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Implementation of EU Rules on Circular Economy in Romanian EEE Sector: Targets and Results

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Abstract: *Our review is focused on the complex issue of circularity in the Electrical and Electronic Equipment (EEE) sector in Romania, taking into account the European regulatory framework and those pressing factors justified by the growing concerns for maintaining a clean environment and protecting public health. Emphasizing the issue of Waste Electrical and Electronic Equipment (WEEE) and the imperative of their inclusion in the circular economy, we compellingly highlight the most significant aspects of this theme, at both the European Union and Romanian levels. Special attention is given to the analysis of norms, practices, and outcomes regarding the management of WEEE at the national level, simultaneously highlighting the main problems and difficulties faced by the addressed field. Clearly, in the conclusion of the paper, we also make a series of proposals for improving the situation. Striving for a comprehensive treatment of the issue, we believe that the work can be of great value to researchers, industry professionals, decision-makers, legislators, as well as entrepreneurs who perceive the EEE/WEEE sector as one where profitable businesses can be conducted.*

Keywords: *EU rules; circular economy; EEE Sector; Romania; risks and benefits; targets and results.*

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Introductory considerations on Waste Electrical and Electronic Equipment (WEEE) and the importance of their recycling

The electrical and electronic equipment (EEE) production sector plays a significant role in the Romanian economy, representing 2% of the GDP (Eurostat, 2022a), with the consumption of such goods clearly on the rise. After a brief period of stagnation (in 2019 and 2020, possibly due to the Covid-19 pandemic), there is a noticeable expansion of EEE sales in Romania in recent years (RG, 2023). Currently, for reasons we will emphasize in this paper, the introduction of circular economy principles has become almost essential in as many sectors as possible, especially where the consumption of EEE plays a significant role. Waste generated from EEE (WEEE) refers to devices of this nature that are out of use, operated with batteries or electric current (from the outlet), and may include a printed circuit board: televisions, refrigerators, irons, washing machines, microwaves, computers, mobile/fixed phones, video cameras, etc. (NAEP, 2023a).

These items exhibit two characteristics that are important in the context of our theme: they are hazardous due to the presence/elimination of toxic substances, but at the same time, they are valuable because of the precious metals they contain (Ciocoiu & Târţiu, 2012). For example, a ton of discarded mobile phones is richer in gold than a ton of gold ore; in a million mobile phones, there are 24 kg of gold, 16,000 kg of copper, 350 kg of silver, and 14 kg of palladium - resources that could be recovered and reintroduced into the production cycle if collected separately as waste (MPWD, 2023). Recovering and recycling gold and other precious metals from WEEE protect natural resources (raw materials) whose extraction harms the environment and contributes to the increase in greenhouse gases. Risks can arise when WEEE is stored in households without allowing the recycling of material components or when consumers dispose of them improperly through household waste. Consequently, efforts to recycle this type of equipment, now considered waste - either as whole assemblies (Figure 1a) or as component elements (including associated consumables) (Figure 1b) - are necessary for maintaining a clean environment and preventing public health incidents.



Figure 1. WEEE - entire assemblies (a) and component elements (b). Source: Compilation made by the author from various images from open source publications (Ecotic.ro, 2023).

WEEE includes various materials, small and complex components, and contains many harmful elements such as CFCs, arsenic, barium, cadmium, cobalt, lead, lithium, mercury, and many others (Forti et al., 2020). Circular economy involves the recovery of materials found in WEEE and their subsequent reintroduction into the production cycle; hazardous substances, such as mercury from energy-efficient bulbs and fluorescent tubes, are separated and safely stored for environmental and human health (RECOLAMP, 2023). Currently, WEEE accounts for 5% of the global total of solid municipal waste, nearly the same proportion as plastic packaging, but WEEE is much more dangerous (Ecotic.ro, 2023) as it contains high-risk substances that need to be extracted and neutralized.

We emphasize that the composition of WEEE is highly complex, with dozens of constituent elements, all posing direct challenges for electronic waste recycling. In their work, Liu et al. (2023) propose a detailed analysis, focusing on the constituent elements to reveal the intricate composition of electronic waste. This composition includes elements that present multiple specific challenges in the process of WEEE recycling. By assessing the role of each element and the materials involved, these wastes can be categorized into several groups: common metals, precious metals, rare elements, rare earth elements, plastic/biomass, glass fiber/concrete, etc. Plastic and biomass are predominantly composed of carbon, hydrogen, and oxygen. Additional elements, such as fluorine, chlorine, and bromine, are often integrated to form compounds like polyvinylidene fluoride, polyvinyl chloride, and brominated substances acting as flame retardants or binding agents. However, these additions increase the ecological risk associated with plastic recycling.

Components with low value (glass fiber, concrete, etc.) mainly contain elements like aluminum, silicon, calcium, sodium, and potassium. These are frequently used in construction or disposed of as waste due to their low value after extracting high-value components. An overview of certain landmarks regarding the diverse content of various WEEE can be obtained through Figure 2.

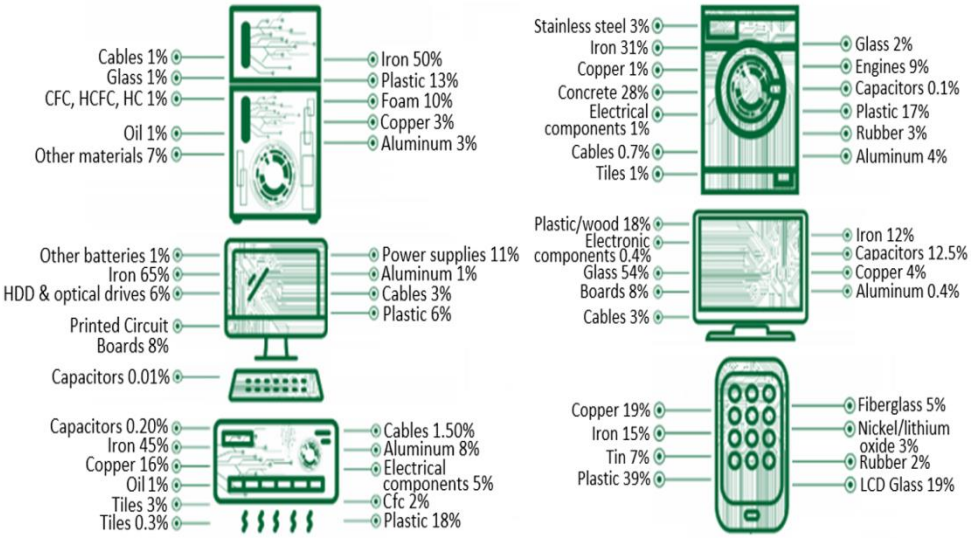


Figure 2. Some highlights regarding the content of various WEEE categories. Source: Compilation/adaptation made by the author after (Ecotic.ro, 2023).

It is important to emphasize that the improper treatment of WEEE (through incineration) generates emissions of dioxins and furans, substances highly persistent in the environment and among the most toxic after radioactive materials. These emissions can cause severe effects such as cancer, hormonal disorders, immune system impairment, diabetes, learning difficulties, lung and skin conditions, chronic fatigue syndrome, hematological problems, disruptions to the nervous system, etc. (Lechpol.ro, 2023). In contrast, WEEE recycling ensures the recovery of significant amounts of secondary raw materials, achieving a high level of recycling-reuse (between 85-90%).

