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Review article

# Morphology for circular economy business models in the electrical and electronic equipment sector of Singapore and South Korea: Findings, implications, and future agenda

Chang H. Kim, Adrian T.H. Kuah*, K. Thirumaran

*James Cook University Australia, Singapore Campus, 149 Sims Drive, Singapore, 387380, Singapore*

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ABSTRACT

Moving to a circular economy requires manufacturers and producers to rethink their business model for a stronger value proposition and delivery. Many businesses have implemented circular economy business models (CEBMs) with different design options to accomplish sustainable business goals and economic prosperity. However, the unexplored options in the design of CEBMs can be a significant obstacle in the transition to a circular society. This paper seeks to investigate the CEBM design options currently reported in the Electrical and Electronic Equipment (EEE) sector of Singapore and South Korea, proposing a research agenda to advance circular economy research in both countries. In this systematic review, we follow four basic dimensions in a business model, value proposition, value delivery, value creation, and value capture, in a morphological analysis of 119 publications to identify business model design options in the Electrical and Electronic Equipment sector of Singapore and South Korea. Our findings showed that producers in both countries were similar in their intentions yet adopted different approaches regarding the four dimensions. In Singapore, result-oriented CEBMs and cooperation with the local government and community emerged as major design options. On the other hand, in the South Korean context, rental or leasing business models using the membership system with personalized home visiting service and the use of digital capabilities were rampant. These findings are expected to help producers and practitioners understand and adopt better design options to drive their business models, highlighting the agenda to further investigate digital servitization and consumer acceptance in CEBMs.



## 1. Introduction

The concept of the circular economy (CE) has amassed attention from government (e.g. Temasek Foundation, 2019; Nordic Council of Ministers, 2019), academic (e.g. Geissdoerfer et al., 2017; Hao et al., 2020) and social (e.g. Ellen MacArthur Foundation, 2013) circles. In contrast to the linear economic model of mass production, consumption and disposal, the circular model seeks to eliminate one-off consumption of consumer goods (Camilleri, 2019). As a new paradigm for sustainability, its key goal is to generate economic advantage for companies and minimize harm to the environment (Geissdoerfer et al., 2017). As part of a global effort to map out compatibility conditions between environmental sustainability and economic growth, Goal 12: Responsible Consumption and Production was established as one of the United Nations Sustainable Development Goals (UN SDGs) in 2015 (Kuah and Kim, 2021). UN SGD Goal 8: Decent Work and Economic Growth similarly promotes that global resource efficiency needs to be maintained in consumption and production, by decoupling economic growth from environmental degradation. Resource use and efficiency can be optimized by employing sustainable production and consumption business models, reducing the amount of waste as well as promoting inclusive and sustainable economic growth. In a similar vein, the efforts of individual countries are also noteworthy. The EU's Circular Economy Action Plan adopted in 2020 highlights a sustainable product policy legislative initiative to make sustainable products the norm, while reducing resource use by 2030. The Singapore and South Korean governments also emphasize the transition to a circular economy through policy efforts called The Singapore Green Plan 2030 and The Korean Green New

*Abbreviations:* CE, Circular Economy; CEBM, Circular Economy Business Model; EEE, Electrical and Electronic Equipment; EoL, End-of-Life; ICT, Information and Communications Technology; IoT, Internet of Things; KR, South Korea; PSS, Product-Service System; SG, Singapore; WEEE, Waste Electrical and Electronic Equipment.

* Corresponding author at: JCU Singapore Business School, James Cook University Australia, Singapore Campus, 149 Sims Drive, Singapore, 387380.

*E-mail addresses:* changkim.phd@gmail.com (C.H. Kim), adrian.kuah@jcu.edu.au (A.T.H. Kuah), k.thirumaran@jcu.edu.au (K. Thirumaran).

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Deal, respectively. Such efforts aim to increase resource efficiency and establish sustainable production and consumption patterns, while ultimately contributing to the transition to a circular economy society.

We assert that a circular economy aims to achieve economic prosperity and improve environmental quality by controlling the resource loops, thereby securing the sustainability of the environment and the economy. Companies create and support the circular economy by applying mechanisms such as recycling, remanufacturing, reuse, repair, and refurbishing to manage resource loops and reduce resource use (Bocken et al., 2016). One laudable effort is helmed by Samsung Electronics, a South Korean multinational electronics company. Samsung recycles and reuses their End-of-Life (EoL) products/appliances as useful resources, thereby reducing the new resources required for sustained production and consumption. Countries and companies have started incorporating CE into their businesses. In the last decade, the paradigm has taken root in industry, shaped national policies, and given further research significance among intellectuals (Geissdoerfer et al., 2017; Guo et al., 2017).

Several scholars (Linder and Williander, 2017; Lüdeke-Freund et al., 2019a) have focused on the design, development, and implementation of circular economy business models (CEBMs) and their concomitant strategies at the company level. Lüdeke-Freund et al. (2019a) reviewed circular economy literature and found 26 major business model types, revealing numerous design options for the development of CEBMs. However, as Linder and Williander (2017) noted that a range of challenges may arise when considering implementation of CEBM strategies, especially due to the inherent uncertainty of reduction in the manufacturing process and consumption behavior. A CEBM is a strategy for achieving a sustainable business model, emphasizing resource loops and a circular value chain (Geissdoerfer et al., 2018). Extending the business model concept—how a firm does their business in creating and delivering stakeholders' value and generate revenue (Teece, 2010) in a system-level and holistic approach (Zott et al., 2011) involves four dimensions, value proposition, value delivery, value creation, and value capture. The sustainable business model adds long-term environmental and social value to the business model (Bocken et al., 2013). Notably, a CEBM seeks a design that considers circular principles as a subset of sustainable business models (Bocken et al., 2014). While some have set environmental and economic issues as the major CE research areas (Homrich et al., 2018), the academic community is interested in how companies apply circularity to their business situations (Manninen et al., 2018). Hence CEBM, at the company level, stems from the perception that producers are 'economic agents' that can play a decisive role in controlling the negative environmental consequences in their production processes.

Meanwhile, the Electrical and Electronic Equipment (EEE) sector is becoming increasingly mindful of the circular economy (Bressanelli et al., 2020), as the quantum of electronic waste (e-waste) is rapidly growing globally. As more products are produced, the extraction and consumption of raw materials increases, thereby increasing the amount of Waste Electrical and Electronic Equipment (WEEE). EEE products consist of hazardous and non-hazardous materials, hence may pose the risk of exposure to toxic chemicals such as cadmium, copper, and mercury through EoL and final disposal stages (Cordova-Pizarro et al., 2019; Jang, 2010). However, the same products can be returned to the sales stage or the consumption stage, ultimately being reused by consumers. Producers in this sector can opt for EoL treatment options—remanufacturing, recycling, reuse, repair, and refurbishment—before and after the products reach the EoL treatment stage to protect the environment and make profits (Zlamparet et al., 2017). Such methods help minimize resource waste from manufacturers and reduce WEEE by slowing or closing loops for the extraction and consumption of raw materials. For this reason, the WEEE industry is gaining primary importance within the circular economy context (Bressanelli et al., 2020), and the application of CEBMs in the EEE sector can have a significant impact. This view is also supported by the Nordic Council of Ministers (2019) who insisted that a circular economy system for EEE products should be the 'next big focus' in their recent report. Therefore, the time is opportune to call for action on the topic of CEBMs not only for the eco-friendly EEE sector but also for sustainable environmental management.

Asia generated the largest quantity of electronic waste (e-waste) in 2019 of 24.9 million tons, followed by the Americas (13.1 million tons) and Europe (12 million tons) (Forti et al., 2020, p. 13). From 2015 to 2019, Asia's e-waste experienced the fastest growth among all the continents (Chatham House, 2020). To escalate the problem, this waste stream is poorly managed (Honda et al., 2016) but the application of circular economy concepts by a company in the EEE sector can bring significant potential to reduce e-waste, as in the case of Samsung Electronics. Nevertheless, there has been little discussion on how the Asian EEE sector can design and develop CEBMs at the company level to reduce e-waste. Given that most of the growth in consumption and resource use is expected to occur in Asia (Retamal, 2017), there is an urgent need to address e-waste at the production process level (Komoto et al., 2016). The EEE sector is one of the main sectors in both Singapore and South Korea (Singapore Economic Development Board, 2017; Statistics Korea, 2017) but both countries experienced relatively high e-waste growth rates at around 30% (Honda et al., 2016). Through a systematic review of the literature, this paper seeks to investigate the CEBM design options currently reported in the EEE sector of Singapore and South Korea, proposing a research agenda to advance circular economy research in Asia, particularly in two relatively advanced Asian Tiger economies, Singapore and South Korea.

### 1.1. Circular economy business models

The circular economy has its roots in industry ecology (Saavedra et al., 2018), as within the discipline, industrial metabolism focused on interactions between energy, materials, labor, and the environment in an industrial system (Ayres, 1998). In particular, the industrial metabolic system focuses attention on the "life cycle" of individual high-quality materials (e.g. fossil fuels, ores) that are extracted from the earth and returned to nature in a degraded form. Companies use industrial ecology principles to facilitate sustainable business activities by enhancing resource productivity and closing material loops (Short et al., 2014). Literature on CEBMs gained further attention with practitioner-oriented contributions from Accenture (2014) and the Ellen MacArthur Foundation (2015). Over recent years, for example, Bocken et al. (2014, 2016), Lewandowski (2016), Moreno et al. (2016), Nußholz (2017), and Pieroni et al. (2020) proposed several archetypes of CEBM that have contributed to the generation of CEBM archetypes such as circular supplies, product life extension, sharing platforms, and product-service systems (or Servitization) that we commonly refer to today.

