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# Implementation of circular economy approaches in the electrical and electronic equipment (EEE) sector: Barriers, enablers and policy insights

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ABSTRACT

Circular economy business models (CBMs) are identified as important levers in the transition to a circular economy (CE). In recent years, a growing body of research has examined the barriers and enablers to these models, however, the available empirical evidence is still limited while sector-specific assessments are lacking. Our study aims to enrich the research in this field by identifying barriers and enablers to the implementation of a variety of CBMs in the electrical and electronic equipment (EEE) sector. Based on this analysis, we provide several policy insights. The EEE sector has been chosen as the focus of this study as a sector with large untapped potential in implementing circularity practices. The study adopts a multi-case study approach and uses a sample of 31 cases developed through the CIRC4Life EU-funded project and the snowball sampling method. To our knowledge, this represents the largest case study sample used to examine CE approaches in the EEE sector. Our findings show that despite the various policy instruments in place to boost the CE transition in this sector, there exist gaps which require policy attention. These include lack of rules for transparency across supply chains, weak enforcement of EU waste legislation rules, limited use of circularity criteria in public tenders and lack of CE standards. Inconsistent requirements stemming from different policy domains can also pose challenges for companies adopting CE practices. Among the suggested actions that can facilitate CE practices include knowledge sharing platforms and business partnerships, R&D project grants, product CE labels, financial incentives and awareness-raising campaigns.

## 1. Introduction

The 'circular economy' (CE) has received increasing attention from policymakers globally as a concept that can support the goals of reducing overconsumption of natural resources while delivering economic benefits (Lieder and Rashid, 2016; Kirchherr et al., 2018). Circular economy business models (CBMs) and business model innovation are recognized in the growing body of CE literature as key levers in boosting the CE transition (e.g., Camacho-Otero et al., 2018; Nuβholz, 2017; Bocken et al., 2014; Salvador et al., 2019; Lewandowski, 2016). Contrary to linear business models which still prevail in many industries and where value creation relies mostly on flows of virgin materials (Linder and Williander, 2017), CBMs are based on a different logic. Their key principle is that value creation ''is based on utilizing economic value retained in products'' (Linder and Williander, 2017, p.183) and seeks ''to improve resource efficiency through contributing to extending useful life of products and parts'' (Nuβholz, 2017, p.13). This can be achieved through designing products that last longer as well as through processes such as recycling, reuse and refurbishment (Näyhä, 2020; Linder and Williander, 2017; Bocken et al., 2016).

In the EU, despite widespread support from policymakers as showcased by a dedicated EU policy mix in place since 2015 and various national government strategies (Salvatori et al., 2019), the transition to a CE is still at a very early stage and only limited progress has been achieved. For instance, generation of waste has been increasing across the EU since 2013, while recycled low-volume metals and rare earth elements account for a small share of the total demand for these materials (EEA, 2019). Although a positive transformation has been observed in some industries, the uptake of CBMs has generally been slow (Trigkas et al., 2020; Vermunt et al., 2019; De Jesus and Mendonça, 2018). The electrical and electronic equipment (EEE) sector is a key sector where progress toward a circular transition has been limited. Specifically, in 2019, Europe was responsible for the second largest share of electronic waste (e-waste) globally and was the leading region in terms of

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generation of e-waste per capita (Forti et al., 2020). In addition, significant quantities of unused consumer electronics such as mobile phones are not collected for recycling or reuse across the EU (Rizos et al., 2019). Globally, Forti et al. (2020) estimate that less than 20% of e-waste generated is properly managed according to sound environmental criteria.

Research on barriers and enablers to implementing CE practices has been increasing recently. However, given that this area of research is in its infancy (Tura et al., 2019), evidence from existing studies is still limited (Ranta et al., 2018; Tura et al., 2019), while most of existing empirical studies focus on a small number of less than ten case studies (Kirchherr and van Santen, 2019). Authors have highlighted the need for more empirical studies on CE barriers and success factors (see Salvador et al., 2019; Tura et al., 2019; Trigkas et al., 2020; De Jesus and Mendonça, 2018), sector-specific assessments (Salmenpera et al., 2021; Vermunt et al., 2019; Kirchherr et al., 2018) and interdisciplinary research on sectors such as EEE (Borthakur, 2020). Other scholars such as Kern et al. (2017) have argued that policy research on sustainability transitions can benefit from insights regarding policy mixes and existing inconsistencies, but so far, the focus has been on looking at the effectiveness of individual instruments.

In light of the above gaps in the literature, this study aims to enrich the research field of barriers and enablers to the implementation of CBMs by providing a large multiple-case study assessment focusing on one specific sector. A sectoral focus has been chosen to allow for an in-depth look at the specific factors impacting the adoption of CBMs in one sector (Trigkas et al., 2020). The EEE sector has been selected due to the significant challenges linked to the generation and management of e-waste as discussed above. The specific research questions addressed by the study are: *What barriers and enablers do companies operating in the EU face when adopting circular economy business models in the electrical and electronic equipment sector? What are the key policy gaps and inconsistencies?* This interdisciplinary study is one of the first to discuss barriers and enablers to the implementation of CBMs across the EU[1] in the EEE sector and provide policy lessons. Earlier studies had a country focus (e.g., UK (Cole et al., 2019), Greece (Trigkas et al., 2020)) or covered one specific circular practice (e.g., reuse (Kissling et al., 2013; Milovantseva and Fitzpatrick, 2015)). To the best of the authors' knowledge, this is the largest multi-case (31) study research on implementing circularity in the EEE sector.

The remainder of the paper is structured as follows. Based on a literature review, section 2 provides a conceptual framework of barriers and enablers to the implementation of CBMs which guides the analysis in the paper. Section 3 elaborates on the methodology and approach for conducting interviews and collecting qualitative data. Section 4 presents the results of the analysis while section 5 features a discussion on the existing policy gaps and inconsistencies. The key conclusions and limitations of this study are presented in section 6.

## 2. Framework of barriers and enablers

This section provides an extensive review of the growing literature on the CE with the objective of preparing a framework of key categories of barriers and enablers to the implementation of CBMs. The categorization builds on earlier work conducted by Rizos et al. (2016) and other authors such as Tura et al. (2019), Adams et al. (2017), Ormazabal et al. (2018), Salmenpera et al. (2021), Govindan and Hasanagic (2018), Vermunt et al. (2019), Bey et al. (2013), Kissling et al. (2013), Hart et al. (2019) and Kirchherr et al. (2018). The key categories identified are *policy*, *finance/economic factors*, *supply chain*, *technology*, *consumer/-society* and *company organization*. Table 1 summarizes key examples of

[1] In terms of geographic scope, the study includes 28 member states since at the time of conducting the interviews and collecting the data UK was still a member of the EU.

**Table 1**
Framework of barriers and enablers to the implementation of circular business models.

| Category | Type | Barrier/enabler | References |
|---|---|---|---|
| **Policy** | Barriers | Complex legislative requirements posing bureaucratic challenges | Van Acoleyen et al. (2016); Trigkas et al. (2020) |
| | | Illegal shipments of e-waste | Kissling et al. (2013); Van Barneveld et al. (2016) |
| | | Weak enforcement of waste legislation | Milovantseva and Fitzpatrick (2015) |
| | | Inefficient taxation policies | Vermunt et al. (2019); Vanner et al. (2014) |
| | | Insufficient ecodesign requirements on circularity | Dalhammar, 2016; Tecchio et al. (2018); Östlin et al. (2009) |
| | Enablers | Regulatory requirements and standards | Ormazabal and Puga-Leal (2016); Mathieux et al. (2020); Tecchio et al. (2017); Sarkis et al. (2010); De Mattos and De Albuquerque (2018); CENELEC, 2017; CEN/CENELEC, 2020; ISO, 2021; Dalhammar et al. (2021) |
| | | Infrastructure improvements | De Jesus and Mendonça (2018) |
| | | Economic incentives aimed at boosting demand for CE goods and services | De Jesus and Mendonça (2018); Tura et al. (2019) |
| | | Technical assistance and capacity-building programmes | Delmas (2002); Testa et al. (2012) |
| | | Voluntary agreements and self-regulation measures | Bundgaard et al. (2017) |
| | | Provision of signals about future direction of markets | Gusmerotti et al. (2019); Leceta et al. (2017) |
| **Finance & economic fafactors** | Barriers | High investment costs for CE processes | Aranda-Usón et al., 2019; Salmenpera et al. (2021); Rizos et al. (2015); De Jesus and Mendonça (2018); Rizos et al. (2016); Gumley (2014); Swain (2017) |
| | | Uncertainty about profitability of circular business | Ormazabal et al. (2018); Ritzéna and Sandström (2017); Sanye-Mengua et al. (2014) |
| | | High risk perception of CE | European Commission (2019); Aranda-Usón et al., 2019 |
| | | Difficulty for SMEs in accessing funds provided available programmes | Vanner et al. (2014) |
| | Enablers | Reduction of waste and energy related costs | Tura et al. (2019); De Jesus and Mendonça (2018) |
| | | Improvement of competitiveness | De Jesus and Mendonça (2018); Bey et al. (2013) |
| | | Opportunities for new revenue streams | |

(*continued on next page*)

**Table 1** (*continued*)

| Category | Type | Barrier/enabler | References |
|---|---|---|---|
| | | | Govindan and Hasanagic (2018); Tura et al. (2019) |
| **Supply chain** | Barriers | Issues of ownership and sharing of costs and benefits | Talens Peiró et al. (2020); Kok et al. (2013); Rizos et al. (2016); Mishra et al. (2018) |
| | | Underdeveloped markets for materials and components | Rizos et al. (2016) |
| | | Geographical constraints | Salmenpera et al. (2021) |
| | | Lack of collaboration | Wooi and Zailani (2010); Rizos et al. (2016); Hart et al. (2019) |
| | | Lack of transparency and information exchange | Vanner at al., 2014; Vermunt et al. (2019) |
| | Enablers | Establishment of long-term relations with partners | Rizzi et al. (2013); Hart et al. (2019) |
| | | Network and partnerships | Rizos et al. (2016); Salmenpera et al. (2021) |
| | | Information-sharing platforms | Rizos et al. (2016); Tura et al. (2019) |
| | | Improvement of transparency of information across supply chains | Kissling et al. (2013); Adams et al. (2017) |
| **Technology** | Barriers | Unavailability of technical solutions | Golev et al. (2014); Abdelbasir et al. (2018); De Jesus and Mendonça (2018) |
| | | Complex data systems | Salmenpera et al. (2021) |
| | | Innovative technologies requiring new skills | Rademaekers et al. (2011) |
| | Enablers | New business models enabled by digital technologies | Pagoropoulos et al. (2017) |
| | | Technological progress on recycling and use of recovered materials | De Jesus and Mendonça (2018); Tentori and Jaworski (2014) |
| | | Technical tools enabling CE innovations | Ormazabal and Puga-Leal (2016) |
| **Consumers & society** | Barriers | Limited consumer engagement | Tura et al. (2019); Gullstrand Edbring et al. (2016); Cerulli-Harms et al. (2018); Van Buren et al. (2016); Van Weelden et al. (2016) |
| | | Buy-new mentality | Ranta et al. (2018); Gullstrand Edbring et al. (2016) |
| | | Lack of awareness or misconception about CE | Van Weelden et al. (2016); Govindan and Hasanagic (2018) |
| | Enablers | Growing societal awareness of environment and climate change issues | EEA, 2019; Ormazabal and Puga-Leal (2016) |
| | | Changing consumer demands | De Jesus and Mendonça (2018); Bey et al. (2013); Catulli and Fryer (2012); Rizos et al. (2016); Beuren et al. (2013) |
| **Company organization** | Barriers | Internal complex hierarchical structures and management systems | Liu and Bai (2014) |
| | | Internal lack of environmental culture | Kirchherr et al. (2018); Trigkas et al. (2020); Dekoninck et al. (2016) |
| | | Limited support from senior managers | Liu and Bai (2014); Dekoninck et al. (2016); Trigkas et al. (2020); Shahbazi et al. (2016) |
| | | Lack of tools to measure progress towards circularity objectives | Tura et al. (2019); Shahbazi et al. (2016) |
| | Enablers | Internal company awareness of its environmental impacts | Rizos et al. (2016); Ervin et al. (2013) |
| | | Managers supporting the transition to a CE business model | Näyhä (2020); Gusmerotti et al. (2019) |
| | | Commitment to change business model due to concerns over resource constraints and environmental impacts | Ranta et al. (2018) |
| | | Enhancing 'green' image and reputation | Ormazabal and Puga-Leal (2016); Ormazabal et al. (2018) |

specific barriers and enablers in the above six categories as identified through the literature review below.

### 2.1. Barriers

Policy is the first key barrier category. At the EU level, it has been observed that some pieces of legislation on waste management include complex requirements posing bureaucratic challenges for businesses but also for national authorities which often lack technical capacities (Van Acoleyen et al., 2016; Trigkas et al., 2020). For instance, the development of cross-border markets within and outside the EU for used EEE is hindered by unclear and often overlapping pieces of legislation that prevent the shipping of equipment to facilities for refurbishment (Kissling et al., 2013) or recycling (Van Acoleyen et al., 2016). The problem is accentuated by widespread illegal shipments of e-waste which often end up in unauthorized recycling facilities and are not treated under high standards of health and safety (Kissling et al., 2013; Van Barneveld et al., 2016). In addition, enforcement of waste legislation is often weak to the detriment of companies that fully comply with the rules (Milovantseva and Fitzpatrick, 2015). Inefficient taxation policies may also fail to provide the right market signals for a widespread adoption of circularity practices (Vermunt et al., 2019; Vanner et al., 2014). It has furthermore been argued that the current policy mix has not sufficiently encouraged the adoption in the sector of ecodesign principles in support of resource efficiency and circularity (Dalhammar, 2016; Tecchio et al., 2018; Östlin et al., 2009).

Lack of finance is among the most often-cited barriers to the implementation of CBMs. Although the level of investment needed for different CE technologies varies significantly, certain technologies and innovations require a financial investment that is often prohibitive for many businesses (Aranda-Usón et al., 2019; Salmenpera et al., 2021; Rizos et al., 2015) and especially for small and medium-sized enterprises

(SMEs) (De Jesus and Mendonça, 2018; Rizos et al., 2016). Examples include technologies for re-processing metals (Gumley, 2014) or recovering specific materials from electronic devices (Swain, 2017). Added to this, many companies are uncertain about whether circular innovations can help them increase their revenue streams and the overall profitability of their business (Ormazabal et al., 2018; Ritzéna and Sandströma, 2017; Sanye-Mengua et al., 2014). An important challenge on the financing front relates to the risk perception of circular innovations which implies that public and commercial financiers often require higher guarantees and collateral (European Commission, 2019; Aranda-Usón et al., 2019). In addition, it should be noted that compared to large companies SMEs find it more difficult to access funds provided by EU and national programmes (Vanner et al., 2014).

Barriers can arise from the supply chain, which often involves a multitude of companies based in different parts of the world (Preston, 2012). Compared to the typical linear models, CBMs may add an additional layer of complexity to the supply chain and questions of ownership as well as how the costs and benefits are shared among the companies affected by a circular process (Talens Peiró et al., 2020; Kok et al., 2013; Rizos et al., 2016; Mishra et al., 2018). In some cases, markets for specific materials and components required for the circular approach are still in their infancy which creates particular difficulties for SMEs (Rizos et al., 2016), while geographical structures can limit possibilities for supply of certain materials (Salmenpera et al., 2021). To this end, successful implementation of such models is largely contingent upon collaboration between different supply chain actors. Nevertheless, collaboration can be hindered due to doubts about the success prospects of the new approach (Wooi and Zailani, 2010), a misconception that the circular product or service is of lower quality (Rizos et al., 2016) or competitiveness concerns (Hart et al., 2019). It has also been reported that information exchange (e.g., on the origin or content of products and materials) between supply chain actors is lacking (Vanner et al., 2014; Vermunt et al., 2019).

Transforming business-as-usual practices can be difficult from a technology perspective. Specifically, improving the efficiency of current processes might be hampered by the unavailability of technical solutions (e.g., technologies for recycling materials present in small quantities in electronic products) (Golev et al., 2014; Abdelbasir et al., 2018) or their slow penetration into the market (De Jesus and Mendonça, 2018). This constraint can extend beyond the availability of technical solutions and refer to complexities in exchanging data and using different data systems for CE operations (Salmenpera et al., 2021) or to the lack of skills or knowledge required for the use of the new technology which can be a burden particularly for SMEs (Rademaekers et al., 2011).

Limited consumer engagement is considered to be another stumbling block to CE approaches. Although studies report that consumers are becoming increasingly interested in CE practices (e.g., Tura et al., 2019; Gullstrand Edbring et al., 2016), in practice only a small share is actually engaged in such practices according to a large survey at the EU level by Cerulli-Harms et al. (2018). Various factors influence this behavior; in the case of refurbished and second-hand products, for example, consumers are often concerned about their quality (Cerulli-Harms et al., 2018), the impact on their social status (Van Buren et al., 2016; Van Weelden et al., 2016) or may simply prefer to buy new products (Ranta et al., 2018; Gullstrand Edbring et al., 2016). Lack of awareness or misconception about what the circular process entails also contributes to this (Van Weelden et al., 2016; Govindan and Hasanagic, 2018).

From an organizational perspective, a company may have complex hierarchical structures and management systems that hamper its capacity to innovate (Liu and Bai, 2014). This is often compounded by an internal lack of environmental culture and willingness to integrate CE principles in the company's strategy (Kirchherr et al., 2018; Trigkas et al., 2020; Dekoninck et al., 2016). Support from senior managers can be limited due to perceived risks, lack of resources (Liu and Bai, 2014; Dekoninck et al., 2016; Trigkas et al., 2020), prioritization of other objectives (Shahbazi et al., 2016) or misunderstanding about what the CE entails (Trigkas et al., 2020). The lack of tools to measure progress towards circularity objectives may be a contributory factor to managers' lack of commitment (Tura et al., 2019; Shahbazi et al., 2016).

### 2.2. Enablers

While barriers are often linked to the existing legislative framework as discussed above, policy instruments can also act as an enabler in driving the circular transition. Governments at various levels can introduce strict regulations introducing requirements for companies to comply with. Such requirements at the EU level can often be established according to specifications defined in standards developed by the European Standardization Organizations CEN and CENELEC (Ormazabal and Puga-Leal, 2016; Mathieux et al., 2020; Tecchio et al., 2017; Sarkis et al., 2010; De Mattos and De Albuquerque, 2018). Some examples in the resource efficiency domain are the standard series EN 50625 for the collection, treatment and management of waste electrical and electronic equipment (WEEE) (CENELEC, 2017) and the EN 4555X series for the introduction of material efficiency aspects (among others on reuse, recyclability, durability) in EU ecodesign regulations (CEN/CENELEC, 2020). Work in this area is also conducted by the International Standard Organization (ISO) which is currently developing standards to define the key principles of the circular economy, related business models, value chains and measurement approaches (ISO, 2021; Dalhammar et al., 2021). Infrastructure improvements (De Jesus and Mendonça, 2018) and incentives to boost demand for circular products and services are two other forms of policy intervention (De Jesus and Mendonça, 2018; Tura et al., 2019). In addition, governments can provide businesses with technical assistance (Delmas, 2002), training (Testa et al., 2012) or a framework though which they can adopt voluntary agreements and other self-regulation measures (Bundgaard et al., 2017). Beyond direct support or introduction of requirements for businesses, policy can have a pervasive influence on the decisions of managers by providing signals about the future direction of markets (Gusmerotti et al., 2019; Leceta et al., 2017).

The adoption and implementation of CE strategies by businesses is often contingent on economic factors. Prompted by increasing concerns over resource depletion and price volatility, businesses are motivated to seek solutions that can help them reduce waste and energy costs (Tura et al., 2019; De Jesus and Mendonça, 2018) as well as improve their competitive advantages (De Jesus and Mendonça, 2018; Bey et al., 2013). CE processes such as recycling and remanufacturing can provide opportunities for new revenue streams and have a positive impact on profitability (Govindan and Hasanagic, 2018; Tura et al., 2019).

Supply chain-related enabling factors may furthermore influence the adoption of CE practices. Companies increasingly participate in a global marketplace where establishing long-term relations with partners can be a key enabler in overcoming barriers to the introduction of new technologies and processes across value chains (Rizzi et al., 2013; Hart et al., 2019). Such barriers can be removed through networks, partnerships (Rizos et al., 2016; Salmenpera et al., 2021) and information-sharing platforms (Rizos et al., 2016; Tura et al., 2019). Improving transparency across supply chains in terms of making information on circularity available to other actors can be a further enabling factor (Kissling et al., 2013; Adams et al., 2017).

