Resources, Conservation & Recycling 140 (2019) 189–208

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

Assessing the efficiency of End of Life technology in waste treatment—A bibliometric literature review

Sergio Tadeua De Almeida*, Milton Borsato

UTFPR, Curitiba, 81560020, Brazil

ARTICLE INFO

Keywords:
Recycling processes
Efficiency
Waste treatment
Bibliometrics
End of Life

ABSTRACT

The current trends of waste present a global challenge pursuing sustainability. In response, recycling is broadly recognised as a solid strategy and the proper approach to attenuate the impact on the environment and human society. However, despite the current strides in recycling the remaining amounts of disposed products keep on increasing. Reversal of this trend is challenging, given the available recycling technology requires both, materials and energy, thus contributing to the depletion of resources. Therefore, for one aiming to cope with waste through recycling, efficient processes must be carefully selected. The current literature reveals a series of strategies, terminologies, processes and technologies, which may be confusing. The adopted methodology uses a bibliometric literature review to assess the available treatment of waste coming from End of Life (EoL) products, pointed out as successful strategies by recognised literature. The findings will deliver a framework of processes covering the different EoL strategies, their steps and processes. Thus, promoting a more sustainable waste handling due to the adoption of strategies and processes found more efficient, but yet reliable and available. In this sense, disruptive technologies are glimpsed as promising substitute solutions. The main contributions are. First, presents an approach for assessing diverse literature. Second, it identifies, clarifies, prioritises and delivers revised concepts and definitions to cope with waste more efficiently. Finally, summarises a vast amount of recycling processes along the EoL, revealing their precursors, constraints and also, the more efficient recycling processes with opportunities for future research.

1. Introduction

Despite the current strides in recycling, the remaining global amounts of disposed waste keep on increasing. To reverse this trend is challenging, given the expected increase in the global population, and as developing countries adopt consuming patterns resembling those of developed countries (Paleologos et al., 2016). As a consequence, the waste increase became a global problem, threatening health, the environment and economies (Song et al., 2015).

A prominent example of waste growth is electronic products, which is the world's fastest growing waste stream at the rate of 3–5% per year (Dwivedy and Mittal, 2013). This category solely generates 50 million tons every year globally, due to the adoption of electronic in products and technological changes (Menikpura et al., 2014). As a solution, industrial product recycling has been adopted as the appropriate approach to manage waste, attenuate the environmental impact and create business opportunities (Oguchi et al., 2013).

However, recycling processes are many and complex. Once most of the waste generated by End of Life products (ELP) contains a wide variety of materials combined with sets of high complexity, their disassembly becomes complicated and expensive (Bakar and Rahimifard, 2008). Instead, to recover materials, many recyclers apply shredding processes where the ELP waste is broken into small particles to release materials, followed by a novel of separation processes (Favi et al., 2012).

To promote effective actions, global treaties, legislation and guidelines already impose rules on waste management (Directive, 2000, 2002; Directive, 2012). However, the efficiency of current recycling technology is only able to separate and recover materials at the minimum levels set by regulation or technical constraints, by adding a series of processes such as disassembly, shredding, separation and cleaning (Devoldere et al., 2009). Nevertheless, each one of such

Abbreviations: AD, Active Disassembly; AS, after shredder; ELP, End of Life product; ELV, End of Life Vehicles; EoL, end of life strategy; e-waste, electronic waste; IoT, internet of things; JCR, Journal Citation Reports (JCR) Impact Factor; LCA, Life Cycle Assessment; LCS, Life Cycle Strategies; LW, Literature Work; OEM, Original Equipment Manufacturer; PCB, Electronic Printed Circuit Boards; SR, shredder residue

* Corresponding author.
E-mail address: stadeua@gmail.com (S.T. De Almeida).

https://doi.org/10.1016/j.resconrec.2018.09.020
Received 8 March 2018; Received in revised form 14 September 2018; Accepted 19 September 2018
0921-3449/

processes is yet an industrial process. Therefore, consuming materials and energy, while generating different kinds of residual waste, thereof, demanding more and more processes to be chosen from a myriad of options (Almeida and Borsato, 2017). Thus, depending on the efficiency, it will make some of the recycling process less sustainable, from economic (Peeters et al., 2015), environmental (Deng et al., 2006) or energetic perspectives (Priarone et al., 2016). Assuming that recycling is a strategy to make better use of resources, its efficiency plays a key role without which, paradoxically, there is no way to ensure, through recycling, the best use of resources at sustainable levels (Vanegas et al., 2015).

Therefore, this work aims to present an evaluation of EoL strategies and their respective processes that focus en ELP and relates literature published on waste management and their efficiency, thereby promoting more efficient recycling practices. Additionally, identifying research new and disruptive approaches and research opportunities. It is organised as follows. In Section 2, the central concepts are presented, and the key aspects of relevant works are briefly described. In Section 3, the adopted bibliometric research method is described in a way that allows the reader to repeat it; in Section 4, the results of reliable and scientific agreements over processes and strategies are shown followed by new and disruptive approaches, trends and future opportunities; finally, in Section 5, the conclusions are presented.

