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# WEEE INDUSTRY IN THE CONTEXT OF CIRCULAR ECONOMY

**Roxana-Maria DRUTA, Geanina-Maria DAVID, Radu-Adrian MUNTEANU, Loredana-Andreea BIRGOVAN, Sorin-Dan CLINCI**

***Abstract:*** *According to the initiators of the concept, the circular economy is "the way to eliminate waste and reduce carbon emissions, through the use of environmentally superior materials, products and processes", which generate green economic growth and create new jobs in the work field. This has emerged as a lesson in sustainability that can separate economic growth from waste generation and resource consumption in the paradigm of circular economy. Therefore, the purpose of the research is to systematize the vast academic literature that is found in the industrial sector of waste electrical and electronic equipment, with a view from the circular economy lens. In total, 30 articles were selected and looked into according to the following three steps (1) planning - justification and protocol; (2) conducting the review - identifying the research, selecting the basic studies, evaluating the quality of the study, extracting and monitoring the data; and the final stage; (3) reporting the results of the review.*
***Key words:*** *circular economy, waste electrical and electronic equipment (WEEE), reuse, durability, repair*

## 1. INTRODUCTION

The notion of waste electrical and electronic equipment (WEEE) refers to every obsolete electrical and electronic equipment (EEE) that fulfills its "role" with the help of batteries or electricity. With the increase of digitalization and industrialization, the production of electrical and electronic goods has also increased. Unfortunately, the accelerated rate for technological development causes some products to become obsolete as soon as they are purchased [1]. All these developments have increased the amount of electrical and electronic waste produced, and this, in turn, has become a clear problem for the environment [2].

The waste electrical and electronic equipment industry shows real importance for closing the loops of circular economy (CE). The CE stimulates provision of leasing and exchange in terms of business models, not only closing the loop of products, materials and components, but also an improvement of EEE design [3-5].

The WEEE refers to any waste arising from electrical and electronic equipment. These include a wide range of products, including large domestic appliances, such as washing machines, household appliances and devices for communication such as computer systems and personal mobile phones [6]. These categories of WEEE are regulated on the territory of Romania through art. 2 para. (1) lit. b) of the Government Emergency Ordinance no. 5/2015 on waste electrical and electronic equipment/categories of waste electrical and electronic equipment where they follow the classification below:

1) Heat transfer apparatus;
2) Any equipment containing monitors or screens with an area of more than 100 cm2;
3) Lamps;
4) Large equipment (having any of the exterior dimensions greater than 50 cm);
5) Large pieces of equipment (without photo-voltaic panels);
6) Photovoltaic panels;
7) Small pieces of equipment (without external size greater than 50 cm);

8) Small, portable computers and telecommunication equipment (without external dimensions greater than 50 cm).

Literature presents various definitions for reuse and associated concepts, some being detailed by Lu et al. [7]. However, the field of WEEE requires a comprehensive study of how the reuse of such equipment and technologies can be enabled in the context of circular economy. Therefore, as it follows, next section describes the methods for the research, section 3 shows the outcomes of the analysis and their discussion, whereas the final section provides the conclusion of the paper.

## 2. METHODOLOGY

This study focuses on the reuse of WEEE and also distinguishes among basic categories of the investigation, coming from the most advantageous research literature. In order to accomplish the objectives, we looked into the main works focused on circular economy and in the field of reuse of WEEE.

The purpose is to examine how circular economy practices shape the reuse of WEEE [8]. We conducted systematic review based on a predefined inquiry strategy, following the process steps suggested by Kitchenham (2004) [9]: (1) planning - justification and protocol; (2) performing the review - identifying the research, selecting primary studies, evaluating the quality of the study, extracting and monitoring the data and synthesis data; and the final stage; (3) reporting the results of the review. We have applied the protocol in Fig.1 for identifying the relevant biography.