Recycling plays a important role in finding sustainable solutions; once products reach the end of their life cycle, they are collected, sorted, treated, and processed, resulting in recycled materials that can be reintroduced into the economy. Through recycling, waste becomes the primary resources of the future, replacing natural resources and contributing

to sustainable economic growth, offering the planet a chance to regenerate. In this context, it is noteworthy that WEEE contains various materials that can become secondary raw materials, with some being considered „critical" by the European Union. By adopting the circular economy, the proposed solutions become extremely important, considering that WEEE provides valuable opportunities in this regard.

An analysis focused on the perspectives of the circular economy in the production and consumption of EEE (Popa et al., 2023) highlights the benefits that consumers obtain from circular solutions proposed by manufacturers. Thus, if manufacturers gain a competitive advantage by adopting these solutions, buyers benefit from equipment that brings multiple advantages, including reduced resource consumption (especially energy and water) and other benefits (price reduction, easy repair of faulty equipment, easy management of equipment at the end of its life, etc.). Given all these considerations, we must state that the purpose of this endeavor is to explore the Circularity Potential of EEE (The Case of Romania), which is of interest to both the academic environment and industry practitioners. In this regard, we have established a suitable structure for the proposed theme, from the content of which all the unequivocal answers and clarifications for some questions we formulate are derived, such as:

Q1 - Has Romania adopted a regulatory framework regarding WEEE?

Q2 - Is this regulatory framework adequately implemented?

Q3 - Is there a „Romanian specificity" that may affect the achievement of objectives regarding WEEE collection and treatment?

Q4 - Do the developments recorded provide premises for Romania to align with the rigor and discipline imposed by the EU regarding WEEE management?

Our specific approach, typical of a review paper, unfolds throughout the process, encompassing the following structure: (1) Introductory considerations on WEEE and the importance of their recycling; (2) Literature review; (3) An approach from the perspective of adopting the circular economy in the EEE sector in the European Union; (4) Norms, practices, and results regarding WEEE management in Romania; (5) Discussion; (6) Conclusions.

Considering the importance and value of the work, we must state that it is based on accurate and up-to-date data and information related to WEEE management in Romania, within the context of specific European and national regulatory frameworks. We first refer to the results of research conducted by valuable authors who have published their scientific works in

prestigious globally recognized journals (Literature Review Section). Furthermore, up to this point, a work comprising such approaches, with the necessary updates, applied to the case of a European Union member state (Romania), has not been published in a foreign journal.

Regarding the utility of our work, we are firmly convinced that it brings significant importance to all those involved in waste collection, as well as for decision-makers, contributing to the improvement of policies related to EEE collection and processing. We believe that legislators - considering the need for refinements in the regulatory framework applicable to the WEEE domain - and potential entrepreneurs contemplating ventures in the field we address might find a particular interest.

It is worth mentioning that in the final part of the paper, after presenting some proposals for improving the situation, we refer to the limitations of the research, as well as future research directions that we have in mind for this ongoing initiative.

Literature review

WEEE is the fastest-growing solid waste stream globally. Undeniably, the goods generating WEEE are increasingly essential for people in society to make their work more comfortable and efficient, leading to an inexorable trend of amplifying the volume of WEEE (Rajesh et al., 2022). Just three years ago, the production of WEEE was approximately 53.6 million metric tons, of which 17.4% were properly collected and recycled, while the remaining 82.6% went unaccounted for (Forti et al., 2020). The global forecast for WEEE indicates an expected surge to 74.7 million metric tons by the year 2030 (Figure 3).

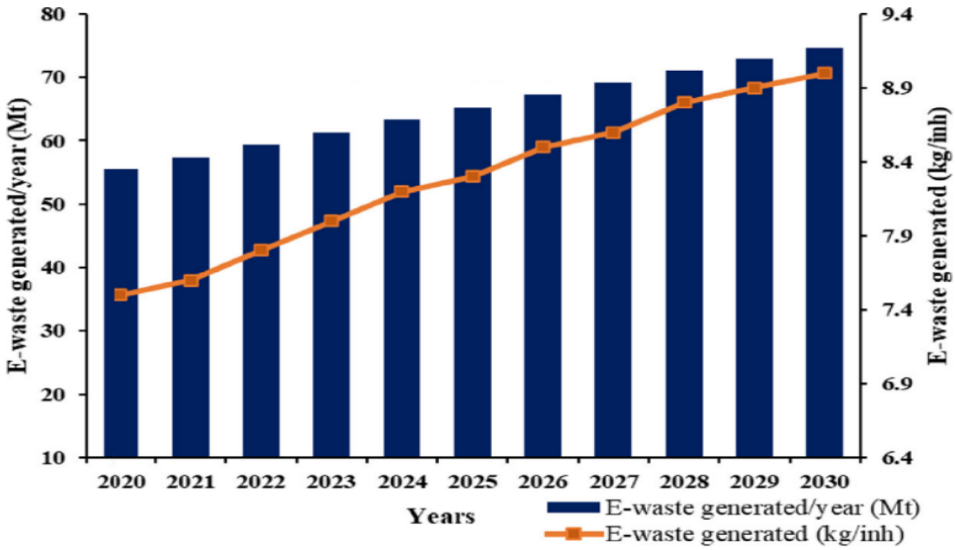


Figure 3. Global quantity of generated WEEE (Forti et al., 2020)

According to Rajesh et al. (2022), nearly 50 million metric tons of WEEE are generated globally each year, with a higher contribution in developed countries such as those in Europe and America; Asia produces almost 24.9 million metric tons of WEEE, followed by America and Europe (Ádám et al., 2021). Europe generates 16.2 kg of WEEE per capita, America - 13.3 kg per capita, and Asia - 5.6 kg per capita. Notably, Europe records the highest rate of WEEE processing/recycling (42.5%) (Ádám et al., 2021). At the same time, China has reduced its import of WEEE in recent years, South Korea has advanced regulations on WEEE, and Japan is the first country to implement Extended Producer Responsibility (EPR). Additionally, India has created its legislation for WEEE management, considering that this country generates almost 2.4 kg per capita (Forti et al., 2020). Jain et al. (2023) argue that WEEE is a type of waste generated by EEE in the industrial sphere, representing one of the most challenging issues that is rapidly expanding. WEEE consists of old or discarded electronic devices, such as computers, laptops, televisions, generators, DVDs, mobile phones, freezers, and other items usually discarded by their original owners due to their short lifespan. They contain a number of hazardous constituents (harmful chemical elements) that have a negative impact on the environment and human health under improper management.

Although WEEE is considered the future of communications, the short lifespans of various EEE lead to their disposal and environmental pollution. On the other hand, Manikandan et al. (2023) concluded that

WEEE is the fastest-growing sector due to the increased use of these items worldwide. This is a consequence of the versatility and accessibility of technological innovation, resulting in massive sales of EEE. WEEE production is rapidly increasing with current industry trends, generally associated with the relatively short lifespan of electronic equipment and the rapid development of technological information. Once EEE completes its lifecycle, it is evident that it falls into the category of WEEE. The generation of WEEE began to increase significantly when various EEE became more accessible, and people massively started to buy new equipment, abandoning repairs. WEEE is the most complex waste produced by society, and when discarded, it can release heavy toxic contents exposing people to health issues. To avoid such issues, waste can be broken down through various techniques, such as toxic metal recovery, and one such process is composting, where metal extraction is known as „leaching".

