INVESTIGATING GOOD PRACTICES IN THE CIRCULAR ECONOMY RELATED TO ELECTRICAL AND ELECTRONIC EQUIPMENT (EEE) THROUGH THE EUROPEAN CIRCULAR ECONOMY STAKEHOLDER PLATFORM (ECESP)

Mariarita Paciolla [1], Marco La Monica [2], Francesca Ceruti [3], Francesca Ferrero [1], Giacomo Seravalli [1] and Tiziana Beltrani [2]

[1] CDCA - Centro di Documentazione sui Conflitti Ambientali, Via Macerata 22/A, 00176 Rome, Italy
[2] Laboratory Resources Valorization (RISE), Department for Sustainability (SSPT), ENEA, Via Anguillarese, 301, 00123 Rome, Italy
[3] Department of Economics and Management (DEM), University of Brescia, Contrada S. Chiara 50, 25122 Brescia, Italy

ABSTRACT: The pervasive integration of electronic technologies in the contemporary digital landscape underscores the paramount significance of electrical and electronic equipment (EEE). Beyond their indispensable utility in daily life, certain components within EEE, such as precious metals and Rare Earth Elements (REEs), hold classification as critical raw materials (CRMs), pivotal for the European economy. Within urban contexts, the proliferation of electronic devices transforms cities into reservoirs or urban mines. This issue not only underscores the inherent value within EEEs but also highlights the necessity of optimizing its sustainable consumption and production patterns at all stages of the life cycle and across various sectors. The optimization of the complete product life cycle serves as a foundational pillar of the circular economy (CE). While the transition from a linear to a CE has been a longstanding objective promoted by the EU, a comprehensive mapping elucidating potential shortcoming in the effective implementation of this transition in Europe for the field of EEE remains elusive. This paper seeks to investigate the state-of-the-art of CE good practices for EEEs in Europe, shedding light on potential strengths and challenges to be addressed. To obtain an empirical perspective, the European Circular Economy Stakeholder Platform (ECESP) serves as a tool to delineate the trajectory of progress throughout the transition to a CE. The analysis encompasses both life cycle phases and the production sector. The findings underscore a prevailing focus on the product's end-of-life phase and sectors associated with recycling and waste management, while the initial life cycle phase remains underexplored in terms of eco-design solutions or innovative processes. On a positive note, several instances of new business models have emerged, redirecting consumption emphasis towards services.

Keywords: EEE, WEEE, circular economy platforms, good practices, urban mining

1. INTRODUCTION

In today's technologically driven world, our reliance on electrical and electronic equipment (EEE) is

undeniable, shaping our daily routines and societal structures. At the heart of this reliance lies the supply chain of EEE, which is strongly connected to the utilization of the so-called Critical Raw Materials CRMs. The CRMs are key components essential for various strategic sectors, including renewable energy production, electric mobility, and defense, that set their economic importance both with the difficult in sourcing them (Carrara et al., 2023). The first list of CRMs was compiled in 2011 (European Commission, 2011) and then regularly updated every three years (European Commission, 2014; 2017; 2020b; 2023a). All materials listed have a supply risk and economic importance higher than a threshold value set by the EU, as defined by the methodology established in 2017. These CRMs, identified by the European Union, play a pivotal role in developing the goals outlined in the 2030 Agenda for Sustainable Development, since their application in strategic sector (Mancini et al., 2019). In order to achieve the sustainability objectives, the availability and responsible management of CRMs emerge as keystones for succeeding. However, challenges in CRM supply chains, coupled with their indispensable role in sustainable development, implies the urgency of strategic action. In this direction goes the Critical Raw Materials Act issued in March 2023 (European Commission, 2023b). It further highlights Europe's commitment to addressing these challenges and leveraging CRMs to advance towards a more sustainable future. Through concerted efforts to secure CRM availability, promote responsible sourcing practices, and foster innovation in CRM recycling. In this context, particular attention is drawn to the urban context, where cities brim with electronic devices. Proper management and recycling of such equipment can lead to virtuous internal flows of CRMs, effectively transforming cities into real urban mines (Andooz et al., 2022). The interest in facilitating the collection of electrical devices for consumers has led to the introduction, since 2008 of extended producer responsibility (EPR) for waste electrical and electronic equipment (WEEE) (European Union, 2008). This obligates producers to manage the end-of-life phase of devices they introduce to the market, involving both assuming the financial burden of their disposal and directly supervising collection efforts. In addition, the European Directive 2012/19/EU, starting from 2019, has set a collection target of 65%, calculated as the ratio between the total weight of collected WEEE and the average weight of EEE placed on the market in the previous three years (European Union, 2012). In 2019, three European countries exceeded the target: Bulgaria, Croatia, and Poland, while Italy reached approximately 40% (European Commission, 2023c).