Technological development can be a driver of change in markets. For instance, disruptive business models driven by digital technologies can create new commercial opportunities for businesses and foster

alternative consumption patterns; product-as-service models represent one such example (Pagoropoulos et al., 2017). Progress on the technology front can enable reuse of products, more efficient material recovery (De Jesus and Mendonça, 2018) or the use of recovered materials for new applications in different industries (Tentori and Jaworski, 2014). As more tools become available (e.g., life cycle assessment), companies can become better aware of their environmental impact and try to introduce practices to reduce their environmental impact (Ormazabal and Puga-Leal, 2016).

At the EU level, societal awareness of the impacts of economic activities on the environment and climate has been rising (EEA, 2019; Ormazabal and Puga-Leal, 2016). In light of these concerns, a consumer segment is changing routines, although progress is often slow as explained earlier. Changing consumer demands can provide signals to markets and be a major catalyst of implementing green economy business models (De Jesus and Mendonça, 2018; Bey et al., 2013; Catulli and Fryer, 2012). This shift may be represented through consumers requesting sustainable products (Rizos et al., 2016) and business models that challenge traditional product ownership (e.g., product-as-service) (Beuren et al., 2013).

Studies have highlighted the role of environmental awareness and culture within the organization (e.g., Rizos et al., 2016; Ervin et al., 2013). Managers can play a key role and lead the transition to a new model (Näyhä, 2020; Gusmerotti et al., 2019). On some occasions, the main motivations behind these shifts are concerns by company stakeholders over resource constraints and environmental impacts (Ranta et al., 2018). Furthermore, for some companies the potential for enhancing their 'green' image and reputation gives added impetus to their sustainability efforts (Ormazabal and Puga-Leal, 2016; Ormazabal et al., 2018).

## 3. Methodology

To address the research questions the study adopted a qualitative research approach based on case studies. Case study research serves the purpose of collecting thorough information from specific cases to develop an in-depth understanding of researched factors rather than drawing conclusions on statistical grounds (Saunders et al., 2009; Palinkas et al., 2015; Voss et al., 2002). We used multiple case studies instead of a single one to increase the robustness of the research findings and reduce biases to the extent possible (Voss et al., 2002; Yin, 2018). For the purposes of this research each case study, often referred to as a unit of analysis (Yin, 2018), is a company that implements a business model supporting circularity in the EEE sector.

The first step in the research process was to develop a conceptual framework of barriers and enablers (see section 2) with the purpose of narrowing the topical focus of the study (Voss et al., 2002) to identify meaningful data correlations (Miles and Huberman, 1994). As discussed later, the framework was used for the collection of data by companies on barriers and enablers and the grouping of data. For the next key step in the process of selecting the sample, we followed the non-random purposive sampling technique (often referred to as judgmental sampling) which ''enables you to use your judgement to select cases that will best enable you to answer your research question(s) and to meet your objectives'' (Saunders et al., 2009, p. 237). The first case studies were selected through the CIRC4Life EU-funded project[2] which develops and demonstrates CBMs and has involved in its various activities several companies in the EEE sector. To further strengthen the sample, the snowball sampling method (see Saunders et al., 2009) was used; this involved asking the interviewed company representatives to suggest other companies implementing CBMs in this sector. The authors also made use of the list of companies that have established CBMs and are featured in the European Circular Economy Stakeholder Platform.[3] In total, 31 companies were used for this multi-case study, of which 18 qualify as SMEs and 13 as large companies according to the EU definition.[4] The sample features both small and large companies with the objective of covering companies with a variety of different core activities and circular processes in their business models. The majority of sampled companies have integrated multiple circular processes in their business model. In more detail, 15 companies are involved in collection of WEEE, 14 offer refurbishment and/or remanufacturing services, 12 aim at designing and producing more circular products, 10 offer reuse services, 9 offer repairs, 8 offer product as service and/or leasing models, 5 recycle WEEE and finally one company offers traceability solutions supporting circularity (see Appendix I).

Data was then collected through structured interviews with company representatives that took place during a 6-month period (between April and October 2020). There were 31 interviews (one per case study) with 38 experts (in six cases more than one company representative participated). Due to the COVID-19 restrictions all interviews were conducted via online tools with each interview lasting between 50 and 90 min. Most of the interviews (25) were with manager/senior representatives, and in the case of 5 of the SMEs, the CEO or owner of the company was interviewed. There were also two cases where the CEO did not participate, either due to language or time restrictions but provided direct inputs to the interviewed company representative.

Prior to each interview interviewees received: i) an informed consent form and ii) a questionnaire to support interview preparation. In line with the EU General Data Protection Regulation (GDPR) rules, the consent form presented the study's objective, method for data analysis and interview process. The questionnaire was used to guide the discussion during each interview and consisted of three parts. During the first part, the interviewee provided a brief description of the company's business model supporting circularity. Interviewees were then asked to describe the key barriers their organization faced when implementing a circularity approach as well as the factors that helped its implementation (enablers). The questionnaire included a categorization of barriers and enablers according to the framework presented in section 2, however, interviewees could also suggest and explain other barriers or enablers. Discussions were interactive and the interviewees were often asked to clarify or give a more detailed explanation of their viewpoint. Two researchers were present in each interview to take notes and use collective insights when interpreting and analyzing the data (Eisenhardt, 1989).

The authors then grouped the collected data according to the general categories of the framework presented in section 2. This step entailed categorizing the barrier or enabler mentioned by the interviewees within the categories identified as part of the literature review and importing them in a spreadsheet. Each barrier or enabler was subsequently assigned to a code describing commonalities among the barriers and enablers mentioned by different interviewees. This allowed for aggregation, identification of common trends and preparation of cross-case study findings. An overview of the methodology applied is presented in Fig. 1 below.

[2] CIRC4Life is financed through the Horizon 2020 EU funding programme. (https://www.circ4life.eu/).

[3] The European Circular Economy Stakeholder Platform is a joint initiative by the European Commission and the European Economic and Social Committee (EESC) (https://circulareconomy.europa.eu/platform/en).

[4] The Commission Recommendation 2003/361/EC states that ''the category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million'' (European Commission, 2003, p.39).