The major issue associated with the recycling and treatment of WEEE is generally due to its heterogeneous material and complex composition. The chemical compositions of WEEE primarily vary depending on the type and age of the discarded object and their combination with other plastic and ceramic materials commonly used as coverings for electronic items. Analyzing economies in development, Ankit et al. (2021) find that in most of them, a significant portion of WEEE is informally managed and treated without authorization. Inefficient technology and administrative indifference contribute to the lack of formal waste recycling setups. Additionally, recyclers find it challenging to obtain industry certification for responsibly recycling WEEE. A pivotal moment in this regard can be achieved by transforming informal players into small entrepreneurs; this can help achieve the global sustainable development goals for 2030, including reduced health complications and deaths/illnesses caused by toxic and hazardous WEEE components.

Regarding the same area of informal WEEE treatment, Jain et al. (2023) point out that even though some developing states have introduced legislation regulating WEEE management and disposal, some of them, such as India, have failed to efficiently implement formal recycling systems. More accurate life cycle assessment models, successfully used in developing countries, should be more strongly supported and effectively adopted, as protecting society from WEEE risks needs to become a top priority. Other authors (Bostan, 2013) refer to the need for a global study plan focused on children and other vulnerable groups to better understand the health effects of exposure to discarded WEEE. The international health community, researchers, policymakers, as well as non-governmental organizations and

national governments, must work together to address WEEE exposure and its health consequences. Rajesh et al. (2022) draw attention to the fact that solid waste separation should not only be done by workers, as consumers also need to be held accountable. They should dispose of their waste in the right place, depending on its type, necessitating proper awareness of WEEE disposal among residential consumers.

Additionally, the availability of local waste collection centers should be increased and continuously provided so that consumers can easily drop off their WEEE. Ciocoiu and Târțiu (2012) highlight the need for implementing appropriate legislation to support the recycling process, emphasizing its essentiality for two fundamental reasons: on the one hand, some components of WEEE have significant value, and on the other hand, they can pose environmental hazards. They propose a comprehensive approach to ensure an ecological environment, emphasizing the concept of „smart cities", which involves multiple conditions, including infrastructure, artificial intelligence, renewable energy, and the recycling of various waste categories, including WEEE.

Other Romanian researchers (Istudor et al., 2023), through their studies, found that the significant increase in EEE sales is linked to consumers replacing these products at increasingly shorter intervals, often due to technological aging or obsolescence, rather than due to malfunctions. Intensified consumption is closely correlated with the rapid advancement of technology, enabling the rapid launch of EEE with advanced features at more affordable prices. Consequently, the global EEE market is evidently growing, and in Romania, EEE sales have shown an upward trend, especially during the Covid-19 pandemic, with telecommuting and online learning being stimulating factors. Manufacturers play a important role in stimulating the demand for EEE, but their business objectives are not always aligned with the EU's goals of promoting product reuse for sustainable consumption. The frequent replacement of equipment by consumers, without environmentally responsible behavior, has turned EEE into a massive and rapidly evolving source of waste globally. The aspects highlighted by the authors support the idea that the limitations of the traditional linear economy are becoming increasingly apparent in ensuring resource security in the future. They argue that solutions for the proper management of WEEE are provided by the principles of the circular economy, which encourage efficient waste collection by optimizing products and their lifespan, using cleaner and renewable technologies, and promoting related policies (Ghisellini et al., 2016).

A recent study (Ciobanu et al., 2023) shows that states giving special attention to the transition from a linear to a circular economy are the most developed, supporting investments in durable products and/or circular business models (Bostan et al., 2010). This leads to a shift in consumer behavior towards repairing and reusing functional products and appropriately disposing of those without reuse potential. Currently, for the sustainable development of any economy, the transition to a circular economy is essential, and this manifests differently depending on sectors and types of products (Dobre-Baron et al., 2022).

In the context of the expansion of the circular economy, the production and consumption of EEE play a significant role (Mosora et al., 2023). However, the same authors, concerned with identifying factors that can influence WEEE collection in the European Union (these being: the type and size of appliances, the quantity of EEE placed on the market, legislative measures, etc.), indicate that, from a collection perspective, large household appliances hold a significant share.

An approach from the perspective of adopting the circular economy in the EEE sector in the European Union

Globally, 90% of used resources are not recycled, resulting in massive overexploitation of the planet's resources, with serious consequences for the environment and climate change (Dhawan & Beckmann, 2019). The increasing consumption of EEE, coupled with the rapid pace of innovation in this field, generates a large amount of waste annually, and management practices are nearly unable to keep up with an adequate pace. In the European Union,

WEEE multiply/generate the fastest, compared to other waste categories. However, less than 40% of them are recycled. In this regard, Figure 4 is highly illustrative.

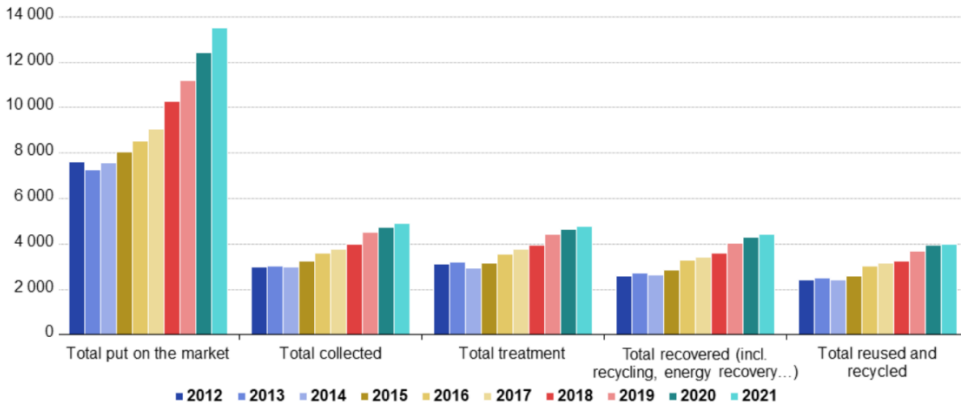


Figure 4. EEE put on the market and WEEE collected, treated, recovered, recycled and prepared for reuse, EU, 2012–2021 (thousand tons) (Eurostat, 2022b)

We observe here the trends in the quantity of EEE introduced to the market and WEEE collected, treated, recovered, recycled, and prepared for reuse in the EU in the years 2012-2021. The quantity of EEE introduced to the market in the EU evolved from 7.6 million tons in 2012 to a peak of 13.5 million tons in 2021. During this period, the lowest level was recorded in 2013, with 7.3 million tons. Throughout the entire period of 2012-2021, the quantity of EEE introduced to the market increased by 77.1%. The total collected WEEE increased from 3.0 million tons in 2012 to 4.9 million tons in 2021 (+65.1%), while the total treated WEEE increased from 3.1 to 4.8 million tons (+54.2%) in the same period. Recovered WEEE developed from 2.6 to 4.4 million tons (+69.8%), and WEEE recycled and prepared for reuse increased from 2.4 to 4.0 million tons (+64.8%) from 2012 to 2021 (Eurostat, 2022b).

This situation necessitates multiple measures to improve these respective indicators, considering the negative effects on the environment and human health (Ghiga et al., 2023). Moreover, at the European level, commendable efforts are already being made to transition to a circular economy (abandoning the linear formula – Figure 5), including in the EEE sector, with significant concerns regarding the reuse of materials used.

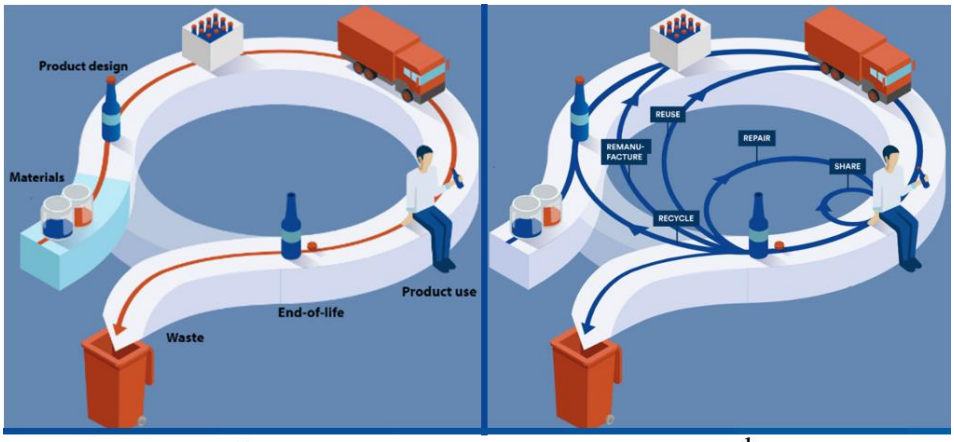


Figure 5. From a linear economy (a) to a circular economy (b) (EP, 2023)

Circular economy involves transforming waste into resources, resulting in a significant reduction in the actual amount of waste. This economic paradigm represents a production and consumption model that promotes the reuse, repair, refurbishment, and recycling of existing materials and products to keep them in the economic cycle for as long as possible (EP, 2021).

This model requires integrating circularity and sustainability within the value chain, from design and production to consumption (Hatzivasilis et al., 2021). In the EEE sector, implementing a model that adheres to the principles/rules of the circular economy can take the form illustrated in Figure 6.

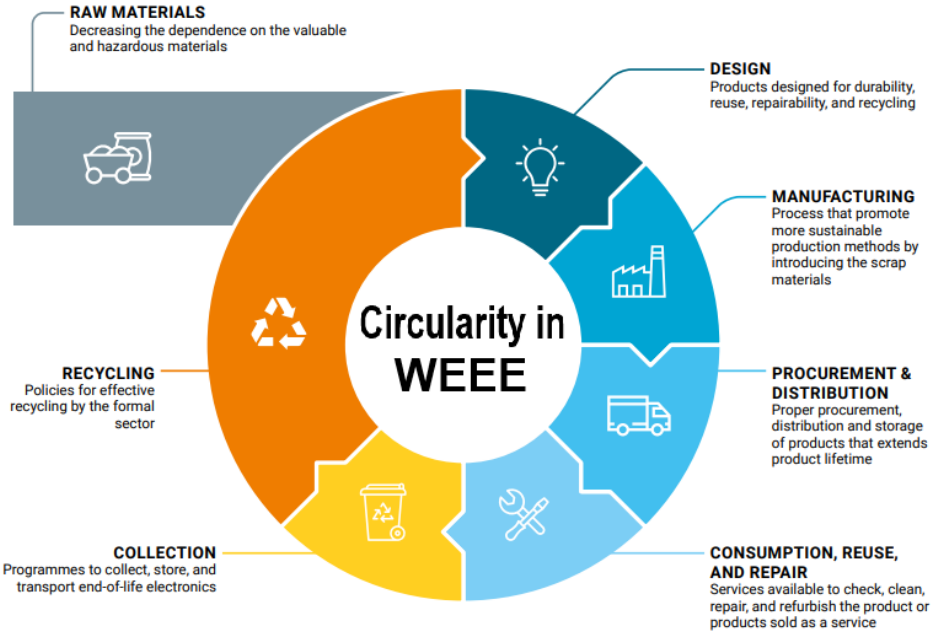


Figure 6. Circularity in WEEE (NRC, 2022)

The Action Plan of the European Commission identifies seven key areas for achieving the circular economy: plastics, textiles, WEEE, food, water and nutrients, packaging, batteries and vehicles, buildings and constructions. The primary focus is on the electronics sector, which contains rare metals or environmentally impactful materials (Mosora et al., 2023).

In response to this, initiatives encouraging the production of goods with a longer lifespan have emerged, facilitating their reuse and repair (EC, 2022a). For instance, under the legal warranty, sellers are proposed to repair products, except when replacement is more economical; moreover, outside the warranty period, easier and more accessible ways of conducting repairs are promoted. Circular economy not only reduces carbon dioxide emissions but also stimulates job creation and economic growth. It is based on a product life cycle that includes stages of using raw materials, design, production/processing, distribution, consumption, collection, recycling, and transforming recycled products into raw materials (Orţan et al., 2016).

The interest and commitment of decision-makers in the European Union regarding WEEE collection are becoming increasingly pronounced. The European Parliament defines WEEE in a way that practically covers any household or business item containing electrical circuits or components, regardless of the power source (mains or battery), including parts discarded

as waste by the owner without the intention of reuse. This refers to those EEE „which constitute waste in accordance with Article 3(1) of Directive 2008/98/EC, including the components and consumables of the product at the time it becomes waste" (EP, 2012). The European Union's involvement in this issue is justified by the rapid increase in WEEE in the EU waste stream, surpassing other types of waste. In 2019, the global population generated 53.6 million tons of electronic waste (Europe generated 12 million tons), and it is estimated that these figures will increase to 74.7 million tons by 2030 (Baldé et al., 2022).

In the European Union, collection primarily focuses on large household appliances such as washing machines or electric radiators, representing over half of the total quantity of collected WEEE. They are followed by IT and telecommunications equipment (laptops, printers), consumer electronics, and photovoltaic panels (video cameras, fluorescent lamps), as well as small household appliances (vacuum cleaners, toasters). All other categories, including electric tools and medical devices, together represent only 7.2% of the WEEE collected in 2021 (EP, 2020), while the European Union recorded a collection of 11.0 kg of WEEE per inhabitant (Figure 7).

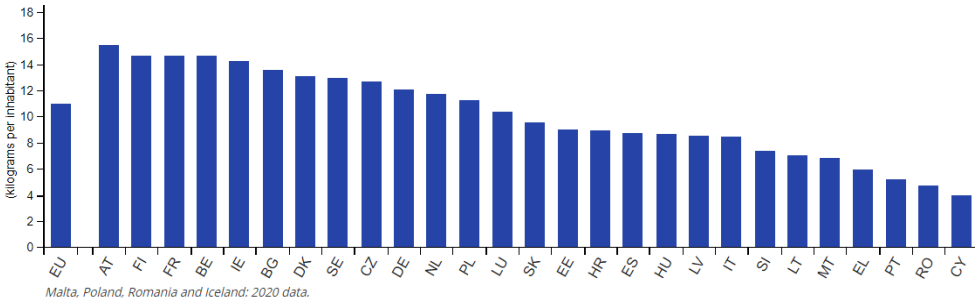


Figure 7. DEEE collected per inhabitant in the EU (2021) (Eurostat, 2022b)

In Figure 8, we present an overview of the performance of the European Union Member States concerning the collection objectives of 45% and 65%. Here, collected WEEE is depicted as the share of EEE introduced to the market, and the share is calculated as the ratio between the quantity of collected WEEE in 2021 and the average quantity of EEE introduced to the market in the three preceding years (2018-2020).