The European effort in sustainability also holds in the action "The Missing Link: A European Action Plan for the Circular Economy" and subsequently, since April 2018, the European package on the CE (Stahel, 2016; Stindt et al., 2014; Neligan et al., 2023; Geissdoerfer et al., 2020, Geissdoerfer et Al., 2017) that contains a series of provisions aimed at promoting the transition to a new circular model. In fact, within the European Green Deal, a circular transition is considered crucial for attaining this goal (European Commission, 2019). This approach not only contributes to climate change mitigation and the promotion of sustainability but is also fundamental for advancing the Sustainable Development Goals (SDGs) from the Agenda 2030 (Lambda et al., 2024; Binsuwadan et al., 2023). In fact, in the European Green Deal, where Member States have been committed to achieving the objective of climate neutrality by 2050, the circular transition is considered crucial for achieving the goal. Therefore, the shift from a linear to a circular economy (CE) is a path advocated by Europe for many years already. However, its implementation within companies is often not widely perceived by society, resulting in a knowledge gap between industry and the broader community (Rocca et al., 2023). This gap contributes to the perception of the circular model as a distant goal rather than an achievable reality. Consequently, there is a pressing need to explore empirical cases shared by companies to gain insights into the key success factors, sustainable challenges, and the necessary steps toward achieving the paradigm shift from linear to circular models. CE platforms have emerged as a response to this need, providing a comprehensive overview of ongoing experiences (Beltrani et al., 2021; 2022). These platforms serve as invaluable tools for sharing and exchanging ideas, strategies, initiatives, knowledge, and challenges among diverse users. Through these platforms, stakeholders can collaborate and learn from each other's experiences, accelerating progress

towards a more CE on a global scale. Furthermore, in the Action Plan updated in 2020, the European Commission identified the electronic components sector among the priority productive sectors (European Commission, 2020a). This further emphasizes the importance of having information regarding the state-of-the-art in the development of circular solutions for EEE and WEEE (Cardenia et al., 2022; Cheshmeh et al., 2023).

To this end, this contribution aims to empirically investigate the spread of CE in Europe, with a specific focus on the EEE value chain. The investigative tool employed was that of good practices (GPs), which represent the primary means of communicating innovation in the CE today. This work will present a comprehensive mapping, within the European contexts, of GPs related to the management of EEE. This mapping of GPs is essential for understanding the characteristics, strengths, and challenges encountered across all phases of the life cycle and the economic sectors involved.

The paper is organized as follows: in the subsequent section 2, an overview of the European Circular Economy Stakeholder Platform (ECESP) is provided. Section 3 describes the methodology adopted for the analysis of the GPs, starting with the criteria for platform research, followed by the identification of study variables and groupings. Section 4 presents the results of the qualitative analysis regarding the life cycle phase and sector of origin. Finally, section 5 presents the conclusions drawn.

2. GOOD PRACTICES AND EUROPEAN CIRCULAR ECONOMY STAKEHOLDER PLATFORM

The ECESP is the main repository of GPs in the field of CE in Europe, established in 2017 as a joint initiative of the European Commission and the European Economic and Social Committee (EESC). Its primary objective is to support the dissemination of CE principles at the European level and enable stakeholders from different countries and sectors to meet and interact, highlighting cross-sectoral opportunities as well as potential challenges. ECESP is composed of a Coordination Group consisting of 24 members representing business networks, workers, consumers, civil society, and local authorities. The Coordination Group is tasked with strengthening interaction among stakeholders, facilitating the exchange of GPs, and promoting a European debate for a full transition to a CE (ECESP, 2024).

In ECESP, in the "Submit a Good Practice" section, each user can submit their GP by completing four sections: the first contains an initial description with the necessary information for completing the following sections; the second requests contact details of the company and the person completing the GP form, as well as consent for publication; the third section requires the title, type of organization, main field of activity/sector; in the fourth and final section, the title and a description of the GP, the qualitative/quantitative results obtained, the level of application, the duration, the original language, the key areas, and the type of funding received are requested (ECESP, 2023).

ECESP has defined and published on its website guidelines (ECESP, 2018) that identify the key criteria/requirements that the review group considers before inclusion on the website, making the approval and publication process faster.

The criteria considered by the ECESP review group as fundamental principles for the publication of GPs are:

- Relevance to the CE;
- Completeness and clarity of information;
- Tangibility of expected results;
- Educational and behavioral contribution/value-added;
- Compliance with European publishing rules.

In this regard, GPs must demonstrate the valorization of resources throughout the entire production cycle: production, consumption, and disposal phases. They must also propose innovative solutions to implement circularity through new business models. The description of GPs must be clear and highlight

their relevance within the CE. The results and purpose must be clear and quantifiable, and the technologies used to achieve them must be specified. The feasibility of GPs must be evidenced by concrete and reproducible results, implying that projects must already be in progress or completed to proceed with publication. GPs that do not directly relate to the production cycle may still be considered if they contribute indirectly to achieving the CE, such as by increasing consumer awareness and incentivizing behavioral changes or facilitating resource sharing and reuse. Finally, GPs included in the ECESP must always comply with European rules, avoiding ethically inappropriate and promotional content without providing useful information.

It is important, finally, to underline that parallelly with the establishment of the ECESP, several European nations have instituted platforms connected to ECESP. In this regard, in Italy, in 2018, ENEA promoted the creation of a national interface for ECESP, giving life to the mirror platform "Italian Circular Economy Stakeholder Platform - ICESP." One of the main objectives of this platform is the collection and mapping of GPs in the Italian circular economy to promote understanding and replicability of successful cases (Del Vecchio et al. 2021; ICESP 2024).