Nonetheless, many archetypes are somewhat overlapping, whereby the distinctive criteria for categorizing CEBMs have not been established. Previous studies have primarily focused on developing archetypes albeit a small number of cases and have often overlooked the four dimensions in a business model, value proposition, value delivery, value creation, and value capture, and how they are combined. Notwithstanding, little is known about how the four dimensions are designed to complete a particular CEBM. In our view, paying attention to how the four dimensions in the business model are composed to create a CEBM is necessary for a con-

crete understanding of CEBMs. These arguments are aligned with Bovea and Pérez-Belis (2018) and Lüdeke-Freund et al. (2019b), who called for further research that contributes to circular products design, insisting that research conducted to date has focused excessively on developing new business models, rather than breaking down how each model offers value proposition, value delivery, value creation, and value capture. Such limitations make it difficult to provide useful knowledge or guidance to manufacturers and service providers seeking to design and introduce CEBMs for sustainable production.

While research on archetypes and accompanying typologies of CEBMs has already been conducted, there have been relatively few studies that explore CEBM design options in guiding companies alongside the four dimensions. CEBM design options refer to different options along the four dimensions that make up the business model (Lüdeke-Freund et al., 2019a). In their recent study, Lüdeke-Freund et al. (2019a) classified twenty-six existing CEBMs into a broad range of CEBM design options using morphological analysis, demonstrating how the existing CEBM archetypes were made up by the four main dimensions of a business model.

Levänen et al. (p. 374) noted that "business models must always be weighed against the local institutional structure, which constitutes context-specific institutional enablers and voids for business activities", as context-specific institutional environments may facilitate or hamper business model activities related to circularity. However, it is not surprising that CEBM studies based on an Asian context are rare, as previous studies were mostly developed by European scholars, with none of the twenty-six existing CEBMs identified by Lüdeke-Freund et al. (2019a) including the Asian context.

Studies on different design options for CEBM based in Asia have received relatively little attention so far, albeit some case studies on a single model level (e.g. servitization or a sharing platform). Insufficient discussions on the CEBM design options in the Asian EEE context can be an obstacle to the Asian producers' attempts to introduce and implement a circular business strategy. Hence, identifying the number of existing CEBM design options being practiced and most common in each country is meaningful in terms of providing valuable insights to manufacturers and academics for the application of a CEBM in the EEE sector. CEBM is important for the EEE sector, given its waste generation potential and use of hazardous substances. Moreover, the 4R scheme, Reduce, Reuse, Remanufacture, and Recycle, has high reuse or recovery potential for materials (Bressanelli et al., 2020). Therefore, providing explanations of the design option types can help stakeholders in the EEE sector by providing useful guidance, while ultimately contributing to the transition into a CE society.

### 1.2. Why Singapore and South Korea?

Many businesses in Asia are still hesitant to shift to CE businesses owing to the traditional linear production paradigm and weak market signals (Temasek Foundation, 2019). In conjunction with the Asian business contexts, clear discussions and arguments about what CEBM design options are available in the EEE sector in Asia are largely absent, thereby hindering advancing Asian CEBM practices in the EEE sector.

Against this backdrop, Asia's e-waste growth rate per capita was 19 percent from 2015 to 2019, the fastest growth among all continents, while the amount of e-waste collected and recycled was merely 12 percent in 2019, approximately one-third of that in Europe (Chatham House, 2020). Among the developed countries in Asia, the growth rate of e-waste in Singapore and South Korea between 2010 and 2015 was 29.5% and 28.8% respectively (Honda et al., 2016). The EEE sector is one of the largest sectors in both countries (Singapore Economic Development Board, 2017; Statistics Korea, 2017) and the e-waste generated (kg per capita) showed similar patterns at 19.9 and 15.8 respectively (Forti et al., 2020).

Although Singapore and South Korea may have similar circumstances in which CE principles can be applied in reducing e-waste, little effort has been made to identify what design options are practiced by local producers (within the EEE sector). Therefore, we conducted a comparative analysis of EEE CEBM design options in Singapore and South Korea using these two countries as exemplars in Asia to identify similarities and differences in the way CEBM design options are employed. It is hoped that this may help to identify opportunities to draw implications in these two contexts and that the findings can be used as a reference for transition to a CE society to neighboring Asian countries by integrating business-level efforts to reduce e-waste.

### 1.3. Purpose and contribution of this study

It is important to consider business model design strategies in the early stage of designing circular businesses to address the rising quantum of e-waste generated in the EEE sector. Lüdeke-Freund et al. (2019a) highlighted that more CEBM design research is needed to advance the CEBM literature in developing and emerging countries, as previous studies have been largely centered within the European context. Previous studies (Bocken et al., 2016; Moreno et al., 2016) highlighting different business models have primarily focused on developing different typologies for the circular economy, with a lack of studies on the attributes (or design options) of these business models. Furthermore, some studies (Lewandowski, 2016; Pieroni et al., 2020) introducing CEBM design using business dimensions have failed to report a comprehensive range of design options available or adoptable. For example, Lewandowski (2016) developed a comprehensive framework supporting every kind of company in designing a CEBM. However, since he addressed the issue of designing a circular business model from the perspective of every company, the question remains how to consider the peculiar characteristics found in a particular industry, such as the value chain network in the EEE sector. Although Pieroni et al. (2020) characterized twenty archetypes for CEBMs with key affected business dimensions, their primary concern was to identify and test business model archetypes, rather than identifying the variety of design options within the archetypes.

The lack of discussion of CEBM design options in the Asian context is an obstacle for Asian countries to transit to a CE society given their unique consumer and producer composition. Therefore, identifying all CEBM design options in a country-specific context is meaningful to help producers transform their current businesses into CE businesses, as well as providing the necessary knowledge to establish and implement CE business strategies for new producers seeking to enter the CE business, ultimately fostering the transition to a CE society. Indeed, as Ünal et al. (2019) highlighted, managerial directions that help companies accommodate the CE paradigm are needed to encourage CE businesses.

To address these issues, this paper seeks to investigate the CEBM design options currently reported in the EEE sector of Singapore and South Korea through a systematic review of peer-reviewed articles and gray literature. Using morphological analysis, this research aims to break down and understand the CEBM dimensions, finally charting the directions for future research pertaining to CEBM research in Singapore and South Korea. This study will provide information regarding CEBM design options on an industry basis and in Asia, helping producers and practitioners understand and compare the various CEBM design options for establishing and driving CE business plans in the EEE sector. In addition, the results can be used as a business modeling tool that encompasses the 'totality of CEBM design options' of the EEE industries in both countries. A research agenda and managerial implications

**Table 1**
Research design overview.

| | Phase 1:<br>Identify and review CEBM literature | Phase 2:<br>Extract and classify business model options | Phase 3:<br>Analyze the coded data with a morphological framework |
|---|---|---|---|
| **Objective** | Identification of CEBM literature<br>*(Data collection)* | Extraction of CEBM options<br>*(Data analysis)* | Development of morphological boxes<br>*(Data analysis)* |
| **Steps** | • Search scientific databases (i.e. Scopus and Web of Science) for articles on CEBMs<br>• Search for additional articles (i.e. gray literature) via Google engine, hand-search, including ProQuest, OATD, and EBSCO<br>• Systematically analyze and select articles using PRISMA | • Extract patterns, descriptions, and examples from original sources into one common database<br>• Two cycles of coding (i.e. holistic coding and pattern coding) | • Apply a morphological framework for analysis<br>• Develop morphological boxes for Singapore and South Korea |

will be also identified, therefore this study will make an important contribution by providing evidence to empirically study ongoing CE businesses in the EEE sector.

## 2. Methodology

A systematic literature review was conducted to identify publications offering EEE CEBM design options specific to Singapore and South Korea (Table 1). An extensive review protocol of tool selection criteria was established using PRISMA. The review focused on publications in the peer-reviewed literature (Scopus and Web of Science) and was complemented by gray literature such as government reports, books, theses, conference proceedings, company publications, and think-tank reports because of the relative immaturity of the field and interest of practitioners in Asia. Publications were identified using a combination of keywords related to the i) circular economy with ii) keywords related to CE business activities in the EEE sector, and iii) 36-specified CE keywords by Bocken et al. (2017). For example, “recycling” was a keyword for the case of Singapore using the Boolean combination of search words (“circular” OR “circular economy”) AND (“business” OR “business model”) AND (“recycle” OR “recycling” OR “recycled”) AND (“electronic” OR “electrical” OR “Electrical and Electronic Equipment” OR “EEE” OR “Waste Electrical and Electronic Equipment” OR “WEEE” OR “electronic waste” OR “e-waste”) AND (“Singapore”). In the same manner, the keyword searching for a total of thirty-six keywords identified by Bocken et al. (2017) was performed for both countries between January and May 2020 for the documents written in English. For a wider collection of data, documents written in Korean were also included for the South Korea study.

Then, the publications were screened and shortlisted in two review rounds to identify suitable literature in line with the scope and purpose of this study. The publication must be relevant to the circular economy or circular economy business models in the EEE sector of Singapore and South Korea, as well as address WEEE-related issues (e.g. efforts to reduce e-waste). To extract business model dimensions, the publication must contain a business case, story, or example (in a broad sense) that demonstrates how circular business practices work in the EEE sector. However, we did not apply exclusion criteria to the review, since we were interested in obtaining as a full range of data sets as possible. Table 2 summarizes the research protocol that was applied.

Following the morphological analysis proposed by Lüdeke-Freund et al. (2019a), we identified, extracted, classified, and structured business model dimensions through reviewing publications on circular economy business cases (Table 1). Morphological analysis is “a method for structuring and investigating the total set of relationships contained in multidimensional, usually non-quantifiable, problem complexes” (Ritchey, 2006, p. 792), thereby allowing researchers to conduct qualitative analyses of multidimensional objects in a business model. Our study concentrated on the generic business model dimensions and subcategories that Lüdeke-Freund et al. (2019a) used for their study:

- Value proposition: products, services
- Value delivery: target customers, value delivery processes
- Value creation: partners and stakeholders, value creation processes
- Value capture: revenues, costs

After identification, screening, and elimination of duplicates, sixty-seven publications for Singapore and fifty-two publications for South Korea were included in this study. Figs. 1 and 2 illustrate the flow diagram of the literature review process using PRISMA.

Shortlisted publications were analyzed and synthesized through two cycles of coding, holistic coding and pattern coding (Saldaña, 2013) to extract and classify the business model options from each publication (Phase 2), which were then coded and clas-

**Table 2**
Research protocol for Phase 1.

| Principle | Description |
|---|---|
| Databases | • Scopus<br>• Web of Science<br>• Gray literature (Government reports, books, theses, conference proceedings, company publications, and think-tank reports) including ProQuest, OATD, EBSCO database<br>• Advanced Google search |
| Keywords | • 37 circular economy-related keywords (Bocken et al., 2017) |
| Search equation | • Example of “Recycle” keyword for Singapore. (“circular” OR “circular economy”) AND (“business” OR “business model”) AND (“recycle” OR “recycling” OR “recycled”) AND (“electronic” OR “electrical” OR “Electrical and Electronic Equipment” OR “EEE” OR “Waste Electrical and Electronic Equipment” OR “WEEE” OR “electronic waste” OR “e-waste”) AND (“Singapore”) |
| Time period | • January 2010 – May 2020 |
| Procedure | 1) Screen titles and abstracts<br>2) Read introduction and conclusion sections<br>3) Review full articles<br>4) Selection made based on the criteria |
| Criteria | 1) The publication must be relevant to the circular economy or circular economy business models found in the EEE sector of Singapore and South Korea<br>2) The publication must address WEEE-related issues and contain a circular economy business case, story, or example (in a broad sense) in the EEE sector of Singapore and South Korea |

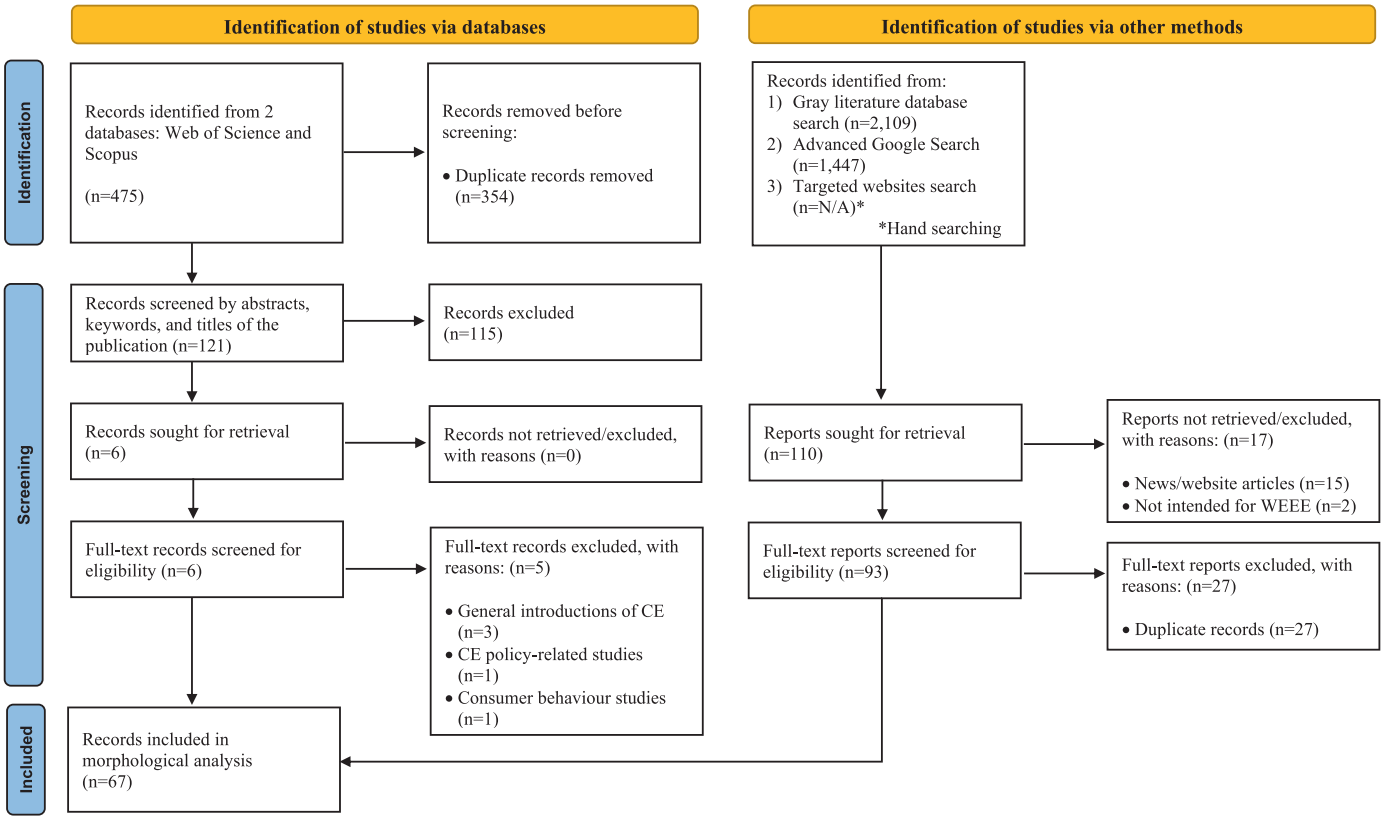



**Fig. 1.** The literature review process for Singapore adapted from the PRISMA principles (Page et al., 2021).

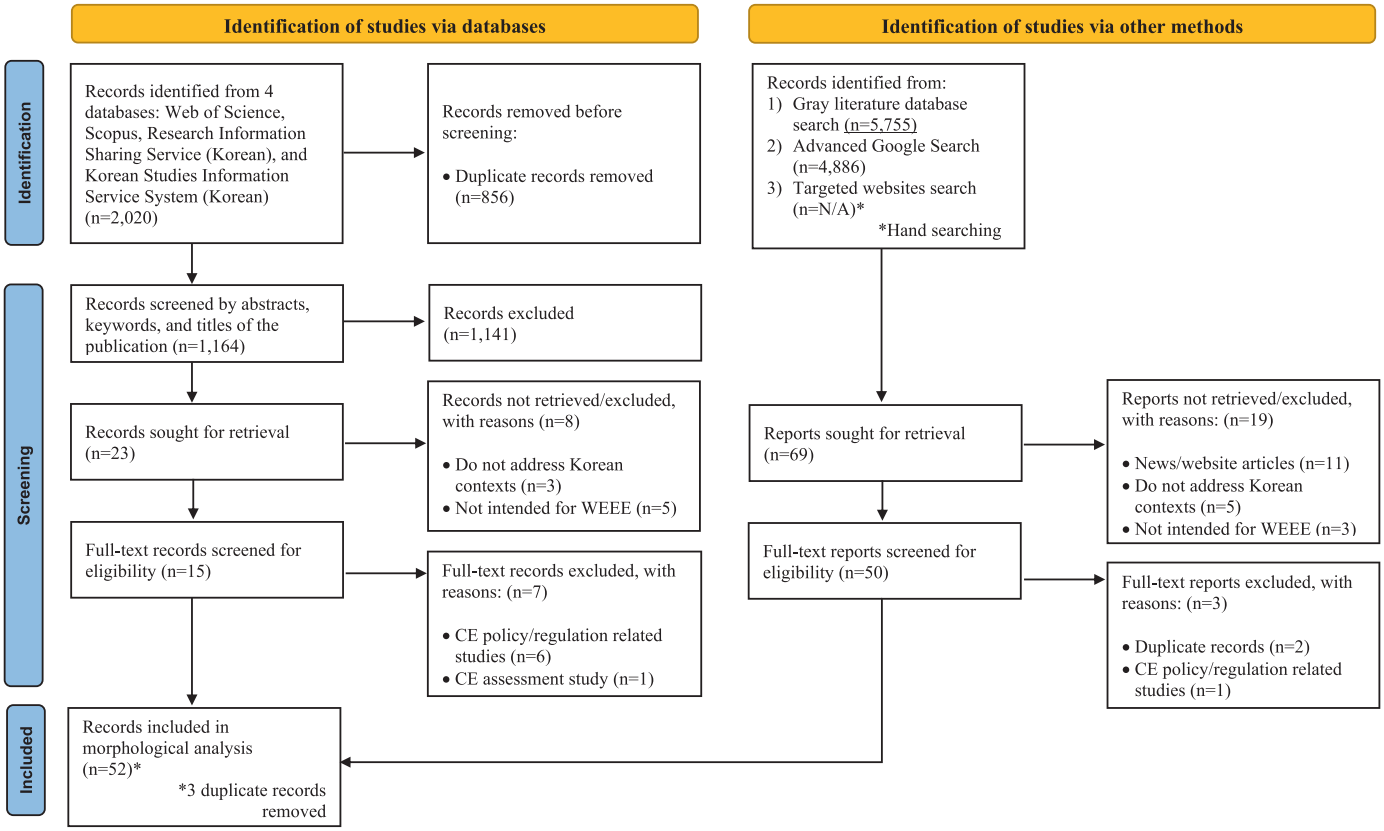



**Fig. 2.** The literature review process for South Korea adapted from the PRISMA principles (Page et al., 2021).

sified into the four business dimensions. The coded data was transferred to one common database file for rigorous qualitative data analysis, then the complied design options were restructured and represented in two morphological boxes for Singapore and South Korea respectively (Phase 3). Appendix A categorizes the different types of selected literature for Singapore and South Korea and tags the identifiers to each publication for morphological analysis to address the research questions: *"What are CEBM design options currently found in the EEE sector of Singapore and South Korea?"* and *"What directions should the future research take in CEBM studies in Singapore and South Korea?"*.

## 3. Findings

From the systematic literature review and pattern coding, this section reveals the value proposition (Appendix B), value delivery (Appendix C), value creation (Appendix D) and value capture (Appendix E) in terms of (a) products and services, (b) customers and value delivery processes, (c) stakeholders and processes, and (d) revenues versus costs, respectively. Taken together, we developed two morphological boxes that collectively represent the current variety of CEBM design options in Singapore and South Korea (Appendix F & G).

### 3.1. Value proposition

Five products and eight service options were identified in Singapore and seven products and ten service options in South Korea. The value proposition dimension revealed that, in both countries, there are an array of design options from recycled, refurbished, remanufactured products to repairing, maintenance, upgrading, warranty, to take-back services for customers (see Appendix B for the country break down).

The most common value proposition was the creation of durable or long-lasting products for customers, practiced mainly by global companies such as Apple, HP, and Electrolux in both countries. There were similar practices in local firms, for example, Coway in South Korea develops and applies its life test method, the so-called 'accelerated life test', to their product line for product durability. Hitachi Singapore requires its suppliers to procure raw materials and parts that must take into account the product durability, providing guidelines for their suppliers stipulating that they must procure durable raw materials and parts. It is noteworthy that modular products and Internet of Things (IoT)-based products have been reported in South Korea, suggesting that consumers now can configure or change product properties directly to suit their needs and emphasizing that producers should proactively acquire consumers' needs in the product design stage.

EEE producers in both countries provide customers with a variety of services to support their products, the most common being repair/maintenance services, and take-back/trade-in services. Several EEE multinational companies such as HP, ASUS, Electrolux, and Samsung Electronics aim for closed-loop material flow through recycling or remanufacturing of their products, implementing product take-back programs to collect EoL products from their customers. In Singapore, Electrolux, Fuji Xerox, Ricoh, Toshiba, and Canon regularly reach out to their customers through a range of workshops and talks to raise public awareness of their recycling programs.

Digital technology-based maintenance/monitoring and rental services in South Korea deserve special attention for sustainable consumption. For instance, Samsung Electronics' remote monitoring and repair system increases access to maintenance and repair services, enabling customers to use the products for a longer period of time. Also, LG Electronics provides a service in which sensors installed in their products send the product status to the cloud server in real-time to detect expected failures in advance, that is, a typical IoT-enabled predictive maintenance service (Schroeder et al., 2020) that combines cloud technology and sensor technology for maintenance optimization. Meanwhile, innovative local companies such as Coway, SK Magic, and Cuckoo Electronics have introduced a rental business model for customers to value the use rather than ownership. As a type of subscription economy, their rental services allow customers to continue to enjoy the value of their products over a long time with regular maintenance services provided by producers (Appendix B).

Regarding value proposition, the following findings across both countries stood out:

*Finding 1:* Durable, recycled, remanufactured, and refurbished products are being offered to consumers (e.g. SG-L35, SG-45, SG-L47, SG-L49, KR-L11, KR-L23, KR-L38, KR-L47). These traditional 3R (recycled, remanufactured, refurbished) products are generally determined and produced from the producers' perspective. This represents a supply-side push rather than a demand-side pull, although the needs of consumers have not been ascertained from the systematic review, suggesting that more should be done to consider the design of their products from the consumers' perspective.

*Finding 2:* Easy-to-repair product design and an abundance of repair/maintenance services were common. Producers in Singapore have offered a variety of community services such as workshops or talks to raise consumer awareness of circular economy activities (e.g. SG-L9, SG-L18, SG-L26, SG-L32, SG-L53, SG-L62), while producers in South Korea have focused on extending the life cycle of products through digital technology-based services that utilize IT technologies such as big data, cloud, and sensors (e.g. KR-L24, KR-L29, KR-L44, KR-L48). The focus on product life extension and product durability is relatively crucial in both countries.

### 3.2. Value delivery

The value delivery dimension revealed that there are three target customer groups (general consumer-centric, industry-centric, and industry and general consumers) and six value delivery process options (see Appendix C for the country break down), with comparable differences in the country's value delivery processes.

Producers in South Korea meet their consumers' needs through their product/service platforms, for example, Samsung Electronics provides a 24-hour online help desk for customer inquiries related to product repairs without time and space constraints. Similarly, local companies such as Osang healthcare, Coway, and i-river have service platforms through which they provide consultancy services for customers. Osang healthcare provides diagnosis and feedback services for customers on their health status using a service platform. Coway, which produces air purifiers and water purifiers, also provides consulting services tailored to consumers' needs through a dedicated mobile application platform. Interestingly, EEE producers focusing on rental services such as Coway, SK Magic, and Cuckoo Electronics contribute to significantly improving the value of rented products to customers through home visits and membership services.

Some cases of Singaporean producers that deliver unique value propositions through the provision of services are also worth noting. In those cases, they appear to be using digital technology-based solutions to provide a results-oriented service. Kaer, which provides air-conditioning, is a representative example of how the value of 'results-oriented service' can be delivered to customers. By focusing on agreed-upon results with customers, Kaer minimizes the resource intensity of its offerings over time (Konietzko et al., 2020). In addition, Kaer provides an artificial intelligence (AI)-

powered solution to perform real-time monitoring and maintenance tailored to the needs of customers, thereby helping reduce unnecessary energy wastage. This business model achieves greater energy efficiency while optimizing agreed-upon results with customers.

In terms of value delivery (Appendix C), the findings across both countries were as follows:

*Finding 3:* Producers in both countries largely set general consumer-centric, industry-centric, or industry and general consumers as target customer groups. This is a rather generic classification without deeper consideration of green consumers (e.g. De Silva et al., 2021) wanting to support CEBMs, such as delivering proposition to cost-, quality-, and environmentally-conscious consumers who want green products.

*Finding 4:* Producers in Singapore deliver value to customers primarily by mutually agreed-upon outcomes like integrated solutions, digital-based solutions, and further product certifications (e.g. SG-L37, SG-L52, SG-L67). They appear to be tailored-made solutions supporting CEBMs. South Korean producers mostly use their own product/service platforms to deliver value to their customers (e.g. KR-L24, KR-L29, KR-L44, KR-L48, KR-L49). There seems to be a greater personal approach in value delivery as some companies drive membership services and deliver them through home visitation in South Korea (e.g. KR-L12, KR-L37, KR-L41).

### 3.3. Value creation

The value creation dimension revealed that there are five stakeholder groups and nine value creation process options for Singapore, and five stakeholder groups and six value creation process options in South Korea (Appendix D). There was also a full spectrum of design options in both countries from local government, waste management companies, to suppliers on different value creation processes.

EEE producers in Singapore largely seek value creation through partnerships with waste management companies. Interestingly, competitors and government agencies come together in a value creation process in Singapore, with Brother, Canon, and Epson Singapore with the support of the National Environment Agency and National Library Board launching the joint-funded toner cartridge recycling initiative, Project Homecoming. Similarly, Panasonic Singapore and Electrolux Singapore formed joint initiatives with government agencies and other companies, respectively, to encourage a behavioral shift of consumers in Singapore. In South Korea, meanwhile, it has been reported that EEE producers use waste management companies as well as independent contractors as partners in value creation for CEBMs.

Regarding the value creation processes, similarities and differences exist between the two countries. Commonly, producers in both countries consider circular concepts such as recyclability, repairability, reusability, durability, and upgradability in the early stages of product design. In Singapore, value is created by increasing product recyclability and disassembly as many producers reported such initiatives, developing principles in recyclable design and manufacturing guidelines for developers and product managers, ultimately seeking materials efficiency. It was evident that companies such as Kaer, HP, Lexmark, Philips, and Ricoh Singapore, whose main business model is product-as-a-service, create value through optimization of bespoke solutions (e.g. SG-L38, SG-L42, SG-L63) agreed with customers, demonstrating how the value of a results-oriented service is created and delivered to customers.

Product value is also created through the application of circular design concepts in South Korea, but more so through digital capabilities, which provide the value proposition (service) and ease the value delivery (process). Producers that create value using digital capabilities such as LG Electronics, Osang healthcare, and Coway have two attributes: (1) they provide digital technology-based maintenance or monitoring service to their customers, and (2) use product or service online platforms to deliver value to consumers. Therefore, it can be concluded that the value delivery and creation processes are aligned and implemented according to the nature of the company's value proposition. Nonetheless, this implies that the three business model dimensions are closely connected. This exploration of the value creation dimension leads us to summarize the following:

*Finding 5:* Producers in both countries often use waste management companies as partners for value creation in their CEBMs. The value creation process through cooperation with the local government and like-minded competitors is evident in Singapore (e.g. SG-L8, SG-L9, SG-L18, SG-L20, SG-L48), while independent contractors are partners in the value creation process in South Korea (e.g. KR-L3, KR-L12, KR-L36, KR-L37, KR-L41).

*Finding 6:* Producers successfully create value by applying different circular concepts such as recyclability, repairability, reusability, durability, and upgradability in the design stage, developing and stipulating product design guidelines to ensure that relevant partners and stakeholders comply. In servitization, South Korean producers offering product-as-a-service primarily use digital capabilities to create value by providing consumers with digital technology-based maintenance/monitoring services (for value proposition) and product/service online platforms (for value delivery) (e.g. KR-L24, KR-L44, KR-L49).

### 3.4. Value capture

There were four revenue and four cost options in Singapore and three revenue and four cost options in South Korea to capture value, with little difference between the value capture logic of the producers in the two countries (see Appendix E for the country break down).

Rental or leasing fees act as a major revenue stream in South Korea's CEBMs. Subscription-based rental business models adopted by Coway, SK Magic, and Cuckoo Electronics can be classified as availability-based PSS, whereby consumers with membership periodically pay small amounts before purchase (Lewandowski, 2016). In Singapore, EEE producers such as Kaer, HP, Lexmark, Philips, and Ricoh generate revenue streams using payments per unit of service or payments for results. In addition, producers adopting a CEBM also generate revenue through sales of used products and more efficient product/service operations.

The cost streams for EEE producers are similar in both countries and categorized into product/service maintenance costs, processing costs for collected EoL materials, material input costs, and disposal costs. Producers reduced material input costs and waste disposal costs to some extent through CE activities, with recycled and reused parts contributing to cost savings. These findings are consistent with the findings of Lüdeke-Freund et al. (2019a) and Urbinati et al. (2017) and can be summarized as follows:

*Finding 7:* Producers in the two countries distinctly offer different value propositions and value delivery to consumers. While not exclusive, producers in Singapore generally charge payments by a unit of service or payments by results (e.g. SG-L32, SG-L41, SG-L42, SG-L51, SG-L63), while producers in South Korea by rent (e.g. KR-L37, KR-K41, KR-L43).

*Finding 8:* Producers in the two countries incur similar cost streams, generally categorized into product/service mainte-

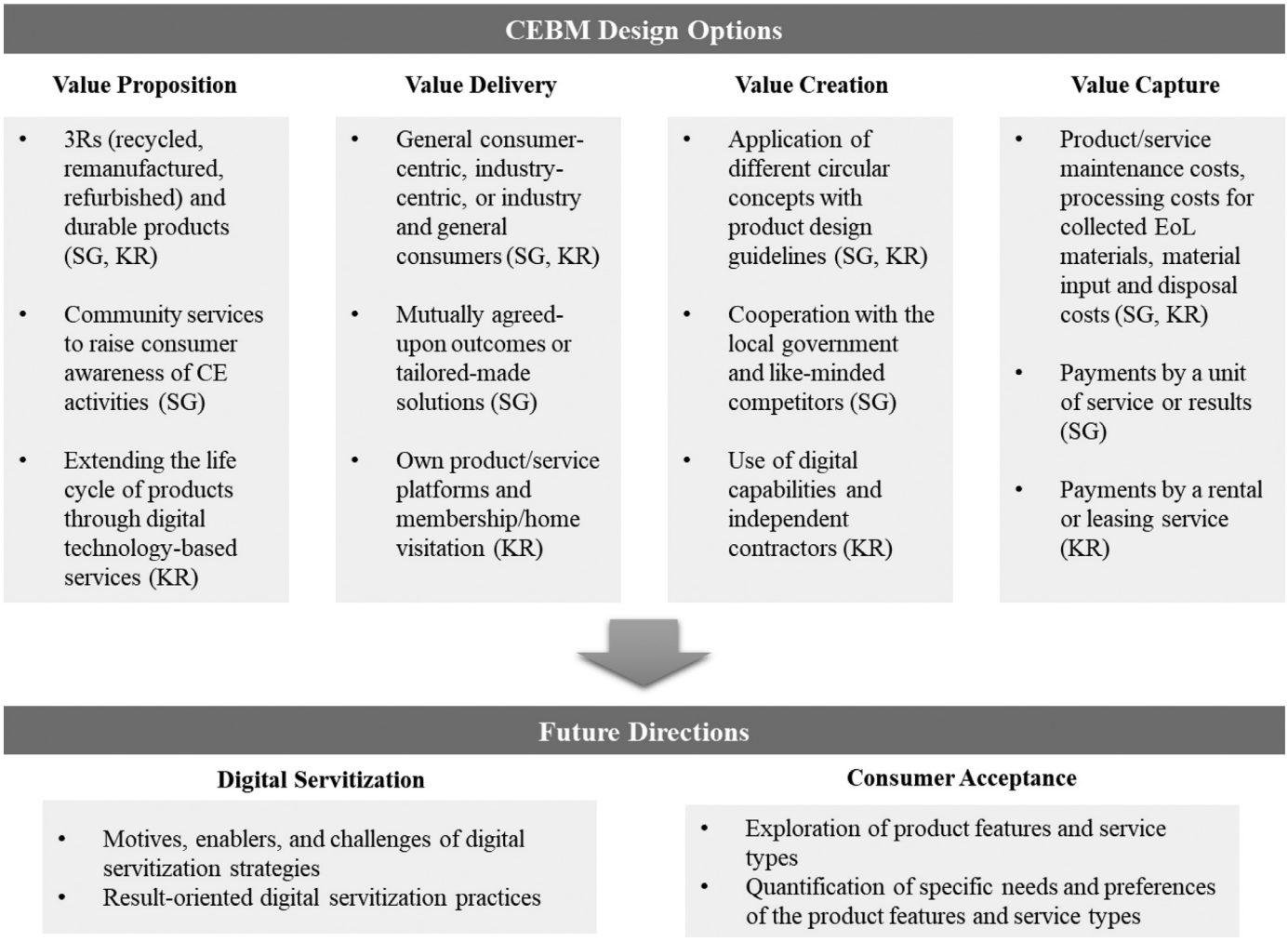



**Fig. 3.** Major findings and future directions.

nance costs, processing costs for collected EoL materials, material input costs, and disposal costs. Producers have reduced material input costs and waste disposal costs to some extent through CE activities.

## 4. Discussion and future directions

In CEBMs, we found value propositions included 3Rs and more durable products achieved through community awareness and digital capabilities. The investigation on value delivery revealed that consumer-centric, industry-centric, and a combination of both industry- and consumer-centric exist in both countries, with bespoke solutions, memberships, and PSS platforms delivering those values. Both countries have also successfully applied circular concepts to create value from the onset of product and service design. In Singapore, value is captured through unit of service, whereas rental or leasing is more common in South Korea. The findings of CEBM design options in Fig. 3, led us to suggest future research directions of digital servitization and consumer acceptance in Sections 4.1 and 4.2 respectively. The last section discusses the limitations of this study.

### *4.1. Digital servitization*

The evidence (Findings 2, 4, 6) has suggested that digital technologies such as big data, cloud, and remote sensors emerged in several design options in CEBMs. For example, 'Coway' in South Korea *(KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51)* and 'Kaer' in Singapore *(SG-L37, SG-L38, SG-L39, SG-L40, SG-L41)* have adopted a servitization strategy using digital technologies in their CEBM, an exemplary case of use-oriented and result-oriented digital servitization, respectively.

It is necessary to pay more attention to digital servitization in the EEE sector because servitization strategies overcome the limitations of product-centric offerings in many Korean small and medium-sized enterprises (Ha et al., 2016). Furthermore, Neely (2008) also found about 50% of Singaporean manufacturers were servitized firms in his survey of manufacturers in twenty-five countries.

Regarding small-medium enterprises, Coway focuses on leasing water purifiers and air purifiers, while Kaer supplies air-conditioning as a service in South Korea and Singapore. Coway provides home visit service and a membership program for regular maintenance of their products, and their 'Air Doctor' service provides efficient arrangement and use of air purifiers through computer simulation of air quality. Gathering sufficient consumer data on their utility (big data), Coway demonstrates how the use-oriented servitization model and digital technologies can be combined for a personal approach. In contrast, Kaer is a representative example of how the results-oriented offering can be delivered to consumers. Their air-conditioning-as-a-service provides 24/7 real-

time monitoring, control, and maintenance services tailored to the specific consumer requirements through a cloud-based platform. Both companies also offer an interactive user interface that can be accessed on a PC or smartphone by their consumers.

The use of information and communications technology (ICT) plays an important role in facilitating different types of circular business models and service innovation (Gago and Rubalcaba, 2007; Magrini et al., 2021). As the business environment becomes digitally oriented, producers can leverage digital technologies to establish digital servitization strategies that meet the bespoke needs of consumers. Digitally-enabled offerings, such as online monitoring, predictive maintenance, and product tracking allow new opportunities in maintenance, repair, and field operations in real-time (Coreynen et al., 2017). Digitalization can be implemented in the form of the confluence of the internet, wireless, predictive analytics, and cloud technologies (Muñoz-Villamizar et al., 2019), and digital technologies have enabled the industrial digital transformation toward digital servitization (Lerch and Gotsch, 2015; Kuah and Kim, 2021). Taken together, traditional producers can utilize digital technologies to create new digital services that target niche markets, thereby delivering new values to consumers.

However, little is known about the motives, enablers, or challenges of such digital servitization strategies in Singapore and South Korea. Most of our findings heavily relied on company publications containing fragmentary evidence, which hindered an in-depth understanding of digital servitization strategies, making the proliferation of the strategies difficult. Soft factors such as organizational culture and human resource management are essential to differentiate when implementing a service-oriented strategy (Homburg et al., 2003). Similarly, Tronvoll et al. (2020) also highlighted an agile mindset to create a collaborative organizational culture for the successful implementation of digital servitization. Bressanelli et al. (2021) concluded that "CE enablers have not been investigated in a systemic and holistic perspective so far: digital technologies are rarely investigated together" (Bressanelli et al., 2021, p. 12).

The arguments and findings suggest the need for research not only of the company's digitalization capabilities but overall organizational culture and capabilities required to benefit from digital servitization, including value chain, human resources, and customer relationship management, and so forth (Sánchez-Montesinos et al., 2018; Zheng et al., 2019). It is a widely held view that firms adopting servitization commonly encounter resistance due to cultural challenges. Organizational cultures—power distance, future orientation, and performance orientation—in manufacturing plants differ between Eastern and Western countries (Naor et al., 2010), implying that servitized firms located in Singapore and South Korea have been operating on a different mechanism than those in Western countries.

Although the servitization model in Asia is a promising business model for both B2B and B2C businesses (Temasek Foundation, 2019), it is still difficult to find evidence and the concomitant literature on how servitization in the Asia context has emerged and developed so far. The servitization cases of Asian manufacturers are not properly collected, and little is known about the types of services demanded by Asian consumers (Boehm and Thomas, 2013; Kim and Toya, 2019). It is noteworthy to point out that authors from Germany, the United Kingdom, Sweden, Netherlands, and Denmark strongly contributed to the servitization field, whereas less than 10% of the contributions came from Asia, as Boehm and Thomas (2013) highlighted in their systematic review study. In a similar vein, Kim and Toya (2019) evaluated their findings as valuable "in terms of understanding servitization not only in Japan but also in other Asian contexts (Kim and Toya, 2019, p. 347)" where servitization studies have rarely been conducted.

For a full picture of digital servitization in Singapore and South Korea, therefore, additional exploratory research or empirical research in a systemic and holistic perspective is needed. Given that most of the existing digital servitization strategies are still undertaken in a product-oriented or use-oriented manner, further work is required to comprehend result-oriented offerings such as the Kaer case (Bressanelli et al., 2021; Zheng et al., 2019).

### 4.2. Consumer acceptance

While digital technologies have expanded opportunities to offer customized value propositions to consumers based on improved service quality and deepened customer relationships (Rust and Huang, 2014), digital servitization creates closer producer-consumer relationships and facilitates a new type of interaction (Kamalaldin et al., 2020; Tronvoll et al., 2020). Our findings *(Finding 1, 2, 4, 6, 7)* support these arguments, as several producers offer value propositions such as predictive maintenance *(SG-L1, KR-L24, KR-L51, KR-L52),* real-time monitoring *(SG-L1, KR-L15, KR-L44, KR-L51, KR-L52),* online-based platforms *(SG-L52, KR-L12, KR-L44, KR-L48, KR-L49, KR-L50, KR-L51, KR-L52),* cloud systems *(KR-L15, KR-L24),* firmware upgrades *(SG-L55, KR-L11, KR-L29),* and IoT-based products *(KR-L44)* through various digital technologies.

It is important to bear in mind that servitization is a combination of product-service bundles to better meet consumers' needs (Vandermerwe and Rada, 1988; Tukker, 2004). CEBM models using servitization are dedicated to improving customers' value-in-use and seek to find the solutions that customers desire (Kowalkowski et al., 2017). Therefore, servitization strategies should offer a value proposition that responds to customers' needs (Baines et al., 2007), that is, servitization (or product-service system) strategies are mostly driven by customer needs. In the EEE sector, in particular, key factors that influence the applicability of servitization models, such as customer type, product type, service duration, and unit cost can be considered (Pollard et al., 2021).

As the range of EEE products is broad, encompassing different functions, features, and associated services, studies to identify the consumers' needs and preferences toward EEE products have been neglected (Atlason et al., 2017; Lieder et al., 2018). The value in a product or service perceived by customers has often been different from the value proposed by producers (Zhang and Banerji, 2017). Product-service design should first begin with consumers' needs and preferences but producers lack awareness (Sakao and Mizuyama, 2014), which can be a barrier not only to implement the servitization strategies but also to reduce e-waste. Product features and types of services that consumers require may differ for each EEE product, hence, research from the consumers' perspective is as important as research from the producers' perspective (Tunn et al., 2019). Since consumers have different consumption values (De Silva et al., 2021; Wang and Kuah, 2018), studies that attempt to identify solutions that consumers desire based on an understanding of consumer needs and consumption habits will have significant value for consumers acceptance of the product and service offerings.

Some studies (Atlason et al., 2017; Lieder et al., 2018) have attempted to identify consumer needs and preferences for the circular economy business, but these were conducted in European countries. Lieder et al. (2018)'s study in Sweden was conducted with a single washing machine item, whereas Atlason et al. (2017) quantified Danish consumer preference based on product features. Both studies assessed market acceptance of a product from a supply point of view, rather than the reasons behind consumer choice from a demand point of view.

Little is known about what needs and preferences Asian consumers have toward CEBMs and the corresponding value proposition design options. The value proposition is a decisive aspect of

**Table 3**
Research findings and potential research directions.

| Research Area | Key Findings | Research Agenda |
|---|---|---|
| 1. Digital servitization | Digital technologies such as big data, cloud, and remote sensors are common across CEBM design options *(Finding 2, 4, 6)*.<br>The motives, enablers, or challenges of digital servitization strategies adopted by Singaporean and South Korean producers are not well known.<br>Additional exploratory and empirical research for a fuller picture are needed for Asia. | 1. Identify the motives, enablers, and challenges of digital servitization strategies adopted by EEE producers in Singapore and South Korea (accounting for organizational culture and digitalization capabilities).<br>2. Investigate result-oriented digital servitization practices in the EEE sector in Singapore and South Korea. |
| 2. Consumer acceptance | Several producers have offered value propositions through digital technologies in attempting to fulfill consumer needs *(Finding 1, 2, 4, 6, 7)*.<br>Yet, it has not been confirmed that these value propositions are the offerings that satisfy the needs and requirements of consumers in Singapore and South Korea. | 3. Explore what product features and service types are desired by Singapore and South Korean consumers in using EEE products.<br>4. Quantify and prioritize specific needs and preferences of the product features and service types required by Singapore and South Korean consumers. |

a business model as it connects suppliers and consumers through products and services (Loock, 2012) but, overall, there has been a relative paucity of studies investigating what value propositions would be acceptable, especially from the Asian market perspective.

Sustainable production and responsible consumption play a crucial role in the transition to CE society (Camilleri, 2019). Producers need insights regarding consumers' preferences and purchasing needs to provide a more enhanced consumer experience (Urbinati et al., 2017) in a circular economy. Understanding the particulars of a certain consumer group will help producers design more effective servitization solutions. Therefore, we argue that efforts to understand the needs and preferences of consumers in Singapore and South Korea of EEE products will significantly contribute to EEE producers' sustainable servitization strategies in both countries. The CEBMs that consumers do not accept are hard to contribute to the transition to a CE society (Merli et al., 2018).

Based on the findings of this review and the discussions about the CEBM design options in the EEE sector in Singapore and South Korea, we propose four research agendas for advancing CEBM research in the EEE industries of Singapore and South Korea. The four agendas are: (1) identifying motives, enablers, and challenges of digital servitization strategies by EEE producers; (2) further examining result-oriented digital servitization practices; (3) exploring product features and service types desired by consumers; and lastly (4) quantifying and prioritizing the consumer needs and preferences. As seen in Table 3, these can be largely divided into digital servitization and consumer acceptance.

### 4.3. Limitations

Nonetheless, our study is not without limitations. First, our work is focused on the EEE sector, and hence implications may differ in other sectors. Secondly, given that our work relied heavily on secondary sources, where publications may not cover all real-life practices and cases under development, so additional in-depth case studies could further support our findings. Specifically, the exploration of case studies on CEBMs can bring us new opportunities. 'Thick descriptions' of case study research can show the interactions between the four business model dimensions more clearly beyond the limitations of fragmentary evidence. Most of the literature included in our study, however, was company publications, and case studies were only handful. While this can help us understand the individual dimensions themselves, it is difficult to provide an overview of how the dimensions work together in the context of a company's business model. Such efforts could eventually contribute to broadening practical knowledge of how companies can design and implement business models for circularity. Hence, we believe more empirical investigation will provide opportunities to shed light on the gaps between theory and practice.

## 5. Conclusion

This paper sheds valuable insights on CEBM practices in both countries and provides implications to key stakeholders. Our key findings show that Asian companies have incorporated the concept of a circular economy into their businesses in different ways. An interesting finding to emerge in Singapore is the number of result-oriented CEBMs focusing on mutually agreed-upon outcomes with customers. Due to the prevalence of product-oriented PSS type models, we did not anticipate that result-oriented cases to emerge prominently. Another notable finding highlighted that cooperation with local government, like-minded competitors, and community was important in the Singapore context. The findings that emerged from South Korea suggest that rental or leasing business models using the membership system and personalized home visiting service were rampant. Digital capabilities were utilized not only to create value but also to deliver value in many South Korean cases.

The implications for policymakers, practitioners, and producers are three folds. First, Asian businesses want to pursue CE models that seek consumers' cooperation and acceptance. This would certainly result in heightened efficiencies and reduced uncertainties. Second, in a country where its population places a higher value in relationships, then businesses must be mindful of developing a network of customer relationships including personalized and bespoke services even in the context of recycling and replacing household electronic products. Third, policymakers can play a pivotal role in encouraging CEBMs through incentive programs for businesses to engage in digital servitization. Government policies that support digital servitization integration with financial incentives may be the right way to motivate businesses to invest beyond their existing products.

Based on this review study, future research agenda lies in two areas. Firstly, the different ways in which consumers purchase CE products and services have not been considered as an important parameter in CEBM design to date. As a result, the needs and preferences of consumers in CEBM design options have been poorly identified and understood, especially in the Asian context where CEBMs are less explored. Second, further research on identifying producers' motives to integrate and benefit from digital servitization will be a huge benefit. More research can be expanded in result-oriented digital servitization, as well as identifying enablers for digital servitization as these areas are growing in importance.

## Declaration of Competing Interest

None.

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

## Appendices

### A. Selected Literature

*Appendix A. shows the selected literature for this study.*
Tables A1–A3.

**Table A1**
Selected literature by publication type.

| Publication type | No. of literature for analysis | |
|---|---|---|
| | Singapore | South Korea |
| Company publication | 54 | 37 |
| Government document | 6 | 3 |
| Think-tank report | 2 | 2 |
| Magazine article | 2 | 1 |
| Journal article | 1 | 3 |
| Dissertation | 1 | 6 |
| Book chapter | 1 | Nil |

**Table A2**
Selected literature by company (Singapore).

| No. | Title of document | Publication type |
|---|---|---|
| SG-L1. | ABB Sustainability Report 2019 | Company publication |
| SG-L2. | Apple Environmental Responsibility Report 2019 | Company publication |
| SG-L3. | Apple Material Impact Profiles 2019 | Company publication |
| SG-L4. | Apple's Paper and Packaging Strategy 2017 | Company publication |
| SG-L5. | Apple Supplier Responsibility – Progress Report 2020 | Company publication |
| SG-L6. | Bosch Sustainability Report Factbook 2019 | Company publication |
| SG-L7. | Brother CSR Report 2019 | Company publication |
| SG-L8. | Brother Environmental Activity Report 2019 | Company publication |
| SG-L9. | Canon Sustainability Report 2019 | Company publication |
| SG-L10. | Canon - Remanufacturing in the Circular Economy: Operations, Engineering, and Logistics | Book chapter |
| SG-L11. | Dell Corporate Social Responsibility Report 2019 | Company publication |
| SG-L12. | Dell Design for Environment – White Paper 2018 | Company publication |
| SG-L13. | Dell Electronics Disposition Partner Performance Standard 2019 | Company publication |
| SG-L14. | Dell Electronics Disposition Policy 2019 | Company publication |
| SG-L15. | Dell on the Circular Economy Position Paper 2016 | Company publication |
| SG-L16. | Dell's Producer Responsibility Policy 2018 | Company publication |
| SG-L17. | Electrolux Position Statement – Recycling of Products 2016 | Company publication |
| SG-L18. | Electrolux – Sharing Initiatives and the Sharing Landscape in Singapore | Think-tank report |
| SG-L19. | Electrolux Sustainability Report 2019 | Company publication |
| SG-L20. | Epson Sustainability Report 2019 | Company publication |
| SG-L21. | Epson The Eco Declaration 2012 | Company publication |
| SG-L22. | Ericsson Business Partner Environmental Requirements 2019 | Company publication |
| SG-L23. | Ericsson – Sustainable Business Awards Singapore 2019 | Government document |
| SG-L24. | Ericsson Sustainable and Corporate Responsibility Report 2019 | Company publication |
| SG-L25. | Fuji Xerox Integrated Recycling System – Efforts on Product Recycle 2016 | Company publication |
| SG-L26. | Fuji Xerox Singapore Sustainability Report 2016–2017 | Company publication |
| SG-L27. | Hitachi Green Procurement Guidelines 2020 | Company publication |
| SG-L28. | Hitachi Sustainability Report 2019 | Company publication |
| SG-L29. | HP Recover and Renew Services 2019 | Company publication |
| SG-L30. | HP Recycling Resources 2019 | Company publication |
| SG-L31. | HP Supply Chain Responsibility 2016 | Company publication |
| SG-L32. | HP Sustainable Impact Report 2018 | Company publication |
| SG-L33. | HP Enterprise Circular Economy Report 2018 | Company publication |
| SG-L34. | HP Enterprise Design for the Circular Economy – Solution Brief 2018 | Company publication |
| SG-L35. | HP Enterprise Living Progress Report 2018 | Company publication |
| SG-L36. | HP Enterprise - Reduces e-Waste with Circular Economy Initiative | Think-tank report |
| SG-L37. | Kaer – Cool New Solutions | Government document |
| SG-L38. | Kaer Air at INSEAD Business School | Company publication |
| SG-L39. | Kaer Better Air for Better Spaces | Company publication |
| SG-L40. | Kaer – Upgrading a 40-year old landmark and making it energy efficient | Magazine article |
| SG-L41. | Kaer White Paper | Company publication |
| SG-L42. | Lexmark Corporate Social Responsibility Report 2018 | Company publication |
| SG-L43. | LG Electronics Environmental Report 2012 | Company publication |
| SG-L44. | LG Electronics Sustainability Report 2018–2019 | Company publication |
| SG-L45. | Miele Sustainability Report 2019 | Company publication |
| SG-L46. | Miele Value Chain 2019 | Company publication |
| SG-L47. | Mitsubishi Electric Group CSR Report 2019 | Company publication |
| SG-L48. | Panasonic Sustainability Data Book 2019 | Company publication |

(*continued on next page*)

**Table A2** (*continued*)

| No. | Title of document | Publication type |
|---|---|---|
| SG-L49. | Philips Refurbishing Solutions for MRI System, 2014 | Company publication |
| SG-L50. | Philips - Succeeding in Specialty Independent Care | Magazine article |
| SG-L51. | Philips Rethinking the Future: Our Transition towards a Circular Economy 2014 | Company publication |
| SG-L52. | RESQ – Tackling the Waste Crisis in Singapore and Asia-Pacific: A Role for Business in Advancing the Circular Economy | Government document |
| SG-L53. | Ricoh Eco Action Day 2019 – Sustainable Waste Management in the Year Towards Zero Waste | Company publication |
| SG-L54. | Ricoh Integrated Report 2019 | Company publication |
| SG-L55. | Samsung Sustainability Report 2019 | Company publication |
| SG-L56. | Schneider Electric Sustainability Report 2018–2019 | Company publication |
| SG-L57. | Schneider Electric Sustainability — The New Critical Success Factor | Company publication |
| SG-L58. | Schneider Electric Electrical Distribution Field Services 2018 | Company publication |
| SG-L59. | Toshiba Environmental Report 2019 | Company publication |
| SG-L60. | Toshiba Data Dynamics Carbon Balance Programme | Company publication |
| SG-L61. | Toshiba Tec Group Integrated Report 2019 | Company publication |
| SG-L62. | Toshiba Tec Singapore Site Report 2019 | Company publication |
| SG-L63. | National Environment Agency - 3R Guidebook for Offices | Government document |
| SG-L64. | National Environment Agency - Celebrating 10 Years of Industry Government Collaboration in Reducing Packaging Waste | Government document |
| SG-L65. | National Environment Agency – CleanEnviro Summit Singapore 2014–2015 | Government document |
| SG-L66. | The Generation, Impact, and Management of E-Waste: State of the Art | Journal article |
| SG-L67. | 'Waste', Value and Informal Labour: The Regional E-Waste Recycling Production Network in Malaysia and Singapore | Dissertation |

**Table A3**
Selected literature by company (South Korea).

| No. | Title of document | Publication Type |
|---|---|---|
| KR-L1. | Hyundai Electric (HHI Group Integrated Report 2019) | Company publication |
| KR-L2. | Hyundai Electric Integrated Report 2020 | Company publication |
| KR-L3. | LS Electric Sustainability Report 2018–2019 | Company publication |
| KR-L4. | Samwha Electric – Samwha Products Guide | Company publication |
| KR-L5. | Environmental design within the Korean electronics industry – With particular reference to handheld devices | Dissertation |
| KR-L6. | Green Transformation of Small Businesses - Achieving and Going Beyond Environmental Requirements | Government document |
| KR-L7. | Apple Environmental Responsibility Report 2019 | Company publication |
| KR-L8. | Apple Material Impact Profiles 2019 | Company publication |
| KR-L9. | Apple's Paper and Packaging Strategy 2017 | Company publication |
| KR-L10. | Apple Supplier Responsibility – Progress Report 2020 | Company publication |
| KR-L11. | ASUS 2019 Corporate Social Responsibility Report | Company publication |
| KR-L12. | Coway 2019 Sustainability Report | Company publication |
| KR-L13. | Electrolux Position Statement – Recycling of Products 2016 | Company publication |
| KR-L14. | Electrolux Sustainability Report 2019 | Company publication |
| KR-L15. | Fuji Xerox Korea Sustainability Report 2017 | Company publication |
| KR-L16. | Heidelberger Druckmaschinen Sustainability Report 2011/2012 | Company publication |
| KR-L17. | HP Recover and Renew Services 2019 | Company publication |
| KR-L18. | HP Recycling Resources 2019 | Company publication |
| KR-L19. | HP Supply Chain Responsibility 2016 | Company publication |
| KR-L20. | HP Sustainable Impact Report 2018 | Company publication |
| KR-L21. | HP Enterprise Circular Economy Report 2018 | Company publication |
| KR-L22. | HP Enterprise Design for the Circular Economy – Solution Brief 2018 | Company publication |
| KR-L23. | HP Enterprise Living Progress Report 2018 | Company publication |
| KR-L24. | LG Electronics 2019–2020 Sustainability Report | Company publication |
| KR-L25. | LG Electronics 2012 Environmental Report | Company publication |
| KR-L26. | Philips Refurbishing Solutions for MRI System, 2014 | Company publication |
| KR-L27. | Philips - Succeeding in Specialty Independent Care | Magazine article |
| KR-L28. | Philips Rethinking the Future: Our Transition towards a Circular Economy 2014 | Company publication |
| KR-L29. | Samsung Electronics 2020 Sustainability Report | Company publication |
| KR-L30. | Samsung Electronics Regional WEEE Take-back Scheme 2019 | Company publication |
| KR-L31. | Green Samsung 2017 | Company publication |
| KR-L32. | Schneider Electric Sustainability Report 2018–2019 | Company publication |
| KR-L33. | Schneider Electric Sustainability — The New Critical Success Factor | Company publication |
| KR-L34. | Schneider Electric Electrical Distribution Field Services 2018 | Company publication |
| KR-L35. | Siemens Sustainability Information 2019 | Company publication |
| KR-L36. | Sindoh Richo Korea Business Report 2018 | Company publication |
| KR-L37. | SK Networks (SK Magic) Sustainability Report 2019 | Company publication |
| KR-L38. | SONY Sustainability Report 2019 | Company publication |
| KR-L39. | SONY Eco Product History | Company publication |
| KR-L40. | SONY 2019 Eco Leaflet | Company publication |
| KR-L41. | A Study on the Corporate Philosophy and Management Strategic of CUCKOO GU BONHAK | Journal article |
| KR-L42. | A Strategical Review on Reverse Logistics Promotion of Electronic Company | Journal article |

(*continued on next page*)

**Table A3** (*continued*)

| No. | Title of document | Publication Type |
|---|---|---|
| KR-L43. | A Study on a Servitization Model Based on Competitive Advantage Strategy, Objective, and Type of PSS | Journal article |
| KR-L44. | Revitalization Plan for Servitization for Innovation in Manufacturing Industry | Think-tank report |
| KR-L45. | Current Trends and Policy Directions of Remanufacturing Industry | Government document |
| KR-L46. | A Study on Servitization Promotion Strategy of Korean Manufacturing Industry | Think-tank report |
| KR-L47. | Repair and Remanufacturing Industry Promotion Strategies of Gyeonggi-Do | Government document |
| KR-L48. | Servitization of Korea Manufacturing firms: Empirical Analysis of firms listed on KOSPI and KOSDAQ | Dissertation |
| KR-L49. | Servitization Process Analysis Based on Manufacturing Servitization Case | Dissertation |
| KR-L50. | A Study on the Collaborative Network for the Servitization | Dissertation |
| KR-L51. | A Study on the Typology of PSS (Product-Service system) based on Competitive Advantage Strategy | Dissertation |
| KR-L52. | Servitization of Manufacturing Companies: Business Ecosystem Perspective | Dissertation |

## *B. Pattern Coding Results for Value Proposition*

*Appendix B. shows the pattern coding results for value proposition of this study.* Tables B1 and B2.

**Table B1**
[Singapore].

| BM Dimensions | | CEBM design options found in Singapore | Cases |
|---|---|---|---|
| **Value Proposition** | ***Products*** | Easy-to-repair products | HP (SG-L32) |
| | | Durable products | Apple (SG-L2, SG-L3), Bosch (SG-L6), Electrolux (SG-L17), Hitachi (SG-L27, SG-L28), HP (SG-L32), Miele (SG-L45), |
| | | Recyclable products | ABB (SG-L1), Mitsubishi Electric (SG-L47), Schneider Electric (SG-L57) |
| | | Refurbished products | Philips (SG-L49) |
| | | Remanufactured products | HP Enterprise (SG-L35) |
| | ***Services*** | Community initiative to increase consumer awareness | Canon (SG-L9), Electrolux (SG-L18, SG-L19), Fuji Xerox (SG-L26), HP (SG-L32), Ricoh (SG-L53, SG-L63), Toshiba (SG-L62) |
| | | Extended warranty | Electrolux (SG-L19), LG Electronics (SG-L43), Miele (SG-L45), Philips (SG-L49), Samsung Electronics (SG-L55) |
| | | Digital technology-based maintenance/monitoring | ABB (SG-L1), Fuji Xerox (SG-L26), Kaer (SG-L37, SG-L41), LG Electronics (SG-L44), Ricoh (SG-L54), Samsung Electronics (SG-L55) |
| | | Product as a service | HP (SG-L32), Kaer (SG-L37, SG-L38, SG-L41), Lexmark (SG-L42), Philips (SG-L51), Ricoh (SG-L63) |
| | | Repair / Maintenance | Apple (SG-L2), Bosch (SG-L6), Brother (SG-L7), Epson (SG-L20), Hitachi (SG-L28), HP (SG-L32), Miele (SG-L45), Mitsubishi (SG-L47), Panasonic (SG-L48), Philips (SG-L51), Schneider Electric (SG-L58) |
| | | Take-back / Trade-in | Apple (SG-L2), Bosch (SG-L6), Brother (SG-L8), Canon (SG-L9), Dell (SG-L12, SG-L13, SG-L14, SG-L15), Electrolux (SG-L17), Ericsson (SG-L23, SG-L24, SG-L65), HP (SG-L32), HP Enterprise (SG-L34, SG-L35), Lexmark (SG-L42), LG Electronics (SG-L43, SG-L44), Samsung Electronics (SG-L55), Toshiba (SG-L64), Anonymous company (SG-L56, L66) |
| | | Upgrading / Updating / Upcycling | Electrolux (SG-L17), HP (SG-L32), HP Enterprise (SG-L35), Miele (SG-L45), Samsung Electronics (SG-L55) |
| | | Others | Philips (SG-L50, SG-L51), RESQ (SG-L52), Anonymous company (SG-L66) |

**Table B2**
[South Korea].

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| **Value Proposition** | ***Products*** | Easy-to-repair products | HP (KR-L20) |
| | | Durable products | LS Electric (KR-L3), Apple (KR-L7, KR-L8), Coway (KR-L12, KR-L43), Electrolux (KR-L13), HP (KR-L20), SONY (KR-L38, KR-L39) |
| | | Recyclable / Reusable products | Coway (KR-L12, KR-L51), Schneider Electric (KR-L33), Siemens (KR-L35) |
| | | Refurbished products | ASUS (KR-L11), Coway (KR-L12, KR-L47), Philips (KR-L26) |
| | | Remanufactured products | HP Enterprise (KR-L23), Coway (KR-L45) |
| | | IoT-based products | Philips (KR-L44) |
| | | Modular products | Samsung Electronics (KR-L29) |
| | ***Services*** | Community initiative to increase consumer awareness | Electrolux (KR-L14), SK Magic (KR-L37), SONY (KR-L38, KR-L40) |
| | | Consultancy | Coway (KR-L12), Osang healthcare (KR-L44), Anonymous company E (KR-L49), Anonymous company F (KR-L49), Heidelberger (KR-L51), Fuji Xerox (KR-L51), Electrolux (KR-L52) |
| | | Digital technology-based maintenance / monitoring | Fuji Xerox (KR-L15), LG Electronics (KR-L24), Samsung Electronics (KR-L29, KR-L46), Osang healthcare (KR-L44), Siemens (KR-L44), i-river (KR-L48), Heidelberger (KR-L51), GE (KR-L50, KR-L52) |

(*continued on next page*)

**Table B2** (*continued*)

| BM Dimensions | CEBM design options found in South Korea | Cases |
|---|---|---|
| | Extended warranty | Electrolux (KR-L14), Philips (KR-L26), Samsung Electronics (KR-L29) |
| | Product as a service | ASUS (KR-L11), Fuji Xerox (KR-L15), HP (KR-L20), Philips (KR-L28), Electrolux (KR-L44) |
| | Rental / Leasing service | ASUS (KR-L11), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), SK Magic (KR-L37), Cuckoo Electronics (KR-L41), Electrolux (KR-L44) |
| | Repair / Maintenance | Samwha Electric (KR-L4), Apple (KR-L7), ASUS (KR-L11), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), HP (KR-L20), LG Electronics (KR-L24), Philips (KR-L28), Samsung Electronics (KR-L29, KR-L48), Schneider Electric (KR-L34), SONY (KR-L38), Cuckoo Electronics (KR-L41), Siemens (KR-L44), Sindoh richo (KR-L48), i-river (KR-L48), Heidelberger (KR-L51), Electrolux (KR-L44, KR-L52), GE (KR-L52) |
| | Take-back / Trade-in | Apple (KR-L7), ASUS (KR-L11), Electrolux (KR-L13), HP (KR-L20), HP Enterprise (KR-L22, KR-L23), