical flow to manage, since they represent a relevant percentage of municipal wastes (8% of the world municipal wastes in 2004 [4]). The WEEE are continuously increasing (about 5% per annum [5]), because the use of electronic devices leads to rapid obsolescence and decrease of product lifetime [6]. However, only a small percentage of WEEE are properly treated and recovered. According to Eurostat figures [7], the WEEE collected in 2014 was about the 50% of the total electrical and electronic equipment (EEE) put on the market in the three preceding years. The recycling rates vary from 11% to 60%, but most of the European (EU) countries had a recycling rate of about 30%. The majority of WEEE has a non-traced end-of-life (EoL) or are illegally exported to underdeveloped countries (particularly Central Africa) where they are treated with impactful processes [8], in unsafe and unhealthy conditions [9]. This means that only one third (in weight) of the EoL materials is reused, and a consistent residual economic value is lost.

In the traditional business model, companies or production chains operate as "isolated systems" that have no relationships with other companies/production chains. In this business scenario, it can happen that material/product wastes have no potential second-life applications. However, extending the perspectives and the business opportunities through the adoption of industrial symbiosis models, materials and components could be remanufactured or reused for different products and applications. In this context, the paper aims to demonstrate how the implementation of industrial symbiosis models in the WEEE sector leads to economic savings and new business opportunities for the involved stakeholders. The links and the inter-relations among different stakeholders belonging to different markets are provided by a structured web platform, which represents the means to achieve industrial symbiosis models. This is the main novelty of the proposed approach.

After this Introduction, the paper is structured as follows. Section 2 illustrates the state of the art about WEEE sector and normative, circular economy and industrial symbiosis. Section 3 presents the approach to favor the creation of industrial symbiosis opportunities. Section 4 describes the functionalities of the platform that implements the proposed approach. Section 5 reports the results obtained in the case study regarding the reuse of waste materials coming from electrical cables. Finally, Section 6 discusses conclusions and future developments.

2. State of the art

Environmental sustainability has been a popular issue in the recent years. Industries have been directly involved in this topic and have been developing strategic plans to cope the issues of environmental protection and resource consumptions [10]. In addition, the waste management and the possibility to make economic profits from EoL industrial products are pushing industries to investigate new possible business models based on the paradigm of circular economy [11]. From the industrial perspective, a strategic approach to pursue the circular economy pattern is the creation of an industrial symbiosis model [12]. The meaning of industrial symbiosis is "to connect the businesses of different industries/productions in a virtuous circle where wastes and by-products of a company become resources for another" [13]. In some case, these models lead to the creation of eco-industrial parks in which the network is limited, in space, to a specific region/site [14].

The regulatory framework in the WEEE sector establishes the minimum requirements for the management of EoL products and encourages the development of industrial symbiosis mechanisms. For electronic appliances, the standard extends the product responsibility far from the product manufacturing [15]. Looking at the proper management of e-waste, the most widespread scenario is the material recycling. In spite of the recycling process allows recovering valuable materials, the current technologies are not efficient; they consume a high quantity of energy and release emissions to air and water [16]. The adoption of more sustainable and cooperative strategies (such as reuse and remanufacture) [17] is driven by policy and legislative requirements, which create a favorable environment for the development of industrial symbiosis models in the e-waste sector [18]. However, only few practical implementations can be found in the market. For instance, Ricoh's business model offers direct