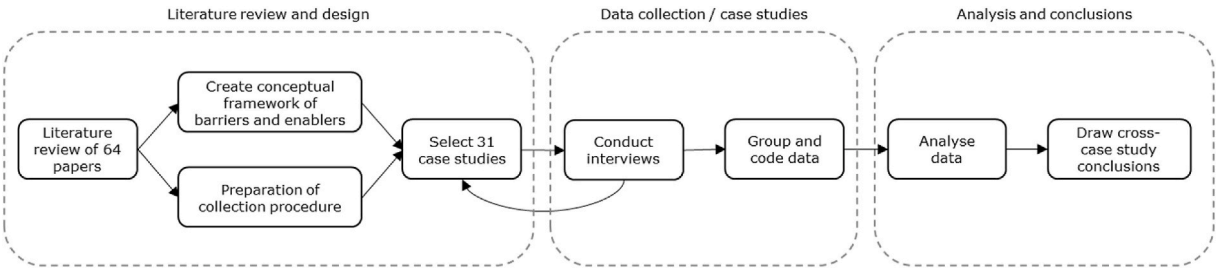


**Fig. 1.** Overview of methodology.

## 4. Results

### 4.1. Policy

Various policy-related barriers were identified through the interview process (see overview in Table 2). At the EU level, the main law for managing WEEE is Directive 2012/19/EU also known as the WEEE Directive. According to three companies involved in the collection and recycling of WEEE, challenges arise from the fact that this legislative act is a directive which sets goals for member states and provides them with the flexibility to put in place specific laws to achieve these goals. This has led to a multiplicity of collection and recycling requirements and diverse interpretations of which materials constitute hazardous waste across the EU. Establishing effective inspection and monitoring mechanisms for WEEE that would also restrict illegal exports has likewise been unsuccessful according to three respondents. Two companies also reported that following the adoption of the Directive, transactions of equipment between EU member states for repairing or recycling have been made difficult due to increased administrative requirements. Difficulties in reusing batteries from older devices or recycling them were also mentioned by one firm producing and leasing EEE and one recycler, respectively. Further challenges raised by four companies relate to extended producer responsibility (EPR) which has been made mandatory by the WEEE Directive. Specifically, three companies involved in collection or recycling of WEEE in Greece reported that transposition of the WEEE Directive into national law has led to a national EPR system centered around one scheme with full control over the quantities of collected WEEE. This has led to the creation of a closed market with limited flexibility for developing more dismantling and recycling facilities across the country. By contrast, in the UK the EPR approach is based on open competition between national EPR schemes on price and unpredictable targets which according to one company act as a block to the establishment of long-term contracts that are necessary for investments in the sector.

Other pieces of EU legislation were also identified as impediments to circular practices. In particular, five companies producing EEE mentioned that the requirements of REACH Regulation 1907/2006 and RoHS Directive 2011/65/EU can create uncertainties about which refurbished products can be placed on the EU market, generate a significant administrative burden or cause difficulties in finding certain secondary raw materials in the market. In addition, the lack of integration of circularity criteria in public tenders was brought up by three interviewed companies. Four companies argued that EU-wide ecodesign requirements that fall within the scope of the EU Ecodesign Directive 2009/125/EC on circularity need to be strengthened while taking into account potential trade-offs (e.g., should a resource efficiency requirement cause an increase in energy demand).

Some policy-related barriers stem from the rules in place at the member state level. Two companies mentioned that a national chemical tax does not differentiate between new and used/refurbished devices thereby posing challenges to the market penetration of the latter. In some cases, respondents referred to government intervention in areas beyond environmental policy that disincentivize CE practices. For example, one company stated that doctors who use older refurbished medical devices receive lower national insurance reimbursements, while another referred to the national VAT rules that do not allow deduction for the cost of spare parts used in refurbished phones. Another company mentioned the lack of compliance with VAT rules as an issue creating unfair competition in the repair and second-hand market.

Turning to the non-EU markets and policies, four companies in the sample experienced challenges related to the regulatory framework in third countries outside the EU. Specifically, two companies highlighted that import bans in certain third countries hinder the development of global markets for refurbished devices, while two other companies noted that obtaining the necessary permissions to ship end-of-life devices from third countries is a slow and complex process. Three companies noted that there is a lack of international standards for different circularity approaches such as refurbishment, designing recyclable products or classifying recycled materials which thus leads to inconsistent approaches in global markets.

Policy instruments that have acted as enablers were also raised during the interviews. Seven of the companies in the sample noted that the provision of grants though EU and national funding programs was a key factor for diversifying their core operations and developing a circular process. Different types of policy instruments at the national level were identified as influential; for instance, one company mentioned that the state subsidizes the repair of electronics, while another one stated that the government finances awareness-raising campaigns for recycling electronics through a central fund. Another company reported that the national data security legislation requires that data must be removed from old devices in the country and this has indirectly supported the local refurbishment business. Furthermore, one interviewed company noted that a new national law on the CE including binding requirements has motivated the company to mobilize internal resources for new circular processes.

The WEEE Directive was seen to be playing a positive role in the collection and reuse of electronics by four companies. The EU policy mix in general and high-level strategies such as the European Green Deal were seen by four companies to send a strong signal to companies about the need to increase their environmental ambitions. According to three companies existing standards such as the ones prepared by CENELEC for the collection, treatment and re-use of WEEE have facilitated their operations. Finally, two companies mentioned that the EU non-financial reporting rules have made their services more attractive to prospective clients.

### 4.2. Finance/economic factors

Regarding finance and economic-related barriers, the higher cost entailed by circular processes compared to linear ones was brought up by eight companies implementing various models from design and production of more sustainable products to refurbishment, collection and recycling. For example, for designers and producers of EEE, incorporating ecodesign principles in products comes at a cost which can also create issues with clients who focus on price. Cost of repair and refurbishment of EEE can be very high especially for small companies, which