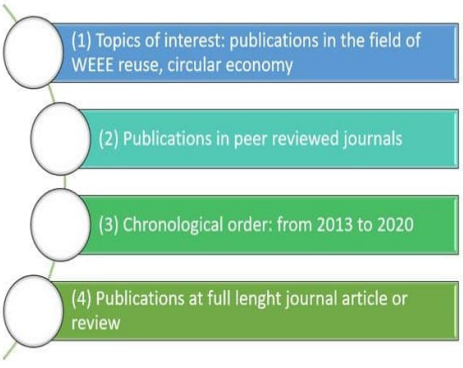


**Fig. 1**. Protocol for SE literature identification

In the first phase, we identified all relevant works between 2013 and 2021 as part of the ISI Web of Science database on the waste reuse sector of WEEE. The search was on the following topics: "circular economy", "waste electrical and electronic equipment" and "reuse". Next, analysis of the results was done according to the years of publication.

A total of 44 papers were identified, most of which were published in environmental journals, environmental conferences, and as part of environmental management. The primary selection was done based on the content of their abstract, whose representative character was weighed and on the basis of the names of the authors (except for works with similar content) and geographical areas.

Therefore, a number of 30 articles fit the research aim and were selected and grouped according to the topics of interest regarding our analysis. Regarding the selection process, we would like to add that the selection criteria applied is as follows: (i) papers published between 2013 and 2021; (ii) articles presenting/analyzing/exploring at least one concept or case study of the circular economy applied in the WEEE field; (iii) articles discussing, analyzing or proposing future directions for the reuse of WEEE. Review articles, book chapters, non-indexed studies, and other reports have been included [25]. Additionally, duplicates and studies without full text were not considered.

In the second part, we only looked into the research papers published in journals with ISI factor higher than 1.00, as in the 2021 ranking, so to provide reliability. All 30 papers provide comprehensible information of CE and the sector of reuse of WEEE inside their contents. Further, we rather chose research papers, than book chapters and books, as a broad area of literature would affect the quality of content analysis.

## 3. THE RESULTS OF THE ANALYSIS

The inquiry shows several extensive definitions suitable for the reuse of WEEE. The analysis of the published papers on the reuse of waste electrical and electronic equipment

(Figure 2) shows that articles emerged in international journals in the category of environmental sciences, sustainability, and engineering. These journals cover papers developed from 2013 to 2021, as this span of time presented the largest number of articles related to the impact of ISI on the CE, waste electrical and electronic equipment, and reuse. Until 2013, there were about 2 articles published per year, most articles being published between 2018 and 2021.

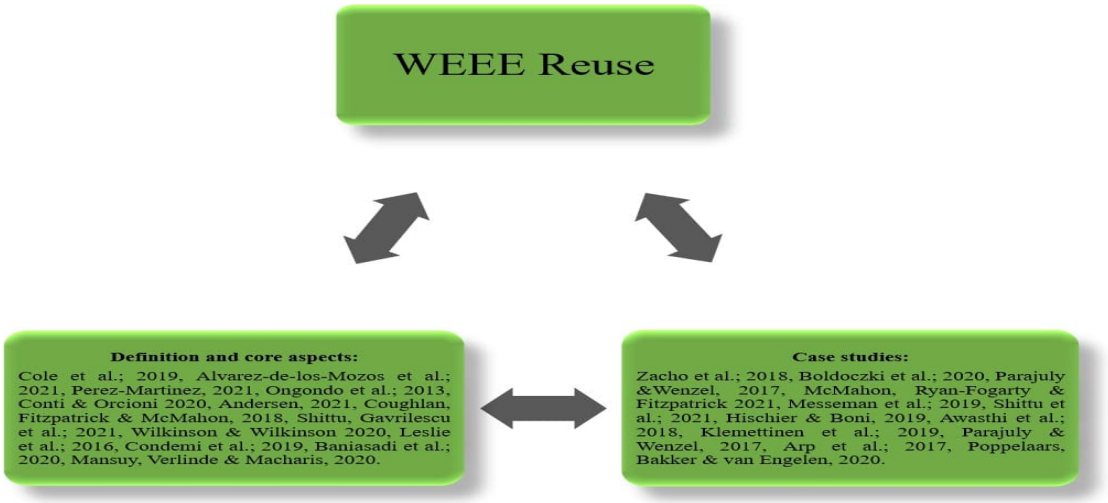


**Fig. 2.** Scientific studies analyzed from the lens of circular economy and the reuse of waste electrical and electronic equipment. Definition and core aspects [11-20]; Case Studies [21-32]