3. METHODOLOGY

The analysis of the GPs presented in this contribution is based on two main criteria: their positioning along the life cycle phase and their reference sector. The choice to analyze the GPs according to these two variables stems from the fact that the objective of this work is to carry out a mapping that helps understand which phases and sectors are most prevalent and which ones, instead, require more attention. This enables an understanding of how Europe is positioning itself regarding the development of circular solutions for EEEs. In the following subsections will be described the selection methods, as well as the definition and grouping of the chosen variables.

3.1 Criteria for identifying good practices

To identify the pertinent GPs, the search engine on the ECESP website was utilized with keywords such as: “EEE”, "Electronic devices", "WEEE" and "E-waste". This search yielded a total of 43 selected GPs concerning electronic devices.

The information regarding the collection, systematization, review, and dissemination of GPs was sourced and analyzed starting from the document that highlights the guidelines for the CE GPs on the ICESP (Beltrani et al., 2021). Many details regarding EEE and WEEE and the related GPs were obtained from the document reported by Working Group 4 of ICESP (Cardenia et al. 2022) where also a list of GPs available on ICESP and ECESP related to WEEE is reported. Other important starting points are provided by "Analysis and Mapping of Italian Circular Economy Good Practices by Sector and Product Life Cycle Phase” (Beltrani et al., 2020) and "Analysis of the Replicability of Good Practices and Quantification of Environmental, Economic, and Social Impact at the National Scale" (Beltrani et al., 2022), both published by ICESP.

3.2 Variable definitions and groupings

By studying the various options that organizations can select when submitting their practices through the dropdown menus on ECESP, several observations were made: whether the fields to be filled in the collection form on the platform were mandatory or not; whether there were differences in terms of the number of options and the possibility of multi-tagging, i.e., selecting more than one option in the respective fields. Based on the conducted study and the gathered information, the life cycle phase and the industrial sector have been selected as study variables.

In the GP collection forms, it is necessary to provide information regarding the life cycle phase and the type of organization, while it is not mandatory to provide information about the funding type, start date, and practice location. Additionally, ECESP allows unlimited multi-tagging for all entries specified by the organization during the GP submission. Since most of the projects submitted on the platform present multiple life cycle phases and industrial sectors chosen by the organizations, a grouping of related areas was constructed. This choice was made to facilitate the analysis, and in the following subsections, both the variables and the groups of items falling under the same main variable will be defined.

3.2.1 Life cycle phases

In Figure 1 are shown the life cycle phases of a product in the CE framework that include: "Innovation and Investments", "Production", "Consumption, "Waste Management" and "From waste to resources" (or "Secondary Raw Materials"). This framework is inspired by the first European Circular Economy Action Plan of 2015, in which specific areas of intervention are identified (European Commission, 2015). These areas are later adopted by ECESP for mapping European GPs in the circular economy. In order to position the GPs along the value chain the information gathered from this variable is cross-referenced with the phases of that model. This association was created ad hoc to identify which life cycle phase is most affected by projects related to the implementation of circular solutions. In other words, the approach involved clustering the items sourced from ECESP based on the life cycle phase variable (or key area), categorized according to each of the five phases outlined in the CE model. The description of each phase is reported in Table 1 and defines in an unambiguously way the framework adopted in this work. The categorization of the phases "Production", "Consumption", "Waste Management", and "Secondary Raw Materials" in Table 1 is based on the conceptual framework proposed by La Monica (2018), which extensively addresses these aspects. On the other hand, the delineation of the "Innovation and Investments" phase constitutes an original contribution by this study, synthesized from the European CE Action Plan of 2015 and insights derived from the ECESP's GPs. In addition, when more than one life cycle phase was indicated by the organization, a critical selection of the representative one was made by studying the detailed description and websites of each GP to verify their correspondence with what is reported in Table 1 for each life cycle phase.

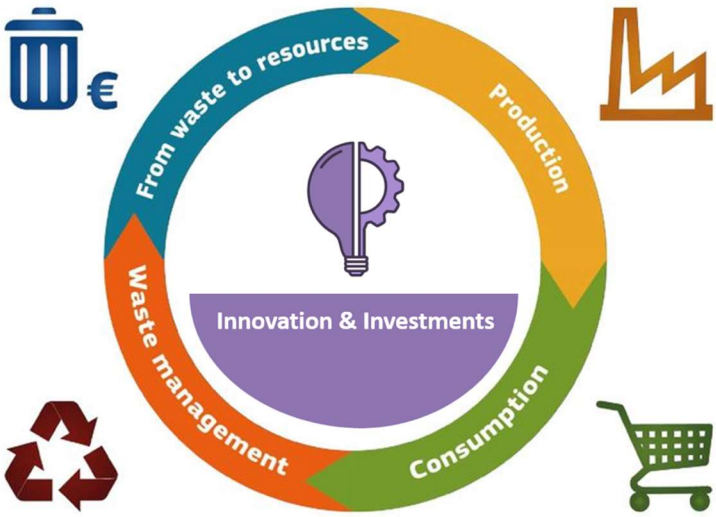

Figure 1. Circular Economy Framework. Source: Authors' elaboration from European Commission (2018)

The analysis of 43 GPs concerning EEE on the ECESP revealed that only 4 GPs are situated in the "Innovation and Investments" phase, 6 are associated with the "Production" phase, 14 pertain to the

"Consumption" phase, 14 are distributed in the end-of-life phase related to “Waste Management”, while 5 are related to "Secondary Raw Materials," representing production scraps or materials derived from recycling processes that can be reintroduced into the economic system as new raw materials.

Table 1. List of groupings for the life cycle phases

Groupings	Life cycle phase
Innovation and Investments	▪ Eco-friendly design or eco-design ▪ Incremental innovation and improvement ▪ Development of new technologies for treatment, separation, and recovery ▪ New platforms and software licenses ▪ Development of new business models ▪ Programs for the implementation of innovative investments
Production	▪ Life Cycle Thinking ▪ Ecologically Equipped Production Areas ▪ Industrial symbiosis ▪ Remanufacturing ▪ Reverse logistics ▪ Dematerialization and digitalization ▪ Eco-Management and Audit Scheme ▪ Maintenance and repair ▪ Identification and replacement of hazardous chemicals ▪ Replacement of non-renewable materials with renewable and recycled ▪ Dissemination of GPs and good techniques in various industrial sectors
Consumption	▪ Green Public Procurement – GPP ▪ Green labels ▪ Sharing economy or collaborative economy ▪ Consumption of services instead of products ▪ Repair and reuse centers ▪ Circular city ▪ Awareness, education, and communication campaigns ▪ Practices to counter planned obsolescence
Waste Management	▪ Integrated waste management ▪ Simplification, certainty, and clarity of waste legislation ▪ Improvement of control and inspection regimes ▪ Resource flow mapping ▪ Traceability of resources, products, services, and supply chains ▪ High-quality separate collection and recycling infrastructure ▪ Extended producer and consumer responsibility schemes ▪ Biological treatment of waste (e.g., bio-refining, composting...)
Secondary Raw Materials	▪ Creation of secondary raw material markets and recycled materials ▪ Platforms to match supply and demand of secondary raw materials ▪ Increased demand for secondary raw materials and recycled materials ▪ Clarity about the sources, composition and quality of secondary materials ▪ Urban and landfill mining ▪ Promotion of non-toxic material cycles ▪ Availability of data on secondary raw materials and information exchange

Source: Authors’ elaboration from La Monica, 2018.

3.2.2 Industrial sectors

In ECESP, all sectors indicated in the drop-down menu can be selected. Generally, the sector submitted by the organization has been retained, but in cases where more than one sector was selected,

an analysis of individual GPs was conducted to identify the most relevant one. This resulted in a single, primary sector of reference for each GP.

To analysis, groupings for the sectors were made. The first grouping relates to sectors closely connected with the "End-of-Use" phase of the product; hence, the categories related to separate collection, repair and reuse, recycling, waste management, and secondary raw materials. The second grouping pertains to "Education and Awareness"; thus, education, consumer awareness and accountability activities, and social engagement. Following that, the third grouping involves "Innovative Solutions," encompassing eco-design, research, and digital technologies. Additionally, "Services" include sectors related to energy and public services, product-as-a-service models, B2B services, and services for individuals and households. Finally, for the analysis, the sectors of agriculture, electronics, packaging, and chemicals were grouped under "Other" as they are not directly related to the previous categories. The sector's group are shown in Table 2 below.

Table 2. List of sectors' groupings.

Groupings	Sectors
End-of-Use	▪ Waste Management and secondary raw materials ▪ Separate collection ▪ Recycling ▪ Repair and reuse
Education and Awareness	▪ Social enterprise ▪ Education ▪ Consumer empowerment
Innovative solutions	▪ Eco-design ▪ Research ▪ Tecnology
Services	▪ Energy and public services ▪ Product-as-a-service ▪ Business-to-Business (B2B) services ▪ Personal and households services
Other	▪ Agriculture ▪ Eletronics ▪ Packaging ▪ Chemicals

Source: Authors' elaboration.

Considering the foregoing, from a general overview of the 43 collected good GPs: 22 falls within the "End-of-Use" sector; 7 pertain to "Education and Awareness" activities; 2 relate to the "Services" sector; 7 represent innovative solutions, and 5 fall under the category of "Other."

4. RESULTS AND DISCUSSIONS

The objective of this section is to analyze the selected GPs related to EEE in the ECESP, focusing on their placement along the life cycle phase and the sector of the organizations that submitted them. This allows us to understand how European countries are progressing towards a circular transition where all phases of a product's life cycle must be considered, both by producers and consumers.

From the life cycle phase point of view the most populated phase are Waste Management and Consumption with 14 out of 43 GPs, followed by Production with 6 GPs, Secondary Raw Materials with 5 GPs and finally Innovation and Investments with 4 GPs. This result highlights that from an empirical perspective ECESP-based and focused on the EEE value-chain the majority of the CE GP are still engaged in the final stage of the product life cycle, mostly regarding its recycling or disposal. Similarly, but in a more pronounced manner, the sector with the highest number of GPs is End-of-Use, with 22 out of 43 GPs. This indicates that half of the organizations that submitted GPs operate in recycling or repair and reuse activities. Following the End-of-Use sector, Education and Awareness, as well as Innovative Solutions, each account for 7 GPs, while Services have 5 GPs, and Other has 2 GPs.

The lower representation of GPs in the Other sector could be attributed to the focus of the paper on EEEs and WEEEs, which are not typically associated with sectors such as Agriculture or Chemicals (see the definition in paragraph 3.2.2). The dominance of Waste Management and Consumption as the most common life cycle phase, coupled with the fact that half of the projects belong to the End-of-Use sector, suggests that the current system remains still rooted in a traditional business model. Of course, this is a partial picture concerning the projects found on the ECESP related to EEE and their waste. The fact that this is the specific outcome for this value chain could actually be a consequence of the introduction of EPR and Extended Consumer Responsibility, as well as the increasing pressure from the EU regarding the collection of WEEE.

To cross-reference the information by life cycle phase and sector, or in other words, to represent how the sectors are distributed across the various life cycle phases and vice versa, the 43 selected projects in ECESP can be represented in a matrix form, using a bubble chart. Specifically, the classification according to the life cycle phase is represented on the ordinate axis, while the sector of the submitting organization is on the abscissa axis (Figure 2). The sizes of the circles in the graph are directly proportional to the number of GPs associated with the specific combination of phase and sector, with the corresponding value indicated within the respective circle. The most populated areas in the Cartesian space (sector, phase) have been highlighted in yellow.

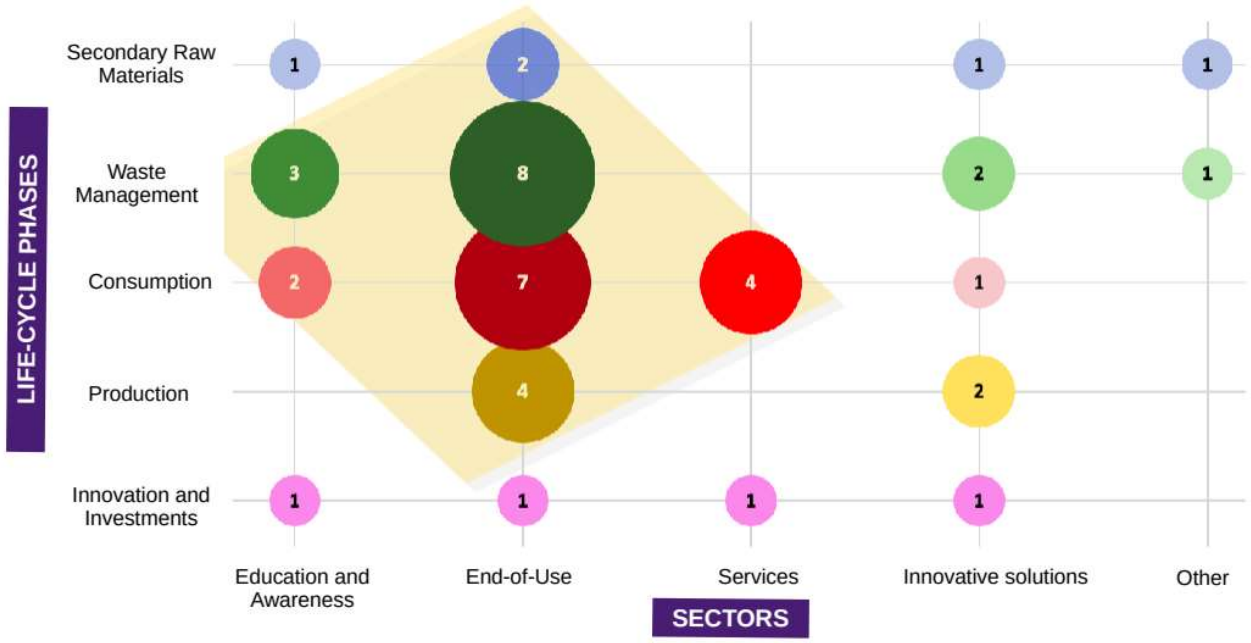

Figure 2. Distribution of good practices across Life cycle Phases and Sectors.

By looking at the most populated area in the plot depicted in Figure 2, it is possible to observe that the

majority of GPs found are situated in the Waste Management phase of the life cycle and in the End-of-Use sectors populated by 8 out of 43 GPs. The projects identified in this area of the plot aim to achieve efficient processes to valorize resources. The goal is to increase the collection of WEEE through technologies for sorting, separation, treatment, recovery, and recycling of materials. Proper recycling permits to valorize materials that can be reintroduced into the production cycle. Examples of this projects include the "Kujala waste symbiosis" in the Finnish region of Lahti and the "Transforming waste into resources" by the Romanian Green Group Holding. The first wants to increase recycling and reduce the amount of waste used for energy production. The mechanical sorting plant constructed for this project can process up to 65,000 tons of mixed waste, waste for energy production, and construction waste per year. From these types of waste, the plant separates fibers, plastics, and metals for recycling. In this case, WEEE are just one kind of materials treated. This is not the case for the second project cited since GREENWEEE International is an integrated treatment plant for WEEE that operates under a WEEELABEX license for large domestic appliances, small appliances, cathode ray tubes, and CFA workflows.

Second in the list of the most populated area is the one that interest the Consumption phase versus still the End-of-Use sector populated by 7 out of 43 total GPs. The projects regarding the phase Consumption and falling within the End-of-Use sector mainly involve the distribution of surplus non-food products or the purchase of defective products, which are then refurbished and sold at a lower price. For example, Fairmittlerei (Fair Mediation, in German) manages a network of donor companies and manages their surplus products (including EEEs), mediates them, and delivers them to NGOs throughout Austria, creating a logistic and financial advantageous situation for all parties involved. Another project in this area is RECOSI based in Ireland, which sells high-quality refurbished laptops, desktops, and IT equipment sourced from global companies and government departments across Europe.

It is interesting to observe that while Consumption is the second most populated phase, the same is not the case for the Services sector, yet it still accounts for 4 out of its 5 GPs being applied in the Consumption phase and the other in Innovation and Investments. This highlights that nearly all organizations (80%) within the Services sector that submit a GP about WEEE and EEE are involved in projects centered around the Consumption phase. This distribution sets apart the subset of GPs within the Services phase from the complete sample and even from the other subsets studied, as Waste Management, which is one of the primary aspects in other cases, is notably absent here. This data shows the emergence of a new consumption paradigm not based on product ownership but on services, thus decoupling possession from ownership. In this area, some GPs involve the rental service of technological items, while others are projects aimed at increasing the adoption of a circular model. An example is the leasing system Commown, where subscribers pay a fixed monthly fee to use the phone but not to own it, providing users with mobile phones without having to worry about repairability, durability, or end-of-life issues. In case of hardware problems, Commown provides its subscribers with quick replacements and independently repairs individual modules or disposes of broken parts using Fairphone's retrieval system. Or another is the case of AIMPLAS that coordinates the C-SERVEES project with the aim of promoting a more efficient CE in the use of resources in the EEE supply chain, by developing new circular business models.

The Production phase has the majority of GPs involved in a single sector: End-of-Use (4 out of 6) while the other 2 belong to the sector Innovative solutions. The 2 GPs in the Innovative Solutions sector refer to the innovative use of recycled plastics in the EEE components or to effort in designing objects that are easier to dismantle, coupled with the development of new commercial models for their introduction to the market, as in the paradigmatic case of Fairphone. In fact, Fairphone aims to create a positive social and environmental impact throughout the life cycle of a phone. In addition to using fair materials and offering good working conditions, this includes long-lasting design; reuse and recycling (by making phones easier to dismantle); product-as-a-service. Regarding the End-of-Use sector in the Production phase, there is a

greater focus on the regeneration and repair of products such as printer cartridges, computers, and audio devices. Across all these circular practices, emphasis is placed on the materials used and the fight against planned obsolescence, implemented through repair services, sometimes even with perpetual duration.

In ECESP, for the Innovation and investments phase the GPs are distributed across different sectors. Specifically, the GPs involve the development of technologies for recovering plastic from End-of-Use WEEE; innovative solutions for building CE for the “Data Centre” industry; management and recovery services of CRMs from electronic devices and photovoltaic waste; and education and awareness projects such as “the WEEE caravan” to engage schools and local communities.

Regarding the GPs in the Secondary Raw Materials phase, they mostly consist of sharing platforms for the reuse, repair, or collection of WEEE. The other GPs involve the reuse of cardboard packaging for EEE, such as the practice carried out by the Elak Electronics webshop, or the paradigmatic case of Miele washing machines, whose components are disassembled and sent to foundries to be reused due to the well-known composition of metals. This allows us to observe that, at least from what has been shared on the analyzed platform in Europe, there is a focus on End-of-Use management, albeit aimed at the development of innovative digital solutions and citizen education and awareness.

Finally, in the Innovative Solutions sector, there are GPs that refer to the application and use of "Big Data", the creation of "smart bins", and innovative products in processes or materials that ultimately move towards eco-design. The products of the last two mentioned GPs are a watch and a mobile phone. The watch, designed and produced by “Circular Clockworks”, is based on the efficient use of secondary raw materials mainly from WEEE, while also addressing End-of-Use management. The mobile phone is the aforementioned Fairphone. The distribution across the different phases of the life cycle is quite homogeneous; in fact, all phases have at least one GP. Specifically, the two phases of the life cycle with the highest representativeness are Waste Management and Production (both representing 29%). The other phases of the life cycle (Consumption, Innovation and Investments, Secondary Raw Materials) all have the same share, which is 14%. This latest finding is noteworthy as it suggests a growing consideration for all phases of a product's life cycle in innovative solutions. Although the attention remains relatively minimal compared to the End-of-Use sector, it signals a step forward towards a circular transition of the European economic model.

5. CONCLUSIONS

The national and international promotion of the development and the spreading of GPs has become a necessary policy instrument for the transition toward circular models.

ECESP contributes to the collection, mapping and sharing of CE European circular economy GPs. This paper identifies virtuous examples related to the real application of circularity and gives an overview of the state of the art and level of maturity of the models applied to GPs for EEEs in Europe, highlighting the limits and barriers on which future activities should focus.

The analyzed data reveals a notable trend: the majority of GPs identified focus on the Waste Management and Consumption phases of a product's life cycle. Additionally, within the sectors of reference, the End-of-Use sector stands out with the highest number of GPs, addressing activities such as recycling, separate collection, and reconditioning. This observation highlights a critical finding in the analysis of CE practices within the EEE sector: a predominant emphasis on the latter stages of a product's life cycle. The fact that this outcome pertains to EEEs and WEEEs likely indicates how European policies related to EPR and targets for WEEE collection are driving actions aimed at enhancing efficiency in this sector and key area. Moreover, it depicts a scenario still oriented towards waste management or recycling rather than waste prevention. Specifically, initiatives related to the Innovation and Investments phase, which encompasses eco-design and the initial stages of the production process, are notably scarce.

Meanwhile, the sector of Innovative solutions is quiet homogeneously distributed among all the life cycle phases. This at least suggests a growing consideration for developing new solutions in all the value chain of a product.

On the other hand, from the analysis of the Services sector, it was found that the phase it mostly focuses on is Consumption. This highlights the emergence of new business models no longer based on ownership but on services, thus decoupling possession from ownership. This is evident in various iterations of the CE model, such as the sharing economy or eco-leasing.

Finally, based on the findings, a key point that emerges is that the dissemination of GPs related to the EEE sector at the European level is still relatively limited. This is evidenced by the low number of GPs found on the ECESP platform.

In conclusion, this study provides a preliminary analysis that contextualizes the current state-of-the-art regarding the implementation of GPs in the CE for EEEs across various industrial sectors and life cycle phases. Further investigation should prioritize examining the organizations implementing these GPs, the types of funding utilized, the levels of applicability, and the geographical distribution across Europe. By delving deeper into these aspects, a more comprehensive understanding of the challenges and opportunities in advancing circular economy principles within the EEE sector can be developed, which will serve as the focus of future research works.

Moreover, several potential future developments warrant consideration. One avenue for exploration involves comparing the findings for EEE sector with those of other sectors of interest. Another avenue entails comparing them with other equivalent national platforms in European countries, such as the ICESP. These comparative analyses could yield valuable insights into the effectiveness and adaptability of circular economy initiatives across different sectors and regions.

ACKNOWLEDGEMENTS

The authors thank the Erion WEEE organization for the grant provided for the "Training for Circularity" project. This work is indeed the result of that journey which, through education and research, aims to promote circularity in the WEEE sector.

REFERENCES

Andooz, A., Eqbalpour, M., Kowsari, E., Ramakrishna, S., & Cheshmeh, Z. A. (2022). A comprehensive review on pyrolysis of E-waste and its sustainability. Journal of Cleaner Production, 333, 130191. https://doi.org/10.1016/j.jclepro.2021.130191.

Beltrani T., Conte M., Creanza G., La Monica M., Creo C,,Cutaia L., Nobili P., Sbaffoni S., Sposato P.,Sezzi E., Gatto F., Re I., Ferrini M., Finamore M., Dalla Valle A., Caoli T., Perrucci D., Sabbatini D., Pecchia G., Palermo M.V. (2020). Report GdL6 Vol.1 "Analisi e mappatura delle buone pratiche italiane di economia circolare per settore e fase del ciclo di vita dei prodotti" del GdL 6 della Piattaforma ICESP". DOI 10.12910/DOC2020-008.

Beltrani T., Creo C., Barberio G. and Cutaia L. (2021). "Linee guida Buone pratiche di economia circolare". ENEA. https://doi.org/10.12910/DOC2021-006.

Beltrani T., De Santis A., Giannoccaro I., La Monica M., Creo C, Barone F., Basili C., Ercoli A.., Cutaia L., Picarelli A., Sbaffoni S., Gresia F., Loponte V., Leoni I., Viti S., Fontana N., Lombani I., Carioli T., Dalla Valle A., Losa L., Dacomo A., Lanzi G., Palermo V. M., Matarazzo A., Mancini G., Arfò S., Raciti G. (2022). "Analisi della replicabilità delle buone pratiche e quantificazione dell'impatto ambientale, economico e sociale a scala nazionale". ENEA. https://doi.org/10.12910/DOC-2022-067.

Binsuwadan, J., Yousif, G., Abdulrahim, H., & Alofaysan, H. (2023). The Role of the Circular Economy in Fostering

Sustainable Economic Growth in the GCC. Sustainability, 15(22), 15926. https://doi.org/10.3390/su152215926.

Cardenia C., Tammaro M., Campadello L., Pellucchi I., Laudadio E., Amato A., Santoro M., Soncini I. and Aiello M. (2022). "L'economia circolare nelle filiere industriali: il caso Apparecchiature elettriche ed elettroniche (AEE)". ENEA. https://doi.org/10.12910/DOC-2022-066.

Carrara, S., Bobba, S., Blagoeva, D., Alves Dias, P., Cavalli, A., Georgitzikis, K., Grohol, M., Itul, A., Kuzov, T., Latunussa, C., Lyons, L., Malano, G., Maury, T., Prior Arce, Á., Somers, J., Telsnig, T., Veeh, C., Wittmer, D., Black, C., Pennington, D., Christou, M. (2023). Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/386650, JRC132889.

