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## Article

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**CIRCULAR ECONOMY PRACTICES IN THE ELECTRICAL  
AND ELECTRONIC EQUIPMENT SECTOR IN THE EUROPEAN UNION**

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**Abstract**

Our research objective is to investigate the circular economy practices implemented by manufacturers in the electric appliance sector. The research methodology was mixed, selecting relevant fragments from the nonfinancial reporting of a sample of entities in the European Union and following the whole process, from the conception of the product to the end of its life. The results indicate that the companies analysed take similar actions. Therefore, the companies' efforts are focused not only on finding solutions for equipment manufacturing based on a circular model (increasing the use of recycled or easily recyclable materials, reducing consumption or recycling more efficiently) but also on changing the way the consumer uses the products (for instance, by finding solutions to recover equipment components and reuse them, by reducing consumption, or even by recycling the generated waste). The study contributes to improving the knowledge of the actions taken to implement a circular business model by companies in a sector that consumes large amounts of resources and generates significant waste, such as the one analysed. The results highlight the intentions and progress made by companies producing electric appliances in their transition to the circular business model.

**Keywords:** circular economy practices; electrical and electronic equipment; electric appliances; extended product value business model; sustainability reporting

**JEL Classification:** P48, Q01, Q57

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## **Introduction**

The circular economy (CE) is “a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible” (European Parliament, 2018). At the European Union (EU) level, special attention is paid to areas in which more resources are consumed, including electronics and IT. Electric appliances (EA) are part of the electrical and electronic equipment industry (EEE), and one of its important segments as well, considering not only the growing sales, but also the potential they present in terms of the transition to a circular economy.

Our research objective is to investigate the CE practices implemented by European manufacturers in the electric appliances sector. The EU statistics show that the largest increase in waste is e-waste, of which only 40% is recycled (European Parliament, 2020). In this context, our study is relevant because it covers the entire lifespan of electric appliances, from the conception and design of the product to the end of its life. It is also important to better understand how companies in the electric appliances sector implement the CE principles.

To fulfil the research objective, this study analyses nonfinancial information published by a sample of European companies in the electric appliances sector, by selecting the relevant fragments using the NVivo software.

Our analysis highlights that electric appliance manufacturers adopted CE practices, not only by internalizing several principles but also by calling for stakeholders to assume responsibility and applying some selection criteria (for example, choosing suppliers based on sustainability criteria), contributing to the viability of the circular business model, and increasing the degree of waste recycling and their reintegration into the manufacturing process.

Furthermore, the study enriches the academic literature focusing on the topic of CE by offering some practical solutions to integrate CE in companies in the field of electric appliances. Similar to Bocken et al. (2016), we included essential elements such as the supply chain in our research. Understanding the actions of companies in this direction is important because they determine the initial resource consumption and the life of the product through the technological improvements they make, and can also help the consumer use the products efficiently and minimise waste at the end of the life of electrical appliances. This research analyses the nonfinancial reporting of companies in the EA industry that has not been exploited for the entities in this field. Therefore, we follow Webster’s (2021) recommendation to approach the topic of CE from a new perspective.

The article has the following structure: first, the relevant CE literature is presented, in general, and for the EEE sector, in particular. The research methodology describes the sample of companies, the data sources, and the coding process using the NVivo software. The research results are discussed at the end, followed by a summary of the main findings and conclusions.

## **1. Literature review**

In recent years, the CE concept has gained greater importance for regulatory authorities, companies, and researchers and is frequently associated with sustainability. Although CE and sustainability are seen as solutions to solve many social and environmental problems, there

is no consistency in the content of each concept (Nikolaou et al., 2021). Thus, at the microeconomic level, CE focuses on reintroduction of waste into production processes knowing that resources can be better used and waste and emissions can be further reduced in circular systems than in linear ones (Geissdoerfer et al., 2017). At the company level, the operational and production procedures have been modified by incorporating the CE classic principles, in the form of reuse, recycling, consumption reduction, redesign, remanufacturing, and reconditioning. Therefore, CE has as its general objective “the realization of a closed-loop material flows in the economic system” (Geng and Doberstein, 2008, p.231) to reach “an industrial economy that is restorative by intention and design” (EMF, 2013, p.14). Furthermore, CE is consistent with the best-known definition of sustainability, which is included in Brundtland Report (1987, p.41): “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Three pillars are considered relevant to ensure sustainable development: people, profit, and the planet. In this way, sustainability can be understood as “a balanced and systemic integration of intra- and intergenerational economic, social, and environmental performance” (Geissdoerfer et al., 2017, p.759). In the academic literature, it was outlined that the general beneficiaries of sustainability are the environment, the economy, and society, while the main beneficiaries of CE are the economic actors who implement such a system, without excluding the environmental and some social benefits in this case as well. CE refers, in particular, to short-term individual economic benefits, by reducing resource consumption, increasing efficiency, and avoiding waste generation, in contrast to sustainability, which aims at the long-term viability of the entire economic-social system (Brundtland, 1987; EMF, 2013). In addition to the CE goals at the microeconomic level (products, companies, consumers), recent research papers also deal with CE from a mezzo-economic perspective, supporting the need for examples of good cooperation practices between companies to promote sustainable development, inclusively through efficient exchange of waste, which ensure the achievement of CE objectives (Saavedra et al., 2018). For the same purpose, starting from the principle according to which “polluter pays”, some authors (Wang et al., 2017) propose some directions in the field of extended producer responsibility (EPR) for electrical and electronic equipment waste: combining funds to encourage EPR with those intended for the design of ecological products; including the second-hand market and remanufacturing companies in the EPR system to stimulate the creation of a cascading cycle system for the use of EEE waste; creating a new business model with a supply chain for the manufacture and consumption of products which corresponds to a reverse supply chain for the recovery and use of EEE waste in order to increase voluntary producer responsibility. At the macroeconomic level, CE (as well as sustainability) can be supported and promoted by introducing CE (sustainability) principles into national legislation. However, although regulated in developed countries, waste transfers are considered pollution transfers when their destinations are developing countries, even if the purpose of the transfer is reuse (Liu et al., 2018).

Although there are similarities and differences between the two concepts, the relationship between them is not fully clarified (Geissdoerfer et al., 2017). Therefore, if the United Nations Environment Programme (2006), Nakajima (2000), Bocken et al. (2014), the European Commission (2014), and Webster (2015) consider CE a necessary condition to

ensure sustainable economic growth, without excluding other growth paths, there are some authors (Zink and Geyer, 2017) who describe not only the benefits, but also the costs and problems generated by CE (the energy needed to recycle the materials and the greenhouse gas generated by this process) that can lead to the reduction or elimination of potential benefits. In this context, the opinions of some authors about CE based on sufficiency are also relevant (Bocken et al., 2022), according to which avoidance of consumption is prioritized over recycling strategies.

Whatever the approaches of the two concepts are, it is necessary to deepen the relationship between CE and sustainability to better understand how they, together and separately, influence the performance of supply chains, the evolution of business models, and innovation systems (Geissdoerfer et al., 2017).

The application of CE principles has facilitated the emergence of new business models such as Extending Product Value (EPV) (Bocken et al., 2016), which allow the elimination of the wear and tear of products and the extension of their useful life, contributing to a reduction in the flow of resources and a more efficient use of those resources. These models are considered attractive alternatives to reducing the useful life of products (Bakker et al., 2014).

Some authors (Cooper and Gutowski, 2017; Sandin and Peters, 2018) state that the EPV model contributes to resource efficiency in two ways. On the one hand, it prevents reaching the end of useful life of products by reducing the impact on the environment through storage or disposal, and, on the other hand, it prevents the manufacture of new products, leading to a decrease in resource extraction and energy consumption. For this business model, factors that have a direct or indirect influence on the environment were also identified. Factor analysis from the perspective of how they influence resource efficiency in the EPV business model was carried out by some authors (Whalen, 2019), by grouping them based on the value components: value proposition; value creation and delivery; and value capture. Table no. 1 illustrates some examples of factors associated with each value component, which influence resource efficiency in the EPV business model.

**Table no. 1. Factors related to the efficiency of the business model resources in relation to EPV**

<b>Value component</b>	<b>Elements that influence the value</b>	<b>Factors related to resource efficiency</b>
<b>Value proposition</b>	Product type	Energy consumption in use
	Customer behavior	Replacement rate Transport
<b>Value creation and delivery</b>	Transportation	Distance traveled Transportation method
	Company operations	Physical stores Warehouses
	Activities relating to the reversal of product obsolescence	Washing, cleaning, repairing, refurbishing, remanufacturing
<b>Value capture</b>	Pricing strategy of the company	New production price

*Source: Whalen, 2019, p.1130*

The CE options related to waste are different depending on the business activity. In the case of electrical and electronic equipment, these options are repair, recycling, and reuse (reconditioning) (Dragomir and Duțescu, 2022). As a result of these processes, raw materials and materials are obtained and can be reintegrated into the production cycle.

Household appliances can be subject to technological or moral depreciation. Therefore, it is important to have some circular services (for instance, updating with the fashion trends - Amend et al., 2022). During use, the EA consumes energy and, in some cases, water. In this context, the questions are whether and when it should be replaced or whether the lifespan is worth extending. Allwood et al. (2011) consider that it is better not to replace products (e.g. laptops) with a relatively high integrated energy compared to their environmental impact, in the use phase, but to extend their lifetime. Other authors (Ardente and Mathieux, 2014) argue that sometimes it is recommended to extend the useful life of products with relatively low integrated energy compared to their environmental impact in the use phase (e.g., washing machines). However, in the case of these products, if more energy-efficient ones are available, it may be more reasonable to replace them rather than extend their useful life.

The user behavior represents a critical factor that depends on the extension of the product's useful life and implicitly on the consumption of resources. In terms of sustainability, the user decides the useful life of the product if he/she wants to repair it, recycle it, etc. Bakker et al. (2014) consider that the lifespan of electrical and electronic products (e.g. refrigerators and laptops) has decreased in recent years, although they have not reached their optimal lifespan. Furthermore, these products are replaced by new products rather than old ones, and, moreover, the reduction in consumption (of water, energy, or other resources) achieved by replacing old products generates additional product purchases (e.g., based on vouchers received for an old product), which, in turn, increase the general consumption of resources or generate behavior that is less attentive to energy consumption (Chitnis et al., 2014). Users of products with modular design (which allows the replacement of certain components) are more likely to use the repair instructions themselves (Amend et al., 2022).

The environmental impact of transporting the product to the customer depends on the frequency, the distance, and the type of transportation means, so that the potential savings of resources is reduced by energy consumption and the emission of greenhouse gases generated by the transport (Zamani et al., 2017). In the case of reconditioning old products for sale, the additional consumption consists of energy for lighting, repairs, heating/cooling of warehouses, and cleaning products.

Regarding the pricing strategy, Ovchinnikov et al. (2014) state that companies can reduce the prices of new products on account of the profits obtained from the sale of old products, which eventually can lead to increased sales of new products and thus to higher resource consumption.

Therefore, the application of the EPV business model is not simple and must be continuously adapted to the evolution of factors that can influence resource efficiency. Furthermore, Whalen's (2019) analysis on the potential of companies using the EPV model to contribute to CE highlighted that companies (grouped into three categories – facilitators, redistributors, and manufacturers) with a higher firm-product interaction have more opportunities to increase resource efficiency.

Bressanelli et al. (2021) developed a conceptual framework that allows for the classification of factors and levers that companies in the EEE industry can exploit to generate economic, environmental, and social benefits of CE. Among the CE drivers, the authors identified: digitization, government intervention, the active role of users, circular design of products, business models centered on the end user and supply chain management. Regarding the design of EEE, Bovea and Pérez-Belis (2018) identified the design methodologies of the main categories of EEE to comply with the CE principles.

## **2. Research methodology**

The sample used in this research paper was chosen based on the most well-known EA brands at the EU level (such as those for equipment such as vacuum cleaners, hair dryers, refrigerators, coffee makers, washing machines, dishwashers, and electric ovens). After identifying them (including after querying specialized databases such as Statista) and the manufacturing companies, we eliminated those that were outside the EU (for example, the Samsung, Haier, or Arcelik groups) and those that have not uploaded sustainability reports in the last two years on their website. In the end, our sample consisted of seven companies.

Our research objective is to investigate the CE practices adopted by manufacturers in the EA sector. To achieve this objective, we analyse the information on CE published by companies in the most recent sustainability reports, annual reports, or on their web pages. Large companies in Europe are required to prepare non-financial statements and to disclose information on at least environmental, social, and employee aspects. Following the preliminary analysis, we found that most companies disclose information on CE in their sustainability reports or in the section dedicated to the non-financial statement in published annual reports. The companies included in the sample and the data used for each of them are presented in Table no. 2.

**Table no. 2. Data source**

<b>Company</b>	<b>Reports</b>
<b>AB Electrolux</b>	Sustainability report 2021 Complementary information - Sustainability report 2021
<b>BSH</b>	Website
<b>DeLonghi Spa</b>	Sustainability report 2020, Nonfinancial statement 2020
<b>Groupe SEB</b>	Sustainability report 2021, Annual and sustainability report 2021
<b>Kärcher International</b>	Sustainability report 2021, Website
<b>Miele</b>	Sustainability report 2021
<b>Philips</b>	Annual report 2021

The CE categories were then established on the basis of the academic literature and the websites of the companies included in the sample. They were tested on a sustainability report for which data was collected in order to compile a final list of categories that includes the following topics: innovation; research and development; supply chain; production; packing; logistics.

The CE principles must be applied not only in the production and delivery of products, but also in managing the product itself: from its use to how it is recycled or reused at the end of its useful life. Unlike Parajuly and Wenzel (2017), who were interested only in the waste

management of end-of-life electronic equipment, we grouped product information into three categories: first use, second life, and end-of-life, respectively. Finally, the stages that followed were those presented in Figure no. 1.

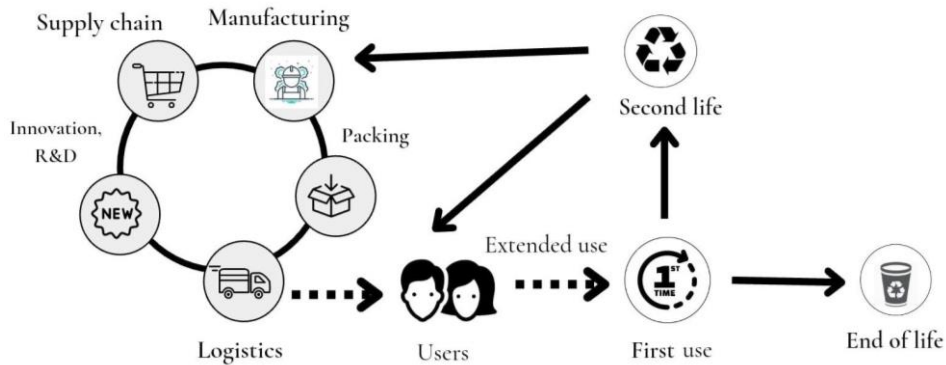


Figure no. 1. Product life cycle

Content analysis was performed using NVivo software. The chosen text unit was the sentence. Other options would have been to use words or paragraphs for analysis. We chose the sentence because we noticed that sometimes the word is not enough to render the information in context, and the paragraphs can also contain information that does not interest us for analysis (for instance, general information, connecting sentences). In the academic literature, the sentence is considered the most reliable unit of analysis (Milne and Adler, 1999; Abed et al., 2016), and is the most frequently used (Gray et al., 1995).

The pdf reports of the selected companies and the information from the companies' websites which were copied into word files were then imported into NVivo software. By using this programme, we created queries within the source files to generate some statistics to point out the importance of the themes (for instance, we determined the frequency of the words), data visualization by drawing diagrams regarding the qualitative material, and manual coding (Dragomir, 2022). Subsequently, we defined a code for each of the eight categories presented above. We cross-coded some sentences (for instance, if the company was looking to develop a product that would have a longer lifespan, we coded both the innovation and the first-use theme) and prepared a list of words. The words searched in the source files (Table no. 3) indicated the paragraphs to be read, facilitating the assignment of codes corresponding to the information disclosed.

Table no. 3. Keywords and coding used in NVivo

Keywords	Coding
Redistribut(ion), refurbish(ment), renewal, upgrade (upgrading)	Second life
Conception, design; development; innovat(ion); research (R&D)	Innovation, research and development
Improve(ment)	Innovation, research and development/Second life
Material(s)	Innovation, research and development/ Supply chain/ Manufacturing



<b>Keywords</b>	<b>Coding</b>
<b>Circular; sustainab(le)</b>	Innovation, research and development/Supply chain/ Manufacturing/Packing/ Logistics/First use/ Second life/End of life
<b>Duration of use</b>	Innovation, research and development/First use/Second life
<b>Supplier(s)</b>	Supply chain
<b>Emissions</b>	Supply chain/ Manufacturing/Packing/ Logistics/First use/ Second life/End of life
<b>Re(use); leas(ing); maint(aining) (maintenance); share(d use); repair</b>	First use/Second life
<b>Consumer(s); consumption</b>	First use/Second life/End of life
<b>Produc(tion)/ manufactur(ing)</b>	Manufacturing
<b>Waste (management)</b>	Manufacturing/Packing/ Logistics/End of life
<b>Energy</b>	Manufacturing/Packing/ Logistics/First use/Second life/End of life
<b>Specialized collect(ion); recycl(ing)</b>	End of life

From the initial list, keywords with low frequency were eliminated; thus, we kept only keywords with high frequencies.

### 3. Results

The most frequently disclosed information is presented on the five stages of the product manufacturing and delivery process, as well as the three stages of use. The frequencies of the CE-related information type reported by the companies from the sample are illustrated in Figure no. 2.

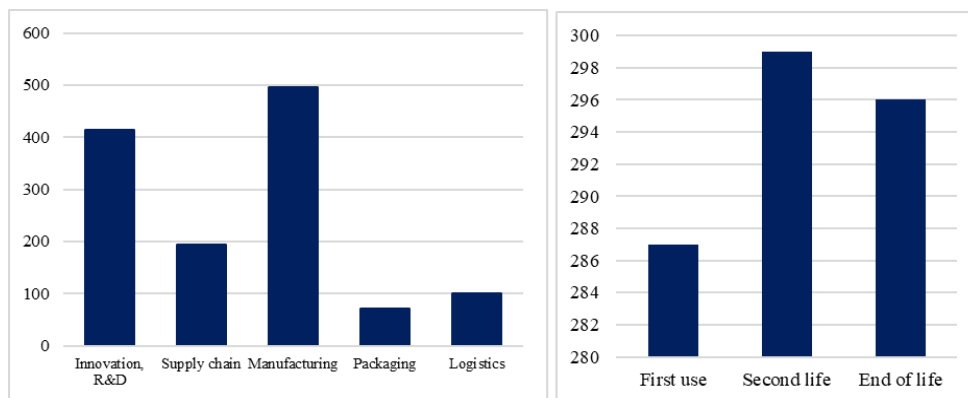


Figure no. 2. The frequency of the codes with respect to CE

### *Innovation, Research, and Development*

Following the analysis of specific information on the innovation, research, and development stage, several important directions in which CE-related efforts are focused emerged. As expected, all companies aim to increase the use of recycled materials and more easily recyclable alternative materials, especially plastic, paper, aluminum, energy, water, and steel (Electrolux: *Our Zero Waste to Landfill program has the objective to reduce our environmental footprint, find opportunities for material reuse and recycling, and [...] decrease the amount of waste [...]*; SEB: *With this in mind, it has implemented concrete actions and, from the design of a product to the end of its life, it takes measures to limit its environmental footprint [...]*).

Finding solutions to make products more easily recyclable and improving them to consume fewer resources (especially water, energy, and plastic) are also important goals (Bovea and Pérez-Belis, 2018). These can be achieved by recovering some components or by transforming the product into raw materials sent back into production (BSH: *[...] simplifying the repair, disassembly, and recycling of the components of our appliances is also an essential part of the product development process*; SEB: *Integrating recycled raw materials, improving energy efficiency, reducing energy consumption without compromising performance, and making a product repairable and recyclable are eco-design drivers*).

The circular model has led to the reorientation of companies' strategies towards consumer-oriented objectives (Philips: *As Philips' business profile has shifted focus towards health technology, we believe we need to shift from transactional product-focused business models towards outcome-oriented, multi-year customer partnership business models enabled by solutions and value-added services*).

Educating consumers to use products more responsibly is a recurring theme. Consumers are provided with efficient methods of use that optimize the resources consumed, mostly energy and water. Some of the analysed companies present their efforts to reduce food waste, a responsibility that must be assumed and shared between producers, consumers, and other entities. For example, food stays fresh longer, consumers can benefit from recipes that use food in the refrigerator, or they can access information that helps them cook quickly. Such efforts to educate consumers for more responsible consumption have also been reported by other industries, interconnected with the electric appliances industry – such as the textile industry (Dragomir and Dumitru, 2022).

The effort must be continuous and not individual. Consequently, partnerships are signed with consumers, non-governmental organizations, and others to find ways to achieve the goals of a CE. DeLonghi, for example, has developed a series of more efficient products in partnership with universities in Europe. Electrolux has entered into partnerships with non-profit organizations involved in educating the public about the formation of more sustainable consumption habits.

The technology facilitates the transition to CE (Uçar et al., 2020; Bressanelli et al., 2021). Companies use solutions ranging from 3D printing of spare parts (which makes products easier to repair), to applications that optimize usage and consumed resources (for example, washing machines can be programmed for easy rinsing, not for washing, which lowers water and energy consumption, but also helps increase the fabric's lifespan), to new technologies

that are more efficient in terms of resource consumption/results (Miele: *Washing assistants [...] provide information on particularly energy-efficient settings; DeLonghi: the innovative solutions [...] have been linked to digital technologies such as the Internet of Things and connectivity, which make it possible to control products remotely and thus benefit from a reduction in energy consumption resulting from their use*).

On the same note, Bressanelli et al. (2022) identified digitalisation (included here as 3D printing and other modern technologies) as an enabler of CE. Product sharing, pay-for-use, and providing incentives for consumers to return old products to be refurbished or recycled are the most frequently mentioned business models in the CE context (SEB: *The Group has been committed to a more circular business model [...] to save the planet's resources by activating several drivers: extending product life and re-use, promoting recycling and the use of recycled materials, and experimenting with shared product use*).

### **Supply chain**

Significantly less information is disclosed about the supply chain. Frequently, the companies under review sign partnerships with suppliers to achieve common CE goals, rewarding the best or penalizing those who do not comply. These partnerships may involve exchanging knowledge with suppliers or finding more CE-oriented solutions from which both partners benefit (Electrolux: *Supplier expert knowledge and co-innovation together with suppliers help improve our sustainability performance in, for example, product energy and water efficiency, circularity and to reduce the environmental footprint of our operations*).

Numerous programmes are held to incentivize suppliers to become more sustainable (Philips: *Rewarding suppliers that comply with our requirements and sharing our sustainability ambitions with them promotes more sustainable practices, technical improvements, and innovation*). Suppliers are selected only if they share the same CE values and have specific obligations to report indicators required by the analysed companies (Electrolux: *We request our strategic suppliers to report their climate impact through CDP*). Periodically, compliance checks are carried out (Karcher: *We carry out regular internal audits and company visits, particularly for production material suppliers; Miele: Miele carries out regular checks to ensure that its direct suppliers are complying with environmental and social standards and determines the origin of individual raw materials such as stainless steel and plastic when necessary*).

### **Manufacturing**

Manufacturing companies have played an important role in improving living standards around the world. However, in a linear business model, they are unsustainable and therefore invest in solutions to transform their production cycle into a circular model. Miele aims for its actions to represent steps towards full CE (Miele: *It aims to enable further steps towards achieving a fully circular economy*). Philips declares that its production process is carbon neutral and works with suppliers and customers to reduce greenhouse gas emissions to create an environmentally friendly value chain and therefore create the transition to a circular economic model. But to operationalize the circular model, the production process involves several activities of repairing, reinstalling, reusing, and recycling – a circular loop.

Manufacturers may receive products back in different quantities, which can create new difficulties in receiving, sorting, and re-manufacturing them.

The companies analysed disclose in their sustainability reports the practices adopted in the production processes in order to create a circular loop (Electrolux: *We will contribute to the circular economy by integrating recycled materials into our product platforms, promoting recyclability, using more sustainable packing solutions, increasing the availability of spare parts to repair our products, and developing circular business solutions*), aiming to reduce environmental impact while increasing financial performance (Philips: *we aimed [...] to generate 25% of our revenues from circular products and services, to extend our 'closing the loop' practices*) and offering high quality products to their consumers (Miele: *It aims to provide great benefit to customers and have as little impact as possible on the environment; DeLonghi: The Group pursues this objective through well-established practices, such as the eco-design of products, which are made up of by components that are easy to disassemble and clean so as to ensure a longer life cycle*).