Regarding the reuse phase and the preparation for reuse, the EU definition is essential for WEEE management [33]. Reuse means “any action where products or components which have not become waste are re-used for the same purpose for which they were intended” while preparation for reuse is defined as “the verification, cleaning, or repair of recovery actions where products or components that have become waste are prepared so that they can be reused without further processing”.

This model of waste stream is crucial in recovery of resources and to reuse them according to the potential they have. “Preparation for reuse” and end-of-life (EoL) planning being regarded as the main options after the “prevention” aspect as presented by the WEEE Directive (Directive 2012/19 / EU). Based on the definitions in the Waste Framework Directive (Directive 2008/98/EC), the reuse phase adds to reducing the amount of generated waste as well as the demand for raw materials needed for production. For example, approximately 45 million tons / year of WEEE are disposed of globally, with the annual growth rate of 3-5% [34]. As a result, several countries have legislation targeting the WEEE sector. One example is that the EU has adopted a specific directive that is focused on the sustainable production and consumption of electrical and electronic equipment by preventing waste generation of electrical and electronic equipment starting with the design and at the same time, by reusing, recovering, and recycling them and their components. This directive mentions the principles of responsibility and commitment of producers and sets targets for the collection of 65% of the total products placed on the market in the last three years for every country [35].

Another aspect researched in the literature is the awareness of consumers and their perception in terms of purchase of reused EEE. Cruz-Sotelo and Ylä-Mella [36, 37] analyzed the probable potential for reuse of mobile phones in Mexico, Spain and Finland through conducting surveys. Both research studies have found that the current storage habits of consumers make it difficult to potentially reuse electrical and electronic equipment waste. An

analogous conclusion was reached by Dindarian and Gibson [38, 39] who applied semi-structured interviews to assess the behavior of consumers who throw away their microwaves. Usually, the main barriers for consumers to purchase reused products is that they regard them as unattractive or outdated, or even possibly contaminated by the previous owners [40].

In addition to environmental and economic sectors, reuse of materials also has many social implications. A market for reclaimed electrical and electronic equipment may not be entirely economically viable from the outset, but it would be justified in terms of its social benefits, as reusing creates jobs for local communities and training for unskilled labor [41-43].

Reuse facilities can undertake all different categories of electronics and at the same time, they can also include recycling and repurposing activities [44]. It is obvious that these organizations can employ many people for the sector of reuse and repair of tons of electronics, more than for the recycling part of a similar amount of equipment [45]. As an example, Rehab Recycle, a social enterprise that reconditions the recycling of ICT and WEEE in Ireland, found out that the reuse of B2B IT generates 10 times more jobs per ton of equipment than the recycling of an equivalent amount of wasted electrical equipment and electronics [46]. For large household appliances (LHA), the French Envie network estimates that they can create 5 times more jobs in collecting and reusing LHA than with an equivalent amount recycled [47].

The design process of electrical and electronic equipment is another highly important aspect. For a longer life of WEEE, it is necessary that EEE is easier to disassemble, to repair and is non-toxic when it reaches its EoL. Also, according to the new rules introduced by the European Commission in 2021 regarding the right to repair to combat waste, manufacturers must ensure spare parts for at least 10 years since they had introduced a new model on the market and provide available information to the public on the reusability of the product [48, 49].