Cheshmeh, Z. A., Bigverdi, Z., Eqbalpour, M., Kowsari, E., Ramakrishna, S., & Gheibi, M. (2023). A comprehensive review of used electrical and electronic equipment management with a focus on the circular economy-based policy-making. Journal of Cleaner Production, 136132. https://doi.org/10.1016/j.jclepro.2023.136132.

Del Vecchio, P., Passiante, G., Barberio, G., & Innella, C. (2021). Digital innovation ecosystems for circular economy: The case of ICESP, the Italian circular economy stakeholder platform. International Journal of Innovation and Technology Management, 18(01), 2050053. https://doi.org/10.1142/S0219877020500534

ECESP - European Circular Economy Stakeholder Platform (2018). "Circular Economy Good Practices: guidelines for submissions to the ECESP website". https://circulareconomy.europa.eu/platform/sites/default/files/ecesp_-_website_-_gp_criteria_-_v3.pdf

ECESP - European Circular Economy Stakeholder Platform (2023). "Good Practices". https://circulareconomy.europa.eu/platform/en/good-practices. Last access: May 17, 2023

ECESP - European Circular Economy Stakeholder Platform (2024). Home page. https://circulareconomy.europa.eu/platform/en. Last access: February 18, 2023

European Commission (2011). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Tackling the challenges in commodity markets and on raw materials. Brussels, 2.2.2011. COM(2011) 25 final.

European Commission (2014). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions On the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative. Brussels, 26.5.2014. COM/2014/0297 final */

European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy. Brussels, 2.12.2015. COM(2015) 614 final

European Commission (2017) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the 2017 list of Critical Raw Materials for the EU. Brussels, 13.9.2017. COM/2017/0490 final.

European Commission (2018). "Measuring circular economy - new metrics for development?". https://ec.europa.eu/newsroom/env/items/624232/en . Last access: March 1, 2024.

European Commission (2019). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions The European Green Deal. Brussels, 11.12.2019. COM(2019) 640 final.

European Commission (2020a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A new Circular Economy Action Plan For a cleaner and more competitive Europe. Brussels, 11.3.2020 COM(2020) 98 final

European Commission (2020b). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability. Brussels, 3.9.2020. COM/2020/474 final.

European Commission (2023a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Proposal for a regulation of the

European Parliament and of the Council establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020. Brussels, 16.3.2023. COM/2023/160 final.

European Commission (2023b). Critical Raw Materials Act. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661. Last access: March 1, 2024

European Commission (2023c). “Waste from Electrical and Electronic Equipment (WEEE): EU rules on treating waste electrical and electronic equipment, to contribute to sustainable production and consumption”. https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en. Last access: May 17, 2023.

European Union (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance). OJ L 312, 22.11.2008, p. 3–30.

European Union (2012). Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) Text with EEA relevance. OJ L 197, 24.7.2012, p. 38–71.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. Journal of cleaner production, 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048.

Geissdoerfer, M., Pieroni, M. P., Pigosso, D. C., & Soufani, K. (2020). Circular business models: A review. Journal of cleaner production, 277, 123741. https://doi.org/10.1016/j.jclepro.2020.123741.

ICESP - Italian Circular Economy Stakeholder Platform (2024). Home page. https://www.icesp.it/. Last access: February 15, 2024

La Monica M. (2018). “Strumenti integrati per favorire un uso più efficiente delle risorse in un'economia circolare a livello territoriale" Conference “Economia circolare: Oltre la gestione dei rifiuti Strumenti ed esperienze per una pianificazione integrata nell’economia circolare”. Ministero dell'Ambiente e della Tutela del Territorio e del Mare Roma – 12 Ottobre 2018. Project CREIAMO PA. https://www.mase.gov.it/pagina/prodotti-l3-wp1. Last access: March, 1. 2024

Lamba, H. K., Kumar, N. S., & Dhir, S. (2023). Circular economy and sustainable development: A review and research agenda. International Journal of Productivity and Performance Management., 73 (2): 497-522. https://doi.org/10.1016/j.jclepro.2020.123741.

Mancini, L., Vidal Legaz, B., Vizzarri, M., Wittmer, D., Grassi, G., & Pennington, D. (2019). Mapping the role of raw materials in sustainable development goals. A Preliminary Analysis of Links, Monitoring Indicators, and Related Policy Initiatives, EUR 29595 EN, Publications Office of the European Union, Luxembourg, 2019. ISBN 978-92-76-08385-6, doi:10.2760/026725, JRC112892.

Neligan, A., Baumgartner, R. J., Geissdoerfer, M., & Schöggl, J. P. (2023). Circular disruption: Digitalisation as a driver of circular economy business models. Business Strategy and the Environment, 32(3), 1175-1188. https://doi.org/10.1002/bse.3100.

Rocca, L., Veneziani, M., & Carini, C. (2023). Mapping the diffusion of circular economy good practices: Success factors and sustainable challenges. Business Strategy and the Environment, 32(4), 2035-2048. https://doi.org/10.1002/bse.3235.

Stahel, W. R. (2016). The circular economy. Nature, 531(7595), 435-438. https://doi.org/10.1038/531435a.

Stindt, D., & Sahamie, R. (2014). Review of research on closed loop supply chain management in the process industry. Flexible Services and Manufacturing Journal, 26, 268-293. https://doi.org/10.1007/s10696-012-9137-4.