Some companies have managed to create their production cycles in which they use raw materials that come from materials that have already gone through a recycling process (second recycling) (Miele: *therefore uses a high proportion of recyclable materials and secondary raw materials in production, i.e. raw materials which have already undergone a recycling process*). Some authors found that products obtained by recycling waste are perceived to be of lower quality (Hazen et al., 2016); therefore, in the reports analysed, many companies emphasize the fact that the properties and quality characteristics of these products are similar or even superior (BSH: *the primary goal of ensuring the materials and services will remain available and high quality, in a sustainable way; Philips: We are committed to delivering the highest quality products, services, and solutions compliant with all applicable laws and standards*). All the analysed companies' reports highlighted the impact of CE practices on the environment, bypassing the social and economic dimensions. Recent academic studies have also revealed the interest of companies in reporting the contributions of circular policies to the environment, leaving the impact on financial results or the social component in the background (Bjørnbet et al., 2021).

### **Packing**

Most companies disclose detailed information on how they have decided to become more sustainable in the packing stage. By replacing plastic with cardboard, using reusable packaging, and using fibers instead of other materials, all companies have aimed to reduce the consumption of hard-to-recycle materials and use more recycled materials, mainly paper products (Electrolux: *the packaging has no single-use plastic; Karcher: We've succeeded in eliminating polystyrene for packaging our [product] – opting for cardboard instead; BSH: The packaging consists of 80% recycled material, such as paper, and the protective cover is 100% biodegradable; DeLonghi: Recycled plastic pallets instead of wooden ones are also used*).

Sustained efforts have also been made to decrease the consumption of resources used for packing, by using reusable packaging types, and finding more efficient ways of packing (such as giving up individual packing): *Other examples of progress on eco-packaging [...] since 2019, they have ceased being individually wrapped and are stored in bulk [...]. Result: 6.5 tons of cardboard and 600 kg of plastic saved a year* (Karcher).

### **Logistics**

The application of CE concepts in the distribution stage involves making decisions related to the transport of manufactured products, decisions with an economic impact (Sureeyatanapas et al., 2018), which can contribute to the reduction of transportation costs (Miele: *In conjunction with optimized transport logistics and the bundling of goods flows, this saves on transport costs and reduces transport-related CO<sub>2</sub> emission*; DeLonghi: *[e-commerce] is part of a drive to increase the efficiency of logistics and deliveries, as it is recognized that reducing the number of operations carried out also generates benefits in terms of environmental impact*). At the same time, the impact on the environment is reduced (Sureeyatanapas et al., 2018), especially by decreasing CO<sub>2</sub> (BSH: *If a technician visit at home is required, we optimize our scheduling and routing to reduce carbon emissions*).

### **First use**

Regarding the “first use” category, we have taken into account the aspects related to the sustainable use of the product. The information disclosed by the companies emphasized the efforts made to extend the product lifespan, with the direct and immediate effect of reducing the impact on the environment as a result of diminishing resource consumption (Karcher: *We tackle various points to ensure this lifetime is as long as possible. In the end, a product that has a long lifecycle gets much more from its raw materials than one which wears or breaks quickly [...] Last but not least, we also construct the machines so that the wear components are easy to access and change*). Depending on the type of products sold, the focus is also on extending the lifespan of other products directly related to those sold (Whalen, 2019). Thus, not only are the new lifespans of washing machines extended, but also the technical characteristics of the washing machines increase the lifetime of the washed fabrics. Increasing the lifespans of the products is achieved not only by finding more efficient technologies, but also by developing some products that allow the quick and inexpensive replacement of those parts with a shorter life, which is not a true repair, but an easy replacement of spare parts (BSH: *Our brands' customer service teams offer helpful cleaning and maintenance tips as well as a range of care packages to help keep an appliance running for as long as possible*). Similarly, Bovea and Pérez-Belis (2018) emphasized the urgent and immediate need to integrate circular design guidelines related to extended life.

Most reports disclose information on the reduction of consumed resources by-products, from electricity (Electrolux: *[...] we develop efficient appliances that save energy throughout their lifespan in people's homes*; BSH: *we will further reduce the energy consumption of our products so that consumers have lower electricity costs at home*; Philips: *reduce the environmental impact [...] by maximizing energy-efficient use [...] and optimizing lifecycle value*), to water (Karcher: *High-pressure cleaners save around 80 percent of water due to their high cleaning performance compared to working with a garden hose*; Electrolux: *The average dishwasher is four times more water efficient than washing by hand per place setting [...]*) and to other consumables. Reducing resource consumption is fundamental in CE because waste is also reduced. For example, an efficient wet vacuum cleaner is more sustainable not only because it requires less water consumption, but also because it generates a smaller quantity of polluting water compared to a less efficient vacuum cleaner (Karcher:

*Recycling systems in gantry car washes, for example, collect up to 98% of the used water, process it and use it for the next cleaning process).*

The consumer must be educated to use the products as sustainably as possible, either by raising awareness of the CE's importance, by providing detailed and transparent information on how the product affects the environment, or by devising efficient programmes in terms of resource consumption/results. Most of the companies analysed engage customers in achieving CE goals (Electrolux: *We also build partnerships to inspire more people to practice better fashion consumption and care; We work to make them more resource efficient and to raise consumer awareness on optimized usage.*)

In their effort to find business models that promote CE, some of the analysed companies offer their products in lease contracts or in exchange for rent based on the use. Thus, the use of rented products, according to need, without purchasing the product, leads to an optimization of resource consumption, reducing the number of necessary products and the resources consumed to manufacture them (Electrolux, SEB Group, or BSH).