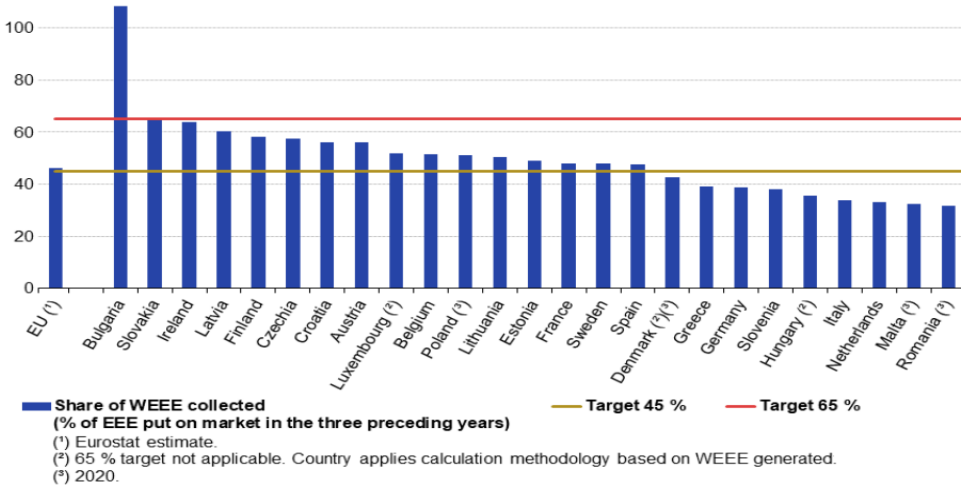


Figure 8. Total collection rate for WEEE in EU, 2021 (% of the average weight of EEE put on the market in the three preceding years) (Eurostat, 2022b)

In 2021, it is observed that 16 member states of the European Union exceeded the WEEE collection target of 45%, while another member state reported a rate close to this target, reaching 42.7%. Additionally, two EU member states achieved a more ambitious objective with a collection rate of 65% in 2021, while two other states approached it with rates of 60.2% and 63.8%, respectively (Eurostat, 2022b). The European Commission has emphasized the reduction of WEEE since March 2020, presenting an action plan for the circular economy. This plan establishes immediate objectives such as the „right to repair" and improving overall reusability, introducing a common charger, and implementing a reward system to promote the recycling of electronic products (EP, 2020). Thus, it is anticipated that the USB Type-C connector will become the common charger for most electronic devices in the EU by the end of 2024, and laptops must be equipped with a USB Type-C port by April 28, 2026.

According to EU-wide research (Ciobanu et al., 2023), it is suggested that by 2030, the average quantity of reused and recycled WEEE could increase by approximately 33.97%, while the recycling rate of these wastes is estimated to increase by 55.40% by 2030. However, improvements are expected, considering that the European Parliament has adopted a resolution on the New Circular Economy Action Plan (EP, 2021), calling for additional measures to achieve a carbon-neutral, sustainable, non-toxic, and fully circular economy by 2050. These measures include adopting stricter recycling rules and setting mandatory targets for material consumption by 2030 (EP, 2021).

Standards, Practices, and Results Regarding WEEE Management in Romania

The Romanian legislative framework regarding the recycling of WEEE

The issue of preventing the generation of WEEE, as well as aspects related to their reuse, recycling, and other forms of recovery, in order to reduce the volume of disposed waste, has been regulated in Romania before joining the EU (RG, 2005a). The aim was, even then, to improve environmental and public health performance through actions carried out by all parties involved in the life cycle of EEE: producers, importers, distributors, consumers, and waste treatment companies. The meaning attributed to EEE was: those devices whose operation is based on „electric currents or electromagnetic fields and the equipment for the generation, transmission, and measurement of these currents and fields (...) intended for use at a voltage lower than or equal to 1,000 volts AC and 1,500 volts DC." (RG, 2005a).

For WEEE, the given definition was „EEE that constitutes waste according to the provisions of Emergency Ordinance No. 78/2000 (...), including all components, subassemblies, and consumable products, integral part of the equipment when they become waste." (RG, 2005a).

After joining the European Union and considering the commitments outlined in the Accession Treaty, WEEE management became a national priority for Romania. Through Government Decision No. 1037/2010 (RG, 2010a), changes were made to the existing legislation to address Cause No. 2010/4000 C(2010)1558, transmitted by the European Commission, in the context of noting delays in the transposition and complete implementation of the provisions of Article 8(2) of Directive 2002/96/EC on waste electrical and electronic equipment (RG, 2010b). This initiative also aimed to transpose the provisions of Article 5 of Directive 2008/112/EC of the European Parliament and of the Council, amending Council Directives 76/768/EEC, 88/378/EEC, 1999/13/EC, and Parliament and Council Directives 2000/53/EC, 2002/96/EC, and 2004/42/EC, in accordance with Regulation (EC) No 1272/2008 on classification, labeling, and packaging of substances and mixtures. In the legislative adjustment process aimed at implementing the provisions of Directive 2002/96/EC, clauses were introduced to facilitate the application of all forms of financial guarantee provided. In parallel with the definitions in the directive, new definitions were added for terms such as „warranty period", „equipment placed on the national market" the „one-to-one" system, „collective

organization", „historical waste" and „EEE intended for use within private households", to clarify their use in the content of the normative act. Subsequent changes focused on controlling and reducing the number of economic operators not complying with current legislative provisions.

These legislative adjustments aimed to improve the legal framework to achieve the country's objectives mentioned in Directive 2002/96/EC and the efficient implementation of the WEEE management system in Romania. Thus, explicit legislative provisions (RG, 2010a) were introduced detailing the obligations of local public authorities to collect WEEE from private households at collection points and to establish and manage these collection points. Rules were also established for determining the percentage rate of producers' obligations to collect WEEE from the population, replacing the quantitatively expressed value.

Other introduced provisions (RG, 2010a,b) relate to the obligation for all authorized economic operators conducting activities in this field to achieve treatment and recovery rates for WEEE. At the same time, the distributors and buyers were obligated to request proof of registration in the register of EEE producers from the seller. Despite these implemented measures, the performance of the WEEE management system in Romania was limited over the next four years. As a result, on March 31, 2014, the European Commission issued a „letter of formal notice for failure to fulfill the obligation to communicate national measures transposing Directive 2012/19/EU of the European Parliament and of the Council." Romanian authorities responded to this request on May 30, 2014, committing to adopt the normative act transposing the directive by the end of August 2014. In reality, Romania adopted the expected normative act (RG, 2015a) only after reaching the last stage of the pre-litigation phase of the infringement procedure.

In the absence of adoption, the contentious procedure for failure to fulfill the obligation to communicate national transposition measures (decided urgently by the Court of Justice of the European Union) could have been triggered, which might have imposed a lump sum or a penalty as a coercive measure. In the context of the recommendations of the European Commission, Romania established, based on Communication SEC(2010) 6106, a minimum lump sum of 1,740,000 euros, with penalties ranging from 2,000 to 124,000 euros per day of delay (RG, 2015b).

This legislative framework, presented in the aforementioned context (RG, 2015a), aims primarily to reduce waste and optimize resource recovery by imposing new standards on the collection, reuse, and recycling of WEEE. In this regard, a register of producers has been implemented, which includes

producers offering WEEE through distance communication means. A significant change involves expanding the scope for both consumer and professional WEEE, excluding large fixed installations (such as oil platforms, airport transport systems, elevators, etc.).

Regarding selective collection, the target of 4 kilograms of WEEE per inhabitant has been replaced with a percentage formula representing between 40% and 45% of the weight of EEE introduced into each market of the Member States of the European Union, starting from the year 2016. From 2021, the minimum annual collection rate is 65% of the average weight of EEE introduced into the market in the last three preceding years (RG, 2017). Until 2020, the collection target was not achieved in any year (NAEP, 2023b). To encourage consumers to deliver WEEE, it was mandated that each locality have at least one collection point, and for localities with a large population, one collection point for every 50,000 inhabitants. EEE distributors are obliged, according to the Directive, to provide conditions for the free take-back of WEEE, simultaneously supplying equivalent equipment, and to ensure the collection of very small WEEE in stores with sales areas of at least 400 m² or nearby, without the obligation to purchase equivalent equipment.

Collection centers in stores for very small WEEE are not subject to registration or authorization requirements (RP, 2011). Another form of WEEE collection has been implemented through collection centers organized by authorized economic operators, operating based on a contract with producers or collective organizations or entering into agreements with economic operators specialized in WEEE treatment on behalf of producers or collective organizations (RG, 2015a,b). To prevent the loss of valuable secondary raw materials, environmental damage, and the provision of incomplete data, the collection objective and the obligation to ensure that all collected WEEE are environmentally treated (including the removal of all liquids from WEEE, in accordance with specific standards for toxic and hazardous substances) and are reported correctly have been established. Emergency Ordinance No. 5/2015 (RG, 2015a) also introduces more rigorous requirements regarding the control of WEEE management and the transfer of used EEE within or outside the EU borders, assumed to be WEEE, aiming to reduce the risk of inappropriate disposal of physically depleted equipment.

Among other things, exporters must demonstrate the functionality and reuse capacity of the transported EEE. The provisions of the same legal act regulate the valorization of WEEE in the period 2014-2019, with annual increases of 5% starting from August 14, 2015, both in terms of valorization

and recycling. After August 15, 2018, EEE are regrouped from the 10 categories defined in the transition period (i - large household appliances; ii - small household appliances; iii - information and communication equipment; iv - consumer electronics and photovoltaic panels; v - lighting equipment; vi - electrical and electronic tools, excluding large fixed industrial tools; vii - toys, leisure, and sports equipment; viii - medical devices, excluding all implanted and infected products; ix - monitoring and control instruments; x - vending machines) into 6 categories (i - thermal transfer equipment; ii - monitors and equipment containing screens with a surface larger than 100 square centimeters; iii - lamps; iv - large equipment; v - small equipment; vi - small information and communication equipment, with external dimensions below 50 cm), maintaining the same targets (RG, 2015a,b).

The regrouping was necessary to align national legislation with Directive 2012/19/EU on WEEE, which came into force on August 13, 2012, and had to be transposed by February 14, 2014. During this transition period, the scope of the Directive was identical to that of the previous Directive (10 categories of WEEE), with the exception of photovoltaic panels, which were added to the scope of the Directive with immediate effect. Starting from August 15, 2018, the scope of the Directive expanded to include all categories of EEE, so they are now divided into 6 categories (instead of the previous 10), as explained above. Regarding the financing of WEEE management, manufacturers have full responsibility for WEEE collection, ensuring funding for WEEE collection throughout the entire lifecycle (RG, 2015a,b).

When introducing a product to the market, they must provide financial guarantees to prevent situations where WEEE management costs from products that are no longer manufactured or cannot be identified (orphan products) are borne by society or active manufacturers. Given the variations in the lifespan of EEE (5-8 years for refrigeration appliances, 20-30 years for photovoltaic and wind systems), it is important that the guarantee established at the time of EEE market entry covers the waste management costs from these EEE when they become WEEE (RG, 2015a,b). Some aspects of these regulations are detailed in subordinate legislation (MEWF, 2011, 2021). Also, starting from March 17, 2023, Law No. 42 (RP, 2023) came into effect, approving the procedure for preparing WEEE for reuse, the technical requirements for WEEE preparation for reuse, and the reporting and monitoring requirements for reused EEE. This transposes into national legislation the provisions of Directives 2008/98/EC and 2012/19/EU - of the European Parliament and of the Council - which prioritize preparation for reuse over the recovery and recycling of WEEE,

respecting the standard SR EN 50614:2020 on the preparation for reuse of WEEE.

We anticipate that, in the context of the Romanian market, these legislative measures will have a significant impact on improving WEEE management at the national level. Involved in this area are manufacturers, their representatives (responsibility transfer organizations), retail chains, municipalities, control authorities, WEEE collection and treatment operators, with the consumer placed at the end of the chain (Green-report.ro, 2023). Central authorities, such as the Ministry of Environment, Waters, and Forests, the National Environmental Protection Agency, the Environmental Guard, and the Environmental Fund Administration, are also involved. It's worth noting that national legislation imposes penalties for not reaching collection targets (Ghenea, 2023).

Since 2020, the Environmental Fund Administration (AFPM) applies penalties per kilogram based on the costs of normal waste management for quantities that do not meet the target. Emergency Ordinance No. 196/2005 (RG, 2015a) establishes a contribution of 4 lei/kg for EEE in case the collection target of 65% from the POM („put on the market") is not achieved, and 20 lei/kg for category 3 - lamps. The contribution for category 3 has been reduced to 8 lei/kg following recent changes (RG, 2022b). Non-compliance with this ordinance attracts sanctions for both individuals and legal entities, and for the latter, the amount of sanctions can reach up to 50,000 lei for improper WEEE collection and treatment, non-compliance with markings upon EEE market entry, or non-registration of producers.

The results of WEEE collection activity in Romania

In Romania, only producers registered in the National Register of Producers and Importers of WEEE, managed by the National Environmental Protection Agency, have the right to introduce EEE to the national market. At the beginning of January 2023, this register included 4,566 EEE producers (NAEP, 2023b). As presented in the preceding section of the document, WEEE management has two main objectives: (i) preventing the generation of WEEE and promoting reuse, recycling, and other valorization methods to minimize waste disposal; (ii) improving the environmental performance of all actors involved in the life cycle of EEE (producers, distributors, and consumers), with a particular focus on companies directly involved in WEEE treatment. Table 1 presents the evolution of quantities of EEE introduced to the market during the period 2019-2021.