2. Theoretical background

2.1. Concepts and terminology

Avoiding the use of inappropriate terms and unambiguous definitions can help to make more progress in sustainable development (Glavič and Lukman, 2007). However, the term “recycling” is itself broad and frequently misleading. In a recent review of terminology, it was revealed that the term of recycling is often an unclear discussion around remanufacturing, recycling, and reuse of waste (Kirchherr et al., 2017). It is worth notice that nowadays, many researchers refer to this closed loop as “Circular Economy”, which is defined as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops through different EoL strategies (Geissdoerfer et al., 2017). Another researcher refers to the circular economy as aiming to systematically eradicate waste across the lifecycle of an industrial process (O’Connor et al., 2016). Moreover, many suggest that only through efficient recycling processes (Almeida and Borsato, 2017) the Circular Economy and sustainability could be achieved (Brears, 2018; Kirchherr et al., 2017).

However, according to recognised authorities on the field, such as the European Environment Agency (EEA), recycling is a resource recovery method involving the collection and treatment of an ELP for use as raw material in the manufacture of the same or a similar product. In a more specific approach, the European Union distinguish waste strategies between reuse, recycling and recovery (EEA, 2017a). Through these definitions and regarding efficiency, became clear that is necessary to verify not only "what" is recycling as a waste treatment but "how" it is performed. Thus, other waste treatment strategies known as End of Life (EoL) shall be investigated.

To accurately define the frontiers of the present research, the waste increase is adopted as the problem in which the broad term of “recycling” is trying to resolve. Thus, waste countermeasures must be the first definition to be understood. According to the EEA (2017a,b), the waste minimisations are measures and or techniques that reduce the amount of waste generated during any domestic, commercial and industrial process. This definition allows to include many EoL strategies and their respective processes inside of the scope of this work. The adoption of such principle obliged, instead of constraining the borders to the field of recycling, to expand its limits to include EoL strategies and their processes in which recycling is revealed as a part.

Next, the main recognised EoL strategies will be described to later, be the object of investigation regarding efficient processes.

2.2. End of Life strategies on product waste treatment

According to Fukushige et al. (2012), the EoL considered promising to manage waste and promote sustainability involves the product lifecycle. Only with lifecycle considerations became possible to reduce environmental loads, consumption of resources and ultimately lowering waste. More specifically, Rose et al. (2002) define EoL as a set of concepts or pre-activities intended to be applied in a given product "at the time that the product no longer meets the original buyer or the primary user". The universe comprising the EoL strategies and the involved processes is illustrated, over time, in Fig. 1.

As shown in Fig. 1, it is possible to understand that the ultimate goal of managing waste implies not only with recycling but also coping with a macro set of strategies and processes known as Life Cycle Strategies (LCS). In this scenario, it is possible to understand that strategic decisions such as “Business strategy”, “product Concept”, and “Environmental targets”, which are not the primary subject to this research, will interact and powerfully affect the overall lifecycle scenario, and ultimately the efficiency of the EoL processes to be used. Also, became evident the existence of a hierarchy, where EoL strategies follow the EoL scenarios and finally, the processes that will perform those intentions into reality. Within this macro set, it is worth noting two moments along the timeline, where the destination of ELP and the efficiency of the EoL processes are profoundly influenced. At first, during the early phases of the Product design, scenarios and processes will be devised, and decisions will be made regarding the configuration of the product. These decisions should seek to simplify and or improve the efficiency of

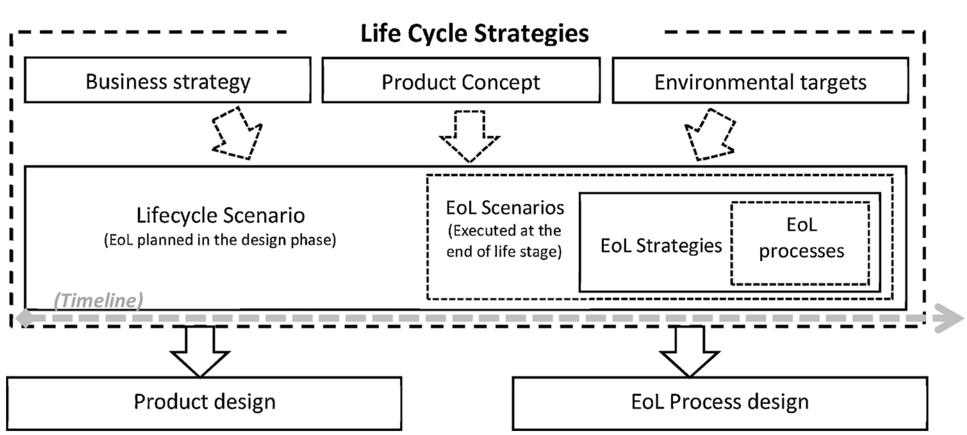

Fig. 1. EoL design processes (Fukushige et al., 2012).