## 4. CONCLUSIONS

From a theoretical point of view, the current research paper contributes to the deepening of the concept of reuse and preparation for reuse of waste electrical and electronic equipment, firstly through the highlight of the current issues that still require practical solutions. Secondly, this work positioned the WEEE in the circular economy in terms of reuse and preparation for reuse, while at the same time provided suggestions for promoting innovation and circular management of resources as part of EEE. The process of developing a circular economy can be demoralizing at times and thus, should become more appealing than not attempting to fulfill its objectives. In fact, it is difficult to implement a circular economy due to the fact that it is necessary to restructure the current linear system. However, taking it step by step, all circular economy aspects can be addressed and a fully functional circular economy can emerge. Indeed, by extending the life expectancy of electrical and electronic products, the manufacturing of fresh goods and the need of materials which are recovered by conventional waste treatment of EEE could be avoided. Along with the environmental impact improvement from WEEE not reaching landfilled, social benefits derived from the creation of jobs is also present in the circular economy paradigm, especially from the external cost generated by the preparation of reuse activities. Therefore, strong management of WEEE in the context of circular economy can provide benefits for the people, for the planet and can also bring profit.

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**INDUSTRIA DEEE ÎN CONTEXTUL ECONOMIEI CIRCULARE**

**Rezumat:** Potrivit inițiatorilor conceptului, economia circulară este „modul de eliminare a deșeurilor și de reducere a emisiilor de carbon, prin utilizarea de materiale, produse și procese superioare din punct de vedere al mediului”, care generează creștere economică verde și creează noi locuri de muncă în domeniu. Aceasta a apărut ca o lecție de sustenabilitate care poate separa creșterea economică de generarea de deșeuri și consumul de resurse din perspectiva economiei circulare. De aceea, lucrarea își propune să sistematizeze vasta literatură științifică care se găsește în sectorul industrial al deșeurilor de echipamente electrice și electronice, în perspectiva economiei circulare. În total, au fost selectate și analizate 30 de articole în funcție de următoarele trei aspecte (1) planificare - justificare și protocol;(2) efectuarea revizuirii - identificarea cercetării, selectarea studiilor de bază, evaluarea calității. a studiului, extragerea și monitorizarea datelor și etapa finală; (3) raportarea rezultatelor recenziei.

**Roxana-Maria DRUTA**, Institute for Research in Circular Economy and Environment ”Ernest Lupan”; Ecological Engineer; Calea Dorobanților street, no. 71-73, 400000, Cluj-Napoca, Romania, Phone: 0264 401 580, Technical University of Cluj-Napoca, Faculty of Electrical Engineering, Department of Electrotechnics and Measurements, George Barițiu street, no. 26, 400000, Cluj-Napoca, Romania, Phone: 0264 401 229, E-mail: roxana.druta@ircem.ro

**Geanina-Maria DAVID**, Institute for Research in Circular Economy and Environment ”Ernest Lupan”; Ecological Engineer; Calea Dorobanților street, no. 71-73, 400000, Cluj-Napoca, Romania, Phone: 0264 401 580, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management, Engineering and Management Department; Bulevardul Muncii street, no. 103-105, 400000, Cluj-Napoca, Romania, Phone: 0264 401 782, E-mail: geanina.david@ircem.ro

**Radu-Adrian MUNTEANU**, Technical University of Cluj-Napoca, Faculty of Electrical Engineering, Department of Electrotechnics and Measurements, George Barițiu street, no. 26, 400000, Cluj-Napoca, Romania, Phone: 0264 401 229, Email: radu.a.munteanu@ethm.utcluj.ro

**Loredana-Andreea BIRGOVAN**, Institute for Research in Circular Economy and Environment ”Ernest Lupan”; Director of Social Development and Community; Calea Dorobanților street, no. 71-73, 400000, Cluj-Napoca, Romania, Phone: 0264 401 580, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management, Engineering and Management Department; Bulevardul Muncii street, no. 103-105, 400000, Cluj-Napoca, Romania, Phone: 0264 401 782, Email: loredana.birgovan@ircem.ro

**Sorin-Dan CLINCI**, Institute for Research in Circular Economy and Environment ”Ernest Lupan”; Department of Sustainable Urban Development; Calea Dorobanților street, no. 71-73, 400000, Cluj-Napoca, Romania, Phone: 0264 401 580, Email: dan.clinci@ircem.ro