Table 1. Quantities of EEE introduced to the market during the period 2019-2021 (tons) (NAEP, 2023b)

Category	2019	2020	2021
1 - Thermal transfer equipment	77,574.175	84,911.802	91,311.804
2 - Screens, monitors, and equipment (with a surface larger than 100 square centimeters)	25,520.678	26,063.396	25,759.219
3 - Lamps	2,132.268	2,434.092	2,367.245
4 - Large-sized equipment (any external dimension larger than 50 cm)	117,611.907	122,863.772	158,693.063
5 - Small-sized equipment (no external dimension larger than 50 cm)	57,311.506	62,672.907	75,113.020
6 - Small-sized information and telecommunication equipment (no external dimension larger than 50 cm)	9,584.868	10,100.607	10,356.015
Total	289,735.401	309,046.576	363,600.366

Regarding the collection of WEEE, to achieve the objectives of reuse, recycling, and valorization of WEEE, producers can act individually, using their own resources, or by transferring these responsibilities, based on a contract, to an authorized company. The total WEEE treatment capacity in Romania has exceeded 120,000 tons/year since 2018 (RG, 2017), with dismantling/recycling centers evenly distributed nationwide. In 2018, there were 883 authorized economic operators in the field of WEEE collection and/or treatment, out of which 75 also held environmental permits for WEEE treatment (RG, 2017). It is worth mentioning that the collection infrastructure at the local public authorities' level is underdeveloped. The evolution of quantities of collected EEE during the period 2019-2021 is presented in Table 2.

Table 2. EEE collected in the period 2019-2021 (tons) (NAEP, 2023b)

Category	2019	2020	2021
1 - Thermal transfer equipment	19,764.14	20,173.210	18,967.810
2 - Screens, monitors, and equipment (with a surface larger than 100 square centimeters)	10,283.45	9,873.065	13,467.713
3 - Lamps	399.24	430.295	152.198
4 - Large-sized equipment (any external dimension larger than 50 cm)	42,292.40	43,814.166	44,457.082
5 - Small-sized equipment (no external dimension larger than 50 cm)	6,292.84	8,803.657	8,427.881
6 - Small-sized information and telecommunication equipment (no external dimension larger than 50 cm)	8,590.96	5,404.468	4,037.488
Total	87,623.02	88,498.861	89,510.172

The achievement method of WEEE, across the six categories of WEEE (classification applicable starting from 2019, according to Emergency Ordinance No. 5/2015 on WEEE (RG, 2015a) is illustrated using Table 3.

Table 3. How to achieve the WEEE recovery objectives (2019 – 2020) (NAEP, 2023b)

Category	Capitalization objective provided by law starting from 2019 (%)	Objective of capitalization achieved (%) in 2019	Objective of capitalization achieved (%) in 2019
1 - Thermal transfer equipment	85	91	88
2 - Screens, monitors, and equipment (with a surface larger than 100 square centimeters)	80	83	90
3 - Lamps	80	81	87
4 - Large-sized equipment (any external dimension larger than 50 cm)	85	90	85
5 - Small-sized equipment (no external dimension larger than 50 cm)	75	82	81
6 - Small-sized information and telecommunication equipment (no external dimension larger than 50 cm)	75	88	77

For the year 2022, we have a situation that reflects the quantities of EEE/WEEE related to the contribution provided in Article 9, paragraph (1), letter w) of Emergency Ordinance No. 196/2005 regarding the Environmental Fund (RG, 2005) (its revenues also come from economic operators introducing EEE to the national market), reported through the Declaration of Payment Obligations to the budget of the respective Fund by authorized companies (Table 4).

Table 4. The quantities of EEE introduced on the national market and WEEE collected in 2022 (kg) (Ecologic.rec.ro, 2022)

Category	Total quantity introduced to the market	Quantity introduced for which objectives are achieved individually	Quantity introduced for which objectives are achieved through transfer to Authorized Operators	Quantity collected individually	Quantity collected by Authorized Operators
Large Equipment	156,427,612.86	1,955,557.87	154,472,055.01	2,104,856.42	99,086,856.48
Small Equipment	63,990,474.80	1,056,860.52	62,933,614.17	125,034.05	17,876,676.21
Screens	24,371,813.15	50,278.89	24,321,534.22	341,996.00	14,418,445.23
Lamps	2,544,669.15	36,283.70	2,508,385.45	4,892.00	1,434,825.93
Telecommunications	9,485,433.97	87,257.57	9,399,176.70	111,726.50	6,210,532.33
Thermal Transfer Equipment	79,272,115.49	84,752.70	79,187,363.79	200,542.00	26,151,626.78
Grand Total	336,093,122.42	3,270,990.95	332,822,129.34	2,889,046.97	165,178,951.96

Observing the annual average of WEEE quantities introduced to the national market during the period 2019-2021 (Table 1), which exceeds 300 thousand tons of EEE, the collection of approximately 195 thousand tons of WEEE would have been necessary in 2022. However, as indicated in Table 4, the collected quantity did not even reach the threshold of 170 thousand tons of WEEE.

Discussion

The issues analyzed in the previous section clearly highlight the challenges existing in Romania regarding the adoption and implementation of principles and norms related to the management of WEEE following the circular economy model. To better understand the discussed issues, we present several approaches here, organizing our ideas and arguments as responses (*R1-R4*) to the problems (*Q1-Q4*) outlined in the introductory part of the paper.

In a first response (R1) addressing question *Q1* – „Has Romania adopted a regulatory framework for WEEE?" – we demonstrate that currently, at the national level, there is a coherent set of rules and procedures regulating WEEE management, in accordance with the relevant legislation of the European Union.

It is essential to underline that the introduction of these norms has consistently been delayed compared to the deadlines stipulated by the legal provisions issued by the European Union, often when the risks of facing sanctions were imminent. We have already exemplified that Romania adopted Government Decision No. 1037/2010 (RG, 2010a) amending certain legislative provisions, compelled to respond within the context of Case No. 2010/4000 C(2010)1558 for delayed transposition and incomplete implementation of the provisions of Article 8(2) of Directive 2002/96/EC on WEEE (RG, 2010b), transmitted by the European Commission.

Additionally, five years later, it enacted Emergency Ordinance No. 5/2015 on WEEE (RG, 2010b), only after reaching the final stage of the pre-litigation phase of the infringement procedure. If this legislative act had not been adopted, the Romanian state would have had to pay a minimum lump sum of 1,740,000 euros, along with penalties ranging from 2,000 to 124,000 euros per day of delay (RG, 2015b).

Subsequently, other national legislative acts regarding WEEE have been adopted in compliance with the European legislative framework. However, it is worth noting, by way of example, that the Emergency Ordinance regulating this field (RG, 2010b) took 9 years to become law in Parliament, and discussions about its amendment do not focus on increasing the quantities of collected WEEE or achieving European objectives but rather on the issue of financial control within the system (60-70 million euros annually) (Ecologic.rec.ro, 2023).

A response (R2) related to question *Q2* – „Is this regulatory framework adequately implemented?" – is affirmative, with certain aspects mentioned. On one hand, Romania tends to align with the parameters of WEEE collection, meeting the normative requirements of the EU. The evolution of most analyzed indicators reflects a satisfactory state, indicating that the transposition/implementation of these norms is proceeding slowly. However, on the other hand, even EU legislation is subject to change.