**Table 2**
Barriers and enablers identified through the interviews with sampled companies.

| Categories | Identified barriers and enablers | | Number of companies out of 31 |
|---|---|---|---|
| **Policy** | **Barriers** | EU chemicals legislation posing uncertainties and administrative burdens | 5 |
| | | Varied EPR rules across EU member states | 4 |
| | | Lack of clear eco-design CE requirements | 4 |
| | | Complex regulatory framework in third countries outside the EU | 4 |
| | | Incoherent implementation of the WEEE Directive's principles | 3 |
| | | Inefficient WEEE inspection and monitoring mechanisms | 3 |
| | | Lack of integration of circularity criteria in public tenders | 3 |
| | | Lack of consistent international rules and standards | 3 |
| | | WEEE requirements complicating transactions of EEE | 2 |
| | | Difficulties in reusing and recycling batteries from old devices | 2 |
| | | National chemical tax rules | 2 |
| | | National insurance rules not supporting the CE | 1 |
| | | VAT rules not supporting circularity approaches | 1 |
| | | Lack of compliance with VAT rules | 1 |
| | **Enablers** | Provision of grants though EU and national funding programs | 7 |
| | | WEEE Directive rules supporting collection and reuse of electronics | 4 |
| | | High-level policy strategies | 4 |
| | | Standards | 3 |
| | | Non-financial reporting EU rules | 2 |
| | | Subsidies for repair of EEE | 1 |
| | | Financing of awareness-raising campaigns | 1 |
| | | National legislation requiring removal of data from old devices | 1 |
| | | National CE law including binding requirements | 1 |
| **Finance/ economic factors** | **Barriers** | Higher cost entailed by circular processes compared to linear ones | 8 |
| | | Competitive market limiting possibilities for CE innovations | 6 |
| | | Lack of financial resources for CE investments | 6 |
| | | Low cost of virgin raw materials | 4 |
| | **Enablers** | Revenue and cost saving opportunities arising from CE processes | 8 |
| | | Growing markets for high-end refurbished devices | 3 |
| | | Crowdfunding providing sources of finance | 2 |
| **Supply chain** | **Barriers** | Difficulties in gaining access to spare parts and components | 9 |
| | | Lack of transparency regarding substances in EEE | 5 |
| | | Poor collection of EEE | 4 |
| | | Difficulties in convincing supply chain partners | 3 |
| | | Complex reverse logistics systems | 3 |
| | | Challenges in cooperating with international partners | 2 |
| | **Enablers** | Establishment of partnerships and collaborations | 11 |
| | | Developing a network of partners | 4 |
| **Technology** | **Barriers** | Difficulties in adapting to technological changes | 3 |
| | | Existence of varied series of devices in the market | 2 |
| | | Technological constraints in extending the lifetime of EEE | 2 |
| | | Challenges in monitoring flows of devices | 1 |
| | | Complexity in creating an effective software system | 1 |
| | **Enablers** | Digital technologies enabling new processes and better use of resources | 3 |
| | | Increased availability of tools supporting tracing of materials | 2 |
| **Consumer/ society** | **Barriers** | Lack of acceptance or interest in CE practices | 14 |
| | | Buy-new mentality | 4 |
| | | Lack of awareness about the benefits of reuse and refurbishment | 3 |
| | | Lack of awareness about the impacts of e-waste | 2 |
| | Enablers | Growing demand for CE products and services | 16 |
| | | Increased public awareness of environmental impacts and climate change | 15 |
| | | Campaigns and awareness programs | 2 |
| **Company organization** | **Barriers** | Lack of time and resources | 4 |
| | | Lack of internal processes and systems | 4 |
| | | Internal culture of focusing on linear processes | 4 |
| | **Enablers** | Being proactive and open to expand their portfolio of services | 8 |
| | | Internal commitment towards circularity backed by concrete objectives | 8 |

*Note that each company was able to mention more than one barrier and enabler.

are sensitive to any cost increase. Recyclers on the other hand face high costs in managing hazardous components in devices or cannot recover all materials in a cost-effective way. Six companies mentioned that they operate in a very competitive market which limits possibilities for disruptive innovations and often pushes them to produce products with a short lifespan at low cost.

Lack of financial resources for investments was noted as a barrier by six SMEs; they face significant challenges in obtaining the initial capital needed, have difficulties in scaling up their operations or cannot finance more advanced technologies (e.g., for high quality recycling). Moreover, specific processes such as implementing traceability across the supply chains of electronics or measuring the life cycle environmental impacts of operations can be too costly to implement. Finally, in four other cases

the low cost of virgin raw materials was discussed as a disincentive for recovering materials and a barrier for developing a market for secondary materials.

Turning to the financial enablers, eight companies observed revenue and cost saving opportunities arising from a variety of CE processes. Four of these companies highlighted that product-as-service and leasing models can open new opportunities and enable direct access to new clients. In addition, such models provide an incentive to design devices that can be used for longer and managed by the company who remains their owner. Two of the companies mentioned that reusing and refurbishing EEE from their network provided financial benefits. Two other enablers raised by three and two companies respectively were growth of markets for high-end refurbished devices and access to sources of finance through crowdfunding.

### 4.3. Supply chain

Difficulties in gaining access to spare parts and components for repairing and refurbishing devices or to support product lifetime extension is a key barrier mentioned by nine of the companies aiming to scale up such practices. This is attributed to a trend of people keeping their devices for longer, uncollected unused devices and various components no longer being produced. In two of these cases, it was mentioned that original spare parts cannot be easily obtained in certain markets which can have an impact on the quality of refurbished products. Another pressing barrier raised by five companies is the lack of transparency regarding substances contained in EEE as well as their different materials and components which complicates the work of several companies involved in recycling and reuse practices. This challenge is often aggravated by the reluctance of supply chain actors to share data. Two of these companies that are producers of EEE specifically raised the challenge of tracing the origins and movement of materials and components.

Four companies mentioned that collection of electronic devices is far from optional with many devices ending up in unofficial registered systems or being collected in poor condition. This has an impact on the quality of recycling and availability of devices than can be repaired or refurbished. Three companies experienced difficulties in convincing their partners about a new circular approach, especially if it entails extra costs, while two companies reported the challenge of ensuring that international partners meet sustainability standards. Finally, establishing reverse logistics systems to support refurbishment, repair, and recycling of devices is a complex task for three of the companies interviewed.

Establishing partnerships and collaborations was the single most important supply chain-related enabler raised by 11 companies. For instance, in two cases developing a stable collaboration with producers of EEE helped two small companies offering repair and refurbishment services to gain access to original spare parts or software updates, while in one case a recycler was able to better anticipate demand for certain secondary raw materials through partnerships with manufacturers. Developing a network of partners, who can also be located overseas, to test a new product or ensure the smooth roll-out of the model was observed by four companies as a key factor of success.

### 4.4. Technology

Three companies mentioned technical challenges in adapting their recycling procedures due to changes in product material compositions, integration of components and slimmer product design. Developing refurbishment processes at scale is often complicated by the existence of varied series of devices in the market according to two companies. Furthermore, two companies stated that for certain types of large EEE there are constraints in extending their lifetime due to technology cycles and equipment becoming functionally obsolete at some stage, while in one case it was noted that setting up systems to monitor flows of devices and assess their functionality for leasing modes is technically complex. One company mentioned the complexity involved in creating an effective software system to offer a type of reward to consumers who decide to dispose of their devices in proper collection systems.

Digital technologies were mentioned by three companies as being a key technological enabler. These have made great advances in recent years enabling new processes and better use of resources. Examples noted include the use of artificial intelligence (AI) to calculate existing inventories, utilization of the Internet of Things (IoT) to anticipate future supply chain disruptions and use of data analytics to manage material flows. Tools that support tracing materials were also mentioned in two cases although they have not yet reached the stage of providing full traceability across supply chains.

### 4.5. Consumer demand and societal awareness

Within the category of consumer demand and social awareness, lack of acceptance or interest in circular solutions by both business-to-consumer (B2C) and business-to-business (B2B) consumers and clients was the most important barrier noted by 14 companies. This was attributed to various factors: In some cases, clients are used to traditional models based on ownership and are not easily convinced about the benefits of product-as-service or leasing models. There is often misconception about the reliability of second-hand, repaired and refurbished products. Perception of functionality of EEE also varies among clients and it is often difficult to convince them to keep the equipment in use for longer periods even if they have not experienced any decline in performance. For many B2C and B2B clients price remains the most influential factor for deciding about a product or service to the detriment of circular solutions. In addition, explaining the benefits of a circular processes to consumers is not an easy task even though digitalization and mobile phone apps have offered multiple opportunities. Four companies also noted that the buy-new mentality is still strong in various markets. Lack of awareness about the benefits of reuse and refurbishment or of the impacts of e-waste were also mentioned as a barrier in three and two interviews, respectively.