### **Second life**

Regarding the “second life”, companies aim to develop products that are easy, quick, and cheap to repair. As part of more responsible use, the product repair process is essential to extend its useful life. From ensuring the existence of spare parts even years after a certain product model is discontinued (SEB Group) to guaranteeing attractive costs (Electrolux, SEB Group) or free repair services (Miele), from offering long warranty periods (which make the repair more attractive than replacement) to offering a post-repair warranty (SEB Group), from ensuring a fast delivery process of spare parts in stock to printing the necessary spare parts using the 3D technologies (SEB Group), companies have made great efforts to make repairs as attractive as possible ( SEB: *SEB continued to act to promote the circular economy by emphasizing the importance of product reparability [...]*).

### **End of life**

Companies are interested in recovering the products at their end-of-life from consumers, either to repair them and distribute them to new customers or to give them for free in social projects (BSH: *To help reduce consumption of natural resources, we also prioritize reusing and recycling appliances and material after their long lifetimes; SEB offers services consisting in product refurbishment (mostly recovered as part of the after-sales service) for resale as “second hand” on-site at fair prices.*)

When products recovered after the first use from consumers can no longer be repaired and used, as many functional components are recovered to be used in available repairing programmes (Phillips: *Pre-owned systems and parts that are refurbished and/or remanufactured or recovered are brought back to customers by Philips as either circular systems or spare parts [...] We also [...] re-use of spare parts in maintenance services.*)

Companies are aiming to recycle as much as possible of their products that have reached the end of their useful life. To encourage the return of products, companies have run various

programs to embolden consumers, such as discounts for newly purchased products, free pick-up of old products, or other advantages. The efforts made to collect the products are welcome considering the previous results of the researchers (Atlason et al., 2017) who showed that, despite the fact that users find the idea of recycling attractive, they often do not recycle electronic equipment (Philips: *[we] established a customer-centric way of supporting replacement deals to actively pursue trade-in of equipment that customers are willing to make available at end-of-use, supporting long-term partnerships – offering an attractive trade-in value, hassle-free take-back, and less downtime when customers decide to continue their partnership*; Electrolux: *These include appliances trade-in programs where consumers can have their old appliances collected for recycling when their new product is delivered*; Miele: *We collect the old appliances when they install new appliances, and they carry out proper recycling*; SEB: *Consumers are encouraged to bring their old products back to the store in exchange for a discount voucher to purchase a new item*).

Through specialized partners or directly, all companies disclose indicators regarding recycling results (Kärcher: *Recycling also has a big role to play at the end of the life cycle of a product. [...] If you dismantle Kärcher products manually, you can recycle over 90% of the materials*; Miele: *After the appliances have been used for a long period of time, as is typical for Miele products, they are to be introduced into return systems and primarily sent for recycling and other disposal methods at the end of their lives*).

The results obtained are summarized in Table no. 4 and illustrate how CE principles integrate with the EPV model.

**Table no. 4. The way CE principles contribute to EPV**

<b>Dimension/Specific elements of EC</b>	<b>Value proposition</b>	<b>Value creation and delivery</b>	<b>Value capture</b>
<b><i>Innovation, Research, and Development</i></b>			
Reduced consumption during usage (such as energy or water)	✓		
Recyclable products (by using recycled materials and more recyclable raw materials, recovering components and other)	✓		
Consumer oriented objectives (such as the percentage of replaced products, healthier products and other)	✓	✓	✓
More responsible use (reducing water and food waste, increased useful life)	✓		
Technology (products easier to repair and with sustainable use, reduced consumption)	✓	✓	
Product sharing (renting, repairing products for re-use)			✓

Dimension/Specific elements of EC	Value proposition	Value creation and delivery	Value capture
<i>Supply chain</i>			
Partnership (shared values among partners)	✓		
Sustainable sources (of raw materials, energy and water)	✓		
<i>Manufacturing</i>			
Circular production cycle (controlling emissions, manufacturing loop)	✓		
Repeated recycling (of water and raw materials)	✓		
<i>Packing</i>			
Reducing consumption of materials that are difficult to recycle and using recycled materials (using cardboard instead of plastic)	✓		✓
Reducing consumption of resources (packing bulk and not individual products)			✓
<i>Logistics</i>			
Making transport more efficient (distance, type of transport)		✓	

The results of our research are grouped into three categories specific to the EPV model: value proposition, value creation and delivery, and value capture. The CE model adopted by the companies selected for this article highlights that the value proposition is implemented for most stages of the value chain. As easily noticed, value creation, delivery and value capture are components in their early form but with the potential to crystallize in the near future.

The words frequently used in the reports analysed are directly related to the circular economy. Thus, words such as “recycling”, “consumption”, “sustainability”, “environment”, and “responsible” are just a few examples.

The information disclosed by the companies is considered reliable if and to the extent that it also contains data to quantify and reflect the results of the efforts made. In fact, we identified two categories: indicators (where we included financial information disclosed or not by the company in relation to the results already achieved) and targets (where we included only those intentions, sufficiently concrete and quantified, assumed in the studied reports). The results show a higher number of reported indicators compared to the assumed targets (about



50% more disclosed indicators). Distributed by stages of the sales and distribution process, most indicators are related to the production process and the stage of product innovation and development, while the targets are almost evenly distributed between the two previously mentioned stages.