In the near future, the production and consumption of EEE will be impacted by significant modifications, such as: (i) The legislative proposal for the Regulation on Eco-design for Sustainable Products (EC, 2022b), which includes the Product Environmental Footprint Initiative, the digital passport, and the eco-label (Prodeee.ro, 2022b); (ii) The revision of Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in EEE (RoHS Directive) and alignment with the Regulation on Registration, Evaluation, Authorization, and Restriction of Chemicals and ecological design requirements; (iii) The Circular Electronics Initiative (EP, 2022), proposing a

unified solution for charging the batteries of mobile devices and plans for retailers to take back products in „take-back" systems; and (iv) Measures to establish a new „right to repair."

Adapting to these legislative changes will promote sustainability, recycled content, upgradeability, maintenance, repair, and access to spare parts, among other aspects.

Next answer (*R3*) related to question *Q3* – „Is there a «Romanian specificity» that could affect the achievement of objectives regarding WEEE collection and treatment?" – requires the consideration of several aspects. Unlike other European countries, Romania faces distinct conditions that significantly influence the achievement of WEEE collection goals (Ecologic.rec.ro, 2023).

In rural areas of Romania, the population is characterized by aging and poverty, and those capable of affording appliances, PCs, or mobile phones are very few. Products such as dishwashers, air conditioners, heat pumps, PCs, or laptops are rarely purchased in the households of Romania's poor villages. Old equipment, whether functional or not, tends to remain in rural households, where people are reluctant to part with old refrigerators or washing machines. Of course, in larger cities, residents make new acquisitions, but few are willing to part with old equipment without receiving a compensatory value. As a result, most of these electronic wastes end up in informal circuits, where they are „sold" to Transfer of Responsibility Organizations (TOR) at exorbitant prices.

A significant cause for this situation is the lack of involvement by local authorities in solving the problem by not establishing collection centers for WEEE. Central environmental authorities have also not contributed significantly to achieving European collection goals. Romania, like most countries in Central and Eastern Europe, faces a target of 65% of the average quantities introduced to the market in the last three years, being a still unsaturated market with many new equipment acquisitions.

Setting a collection target of 85%, as Hungary and Luxembourg do, would be more realistic and contribute to the continuous improvement of collection performance (Gurău, 2023). Furthermore, Romania faces some of the highest penalties in the European Union for not meeting the targets, while municipal collection infrastructure has deficiencies. The oversized collection target, together with high penalties (2 lei/kg), creates a context that encourages illegal practices such as speculation, fraud, etc.

The final answer (*R4*) related to question *Q4* – „Do the developments recorded provide the premises for Romania to comply with the rigor and discipline imposed by the EU regarding WEEE management?"

– we formulate it further. In broad terms, we can assert that Romania aligns with the rigor and discipline imposed by the EU regarding WEEE management.

However, for better compliance, several objectives and priority actions for the EEE sector have recently been established (Table 5).

Table 5. Objectives and actions for the EEE sector (RG, 2023)

General Objectives	Specific Objectives	Priority Actions
• Promoting responsible consumption and environmental education;	• Enhancing the durability and reusability of EEE and preventing the generation of WEEE.	• Preparing the private sector to comply with the future Regulation on Eco-design for Sustainable Products and the Sustainable Products Initiative, which will establish new legal requirements for eco-design to ensure sustainability, maintenance, modularity, repairability, and recyclability by promoting R&D and technology transfer for eco-design and the application of circular economy concepts.
• Preventing waste generation and ensuring sustainable waste management.	• Proper management of used EEE and WEEE to extend their lifespan.	• Adopting policies to encourage the reuse and repair of EEE.
• Prioritizing the promotion of innovation and research in the field of EE (Electrical and Electronic) products.	• Increasing the rate of separate collection of WEEE.	• Improving the national system for collecting EEE and B&A (Batteries and Accumulators) waste generated by the population.

In addition to the previously mentioned actions, to comply with the requirements and discipline imposed by the European Union regarding WEEE management, Romania should adopt the following measures (RG, 2023): (i) Transparency of costs associated with the collection, transportation, repair, treatment, and valorization; (ii) Adoption of harmonized EU standards regarding specific processes of WEEE recycling; (iii) Implementation and continuous improvement of integrated databases in the WEEE sector, including information related to EEE introduced to the market, reused and repaired items, as well as generated and collected waste.

Strong and ongoing online consumer education campaigns could provide significant benefits, as well as support from local public authorities

for the development of appropriate infrastructures, including repair and refurbishment activities, known for their advantages in extending the lifespan of EEE. As these measures are implemented, Romania's position is strengthened among EU states that adhere to new principles and rules regarding WEEE management.

Conclusions and Proposal

Posing multiple risks to the environment and human health, but, on the other hand, offering a whole array of economic benefits, WEEE and the application of circular economy principles related to them constitute a quasi-permanent research theme from various perspectives. We reinforce this statement by acknowledging that the scale of WEEE has experienced exponential trends, significantly influenced by the expansion of the Internet and the multitude of goods and tools supporting human activities in all dimensions: professional, educational, household, leisure/recreation/sports/tourism, healthcare, etc.

Therefore, our study considered the current situation in Romania's EEE sector, which needs to implement the European legal framework in this matter. We focused on the application of various norms, actual practices, and results concerning WEEE management (with an emphasis on collection, post-2019, when reporting shifted to six WEEE categories). Before delving into these aspects, we conducted a study of several valuable authors who published scientific works in globally recognized prestigious journals. Additionally, we included an approach from the perspective of adopting circular economy principles in the EEE sector of the European Union.

Our approach highlights that Romania has made satisfactory progress in the studied domain, considering that in 2015, it seemed entirely resistant to adopting and implementing EU norms applicable to the WEEE sector. We emphasize that legal compliance was driven solely by the imminent application of massive sanctions by the European Commission against the Romanian state, reaching the final stage of the pre-contentious phase of the infringement procedure. Although EU collection targets have not yet been achieved (with few European states succeeding, as detailed in our study), the trend in the obtained results indicates certain improvements.

In our work, we highlighted the causes and difficulties faced by Romania in achieving the established indicators/targets, which are of a socio-economic nature (population with low purchasing power, lack of incentives), cultural/educational, organizational/managerial, legal (informal collection, leading to illegal WEEE dismantling for metal extraction, remains uneradicated), etc. There are multiple deficiencies in municipal collection

infrastructure. One of the main causes is the lack of involvement of local public authorities, neglecting the establishment of WEEE collection centers.

Our proposals to improve performance in WEEE recycling activities, beyond the intentions expressed in governmental strategies and related action plans, include encouraging the creation of companies specializing in the temporary rental of EEE (household or industrial), expanding the number of those providing repair/refurbishment services for WEEE, and identifying an optimal formula for granting public support/financial incentives (budget allocations/tax deductions) for recycling companies. Clearly, local public authorities must initiate programs, attracting European budgetary sources, aiming to develop a territorial network of WEEE collection centers, adequately supported by technical personnel.

Certainly, our approach has some limitations. Although we address the issue of WEEE norms even before Romania's EU accession, remarks and observations on the actual WEEE recycling activity (assortments, groups/categories, quantities, etc.) predominantly focus on the period 2019-2022. We chose this period due to the homogeneity of WEEE generation and collection reports (transitioning from 10 to 6 categories, in accordance with Directive 2012/19/EU on WEEE) and the fact that specific reports for 2023 are not finalized.

As a result, we commit to a future research direction investigating a more extended timeframe (minimum 5 years), making necessary correlations with data and information from government bodies and Eurostat to draw more valuable conclusions and make pertinent/efficient proposals.

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