While many consumers are still skeptical about circularity approaches as discussed above, a growing demand for circular products and services was observed as a key enabler by 16 companies. There is an increasing change in attitude by consumers towards circular products but also towards product-as-service and leasing models. The success of some frontrunner companies was reported to make an impact in the market by increasing the acceptance of alternative products and models. Interest in how products are made and how their life cycle impacts are calculated was also reported to be increasing, while in the B2B market it was noted that there was an increased demand for circularity elements in products. In addition, 15 companies noted that public awareness of environmental impacts and the need to reduce $CO_2$ emissions is on the rise. In two cases it was mentioned that campaigns and awareness programs have had a positive impact on consumer awareness.

### 4.6. Company organization

Lack of time and resources within the company to collect the required data, establish new processes or properly measure their environmental impacts was a barrier discussed in four cases. In addition, four companies mentioned that they did not have the internal processes in place, including IT systems, to implement a new leasing model or produce a new product. Four large companies furthermore reported that the company had an internal culture of focusing on linear processes which cannot easily change or was generally inexperienced in working with new CBMs.

With regard to organizational enablers, eight companies indicated that being proactive and expanding their portfolio of services to incorporate emerging practices such as repair and reuse of devices or product-as-service models can differentiate them from competitors and provide them with a cutting edge in the growing markets for more sustainable

products. Showcasing an internal commitment towards circularity at all levels within the organization and having concrete objectives that can drive the company forward was mentioned as a key enabler by eight of the interviewed companies.

## 5. Discussion

In this section we discuss some key barriers and enablers observed in our analysis and highlight particular areas requiring policy intervention. First, it was observed that there is incoherent implementation of the WEEE Directive's principles across member states leading to different requirements regarding collection and recycling of WEEE. This is also evident in the implementation of EPR rules which have affected the development of recycling and reuse markets across EU member states. Based on Rogge and Reichardt (2016, p.1626) who suggest that coherence in the policy implementation process can contribute ''either directly or indirectly towards the achievement of policy objectives'' we suggest that implementation of WEEE requirements is an area that warrants the attention policymakers. Interview evidence also revealed some inconsistencies in the existing policies hindering the further scale-up of circular practices. For instance, according to interview responses the rules deriving from EU chemicals legislation often create uncertainties and administrative burdens that restrict recycling and reuse practices. Inconsistencies were also identified at the member state-policy level as instruments from different policy domains (e.g., VAT or insurance rules in some countries) do not support uptake of CE processes. Drawing on the work of authors such as Kivimaa et al. (2017), Rogge and Reichardt (2013) and Kern and Howlett (2009), we argue that such tensions between different policy goals and instruments should be identified and reduced to the extent possible, for example via ex-ante and ex-post assessments.

In addition, various companies face barriers related to the regulatory framework in third countries which reflects the importance of identifying mechanisms to facilitate trade of CE products and components. We argue that policy tools such as bilateral trade agreements and development of forums for policy dialogue and expertise exchange can be used to reduce these barriers. A further identified barrier in relation to international markets and global supply chains concerned the lack of global standards for circular practices and goods.

Policy instruments at the EU and member state level that were perceived to positively influence the development of CBMs and that could therefore provide messages about the future direction of policies were also identified. A key enabler was the provision of funding for research and innovation projects which can be further used, as discussed below, to help companies adopt CE innovations. Other instruments acting as enablers included financial support for repair practices, standards for recycling and refurbishment, EU non-financial reporting rules and high-level policy strategies.

Several interviewees reported that CE in its various forms can provide economic-type benefits to companies. However, despite these positive observations, many companies reported that they still face significant cost or competition challenges when implementing a circular approach, while lack of financial resources appears to be a key barrier for SMEs wishing to expand their circular operations. These findings call for more support in this domain which can take the form of funding for R&D projects or economic instruments such as tax incentives for companies operating a circular business model. Moreover, the use of green public procurement, whose underutilization was identified as a barrier in the analysis, can be further enhanced to boost demand for such products and services.

While markets for circular products and services are reportedly growing, supply of spare parts, components or materials is often difficult. At the same time, it was revealed that partnerships and networks involving different actors in the supply chain can be instrumental in helping companies overcome existing barriers. EU and national policymakers can play a role in this domain by orchestrating initiatives that encourage businesses to cluster their efforts. In addition, although rules for the proper collection of WEEE or for tackling illegal exports have been in place for some time, enforcement is often weak which limits supply of quality equipment for recycling or reuse. As suggested by Andersson and Stage (2018), weak enforcement can slow down progress in achieving waste management goals and deserves particular attention from policymakers. A further tangible policy gap requiring attention relates to the lack of transparency across supply chains. In particular, in the absence of effective rules and mechanisms it is often challenging to have clarity regarding substances and materials in EEE or to trace the origins and flows of materials.

Furthermore, interview evidence indicated that while keeping up with the latest technological trends is often challenging for companies implementing circularity approaches for electronics, digital technologies are a key enabler and often provide the backbone for new innovative circular approaches. This showcases the need for financial support for R&D projects dedicated to the use of digital tools to meet the information and data needs of CBMs. Business partnerships and collaborations can also help companies at opposite ends of value chains to better anticipate technology trends; one such example concerns recyclers who need to be better informed about current trends related to the design of devices that at some point will end up in recycling plants.

Additionally, the findings showed a divergent trend in relation to consumer acceptance or interest in circular solutions. While increased demand for circular goods and services is a key impetus to their circular model for many companies, some interviewees noted that their consumers and clients in both B2C and B2B are still skeptical about such products or do not really understand their benefits. Moreover, price and perception about the reliability and quality of circular products appear to be important determinants for selecting a circular product. We thus argue that informational instruments need to be used on a wider scale; examples include awareness campaigns, platforms showcasing successful examples and product labels informing consumers about the reliability of second-hand or refurbished products based on credible measurable methods. From an organizational point of view, lack of time, internal resources and technical know-how were mentioned as obstacles hindering the development of a new product or model such as leasing. To address this challenge, capacity-building instruments such as technical assistance programs, material efficiency tools and technical information centers can be assisted or financed by the EU or national governments. High-level policy strategies demonstrating a clear commitment of governments to achieve a CE can influence internal company attitudes toward circularity.

## 6. Conclusions

While the literature on the CE has been growing, there is limited sector-specific research on CE barriers. This study provides a multi-case study analysis of barriers and enablers focusing on the EEE sector. Using qualitative data collected through in-depth interviews with 31 companies we provide insights about the existing policy mix for supporting circularity in this sector.

Several existing policy gaps and issues have emerged through this analysis. Among them are limited ecodesign requirements on circularity, weak enforcement of WEEE requirements, limited circularity requirements in public tenders, lack of rules for transparency across supply chains, lack of international CE standards and lack of incentives for collecting unused devices. Inconsistent requirements deriving from different policy domains at both the EU and national level were also found to act as barriers. Incoherent implementation of the WEEE Directive's principles across the EU member states is a further issue. On the other hand, provision of funding for R&D projects, awareness-raising campaigns, support for knowledge sharing and business partnerships, product labels including CE information, tax incentives, development of international forums for policy dialogue and expertise exchange and support for technical capacity-building are some suggested actions that

can act as enablers to CE business practices.

Our findings indicate that no single instrument alone from a specific policy domain can address the variety of existing barriers and gaps. Instead, steering CE practices in this sector will require policy action on multiple fronts addressing different life cycle stages of EEE and spanning various administrative and policy levels. This underlines the need for enhanced coordination among different policy departments and regular reviews of the existing policy mix to maximize synergies among various instruments and reduce inconsistencies. Trade-offs between different policy goals need to be identified and carefully assessed in case a different choice of instruments could help mitigate these tensions.

This study has some limitations. Although we attempted to cover a multitude of companies in the EEE sector and circular activities, the sample cannot claim to cover all the different types of companies that integrate circularity in their business models. An additional limitation is that the study does not examine in more detail the various policy gaps and inconsistencies identified. Conducting further in-depth research to better understand the specific policy processes behind these issues and also to assess possible policy coordination mechanisms are some avenues for future studies in this field. Moreover, this study cannot provide conclusive results for the overall policy mix for the CE, which crosses over several sectors and policy domains. We therefore suggest that such interdisciplinary research on barriers, enablers and policy gaps can be repeated for other sectors.

## CRediT authorship contribution statement

**Vasileios Rizos:** Conceptualization, Supervision, Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Julie Bryhn:** Investigation, Data curation, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix 1

Companies in the sample

| Number | Size | Core company activities | EEE Category | Circular processes | Interviewees' position |
|---|---|---|---|---|---|
| Firm 1 | Large | Refurbishment | IT and telecoms equipment | Refurbishment; Collection | Head of Innovation; Marketing Director |
| Firm 2 | SME | Information Technology Services | IT and telecoms equipment | Reuse; Repairs; Refurbishment | Co-director |
| Firm 3 | Large | Medical Technology | Medical devices | Repairs; Refurbishment | Head of Business Line; Senior Manager |
| Firm 4 | SME | Refurbishment | IT and telecoms equipment | Refurbishment; Collection | CEO |
| Firm 5 | Large | Technology solutions | IT and telecoms equipment; Medical devices; Projectors; Others | Design & Production; Product as service | Sustainability Manager; Safety Expert |
| Firm 6 | Large | Telecommunications | IT and telecoms equipment | Reuse; Refurbishment; Collection | Head of Environmental Department |
| Firm 7 | Large | Environmental compliance services | Multiple types of WEEE | Collection | Policy Director; Policy Advisor |
| Firm 8 | SME | Repair and other services | Household appliances IT and telecoms equipment; Others | Leasing; Reuse; Repairs; Refurbishment | CEO |
| Firm 9 | SME | Refurbishment, repairs and reuse | IT and telecoms equipment | Reuse; Repairs; Refurbishment; Collection | Partner/Vice-President |
| Firm 10 | Large | Telecommunications | IT and telecoms equipment | Design & Production | Senior Quality Manager; Logistics Manager |
| Firm 11 | Large | Manufacturer | Household appliances | Design & Production; Product as service; Leasing; Repairs; Refurbishment; Recycling | Senior Expert |
| Firm 12 | SME | Lighting solutions | Lighting products | Design & Production; Reuse; Refurbishment | Partner/Director of Strategy |
| Firm 13 | SME | Remanufacturing | IT and telecoms equipment | Refurbishment; Collection | Strategic Executive |
| Firm 14 | SME | Sustainability services | IT and telecoms equipment | Collection | Director |
| Firm 15 | SME | Lighting solutions | Lighting products | Design & production; Leasing | Senior Engineer |
| Firm 16 | SME | Digital technologies | Multiple types of EEE | Traceability solutions | Senior Specialist (with input from CEO) |
| Firm 17 | SME | Production | IT and telecoms equipment | Design & Production; Repairs; Collection | Head of Innovation |
| Firm 18 | Large | Production | Household appliances | Design & Production; Product as service; Reuse; Repairs | Director Circular Economy |
| Firm 19 | Large | Manufacturer | IT and telecoms equipment | Design & Production; Product as service; Refurbishment; Collection; Recycling | Head of Sustainability; Manager |
| Firm 20 | SME | WEEE management | Multiple types of WEEE | Collection; Recycling | Innovation Researcher |
| Firm 21 | SME | Collection services | Multiple types of WEEE | Collection | Owner |
| Firm 22 | Large | Telecommunications | IT and telecoms equipment | Design & Production | Sustainability Director |
| Firm 23 | SME | Lighting solutions | Lighting products | Design & Production; Reuse | Communication and marketing (with input from CEO) |
| Firm 24 | Large | Recycling of metals | Multiple types of WEEE | Collection; Recycling | Commercial Manager |
| Firm 25 | SME | | Multiple types of EEE | Reuse; Recycling | Chemical Engineer |

(*continued on next page*)

(*continued*)

| Number | Size | Core company activities | EEE Category | Circular processes | Interviewees' position |
|---|---|---|---|---|---|
| | | Recycling and reuse services | | | |
| Firm 26 | SME | Collection services | Multiple types of WEEE | Collection | Owner |
| Firm 27 | Large | Refurbishment and repairs | IT and telecoms equipment | Repairs; Refurbishment; Collection | Head of Business Development |
| Firm 28 | SME | WEEE management | Multiple types of EEE | Reuse; Refurbishment; Collection | Communication and Business Development Manager |
| Firm 29 | SME | Design and leasing | Small Consumer Electronics | Design & Production; Leasing | Office manager |
| Firm 30 | Large | Information technology services | IT and telecoms equipment | Leasing; Reuse; Repairs; Refurbishment | Director of Sustainability |
| Firm 31 | SME | Design and production | IT and telecoms equipment | Design & Production | CEO |

## Appendix 2. Interview guide

*I. Description of company activities*

Role in the company of the interviewed expert(s):
Location:
Size of company:
Activities:
Description of the circular economy business model that you have implemented:

*II. Barriers/challenges*

Which were the key barriers faced by your organization when implementing your circular economy business model? Which were the major challenges that you faced? Please also provide a short description of each of these barriers that you faced.

Key categories of barriers: Policy and regulation, Finance/economic factors, Supply chain, Technology, Consumer/societal awareness, Company organization, Other.

*II. Enablers*

Which were the major enablers that helped your organization successfully implement your circular business model? How did you manage to overcome the barriers mentioned before? Please also provide a short description of each of your enablers.

Key categories of enablers: Policy and regulation, Finance/economic factors, Supply chain, Technology, Consumer/societal awareness, Company organization, Other.

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