The most common indicators presented in relation to CE cover recycled materials consumption, recyclable materials recovery percentage, the consumption of non-renewable, difficult-to-recycle, or critical resources, the amount of uncollected generated waste, as well as associated CE financial indicators, such as income from products and services resulting from the use of CE principles (Philips). The assumed objectives are vague and not always quantifiable. The most frequently mentioned are increasing the use of recycled and easily recyclable materials, consumption efficiency, reducing generated waste, and the ambition to become more sustainable or inspire consumers in the transition to a CE.

### **Conclusions**

The objective of our investigation was to investigate the CE practices adopted by manufacturers in the EA sector. The study provides an overview of the solutions adopted by EA manufacturers as a response to the challenges and opportunities offered by the market. Among the factors that influence resource efficiency according to the EPV business model (Whalen, 2019), the most frequently considered by the analysed companies are energy consumption during use, transportation, repair, and refurbishing. Using the EPV conceptual model, this research highlights the intentions and progress made by electric appliance companies in moving to the circular business model. All stages of the value chain were investigated, and our results confirm the sustainability commitments of the companies.

The reports analyzed mainly highlighted the impact of CE practices on the environment, giving less importance to social or economic aspects and putting the impact on financial results in the background, as shown by previous research (Bjørnbet et al., 2021).

Although it is considered that the main beneficiaries of the circular business model are the very companies that adopt such a system, our analysis also highlighted how EA buyers benefit from the circular solutions provided by manufacturers. Thus, if the producers benefit from a competitive advantage as a result of the proposed solutions, the buyers enjoy equipment that brings them, in addition to the advantage of lower resource consumption (in general, energy and water), other categories of benefits (reductions in price, easier repair of defective equipment, end-of-life equipment takeover, etc.). These findings are consistent with previous ones (Whalen, 2019), which observed that when companies have a high interaction with products, regardless of whether they have adopted the EPV model or not, they can decrease environmental impact and increase resource efficiency.

Our study contributes to the success of implementing CE in this area. The research revealed that the effort to switch to CE must be long-term and collective, involving several stakeholders (e.g., the state, suppliers, customers, and end-consumers). These findings agree with the results obtained by Wang et al. (2017) and Zink and Geyer (2017), who believe that simply encouraging private companies to find profitable opportunities in the circular economy can reduce or eliminate potential environmental benefits if all participants in the value chain are not involved. Manufacturers can make electric appliances more easily

recyclable if they find suppliers that offer sustainable materials and if they manage to educate, convince, and motivate users to recycle them at the end of their life.

As our results emphasize, in the EA industry the linear business model changes to a circular business model, with real premises to fulfill economic, social, and environmental objectives. One may note the concerns of the selected companies in the direction of the reintroduction of waste into production and the creation of innovative products that contribute to the reduction of energy and/or water consumption. Extending the useful life of equipment, through further improvements or repairs, is a carefully pursued objective because it helps reduce waste. The goal of CE- “second life” is achieved through recycling or reuse. Similar research (Ovchinnikov et al., 2014; Sadin and Peters, 2018; Sigüenza et al., 2021; Amend et al., 2022) identified practices of the circular business model used by companies in the production of goods. Measuring the impact of these practices on economic, social, and environmental objectives is a difficult process because CE is a new concept, under implementation (Kulakovskaya et al., 2022; Moraga et al., 2019). Thus, although our study considers positive the efforts of the analysed companies to ensure EA repair, Agrawal and Ülkü (2013) suggest that modular upgrading may increase the environmental impact due to accelerated obsolescence resulting from more frequent replacement of some components.

Similarly to the results of previous studies (Uçar et al., 2020; Bressanelli et al., 2021), our research shows that technology plays an important role in EPV, by optimizing consumed resources, by offering additional benefits to consumers, or by extending the duration of life achieved by 3D printing spare parts.

Because in our study the unit of observation was the company, the solutions can be applied by similar companies. Research and development activity, which also results in innovation, is one of the solutions to the high competition in the field of EA, but also to the growing pressures to reduce energy consumption.

The limitations of this study are represented by the small number of companies included in the sample and the data source based on the last nonfinancial report available on the companies' website, without allowing a longitudinal analysis regarding the evolution of CE practices. Research methodology based on the setting of codes by the research team can be subjective. However, the use of NVivo software reduced the subjectivity of researchers. Furthermore, the differences from one non-financial report to another are not significant, so we believe that relevant conclusions can be drawn based on the information presented in a single year.

The analysis of CE practices in the electric appliances manufacturing sector can support the development of policies and regulations to encourage the reuse of equipment or the recycling of waste. As other studies have stated (Das and Posinasetti, 2015; Hankammer et al., 2018), the circular economy creates benefits along the entire value chain and reduces the negative impact on the environment (Agrawal and Ülkü, 2013; Kim and Moon, 2019), but sometimes CE practices are not profitable (such as recycling electric car batteries - Ahuja, 2020) and then regulation is needed. The three-dimensional approach (economic, social, and environmental) of the circular business model requires more empirical research that also considers other business sectors.

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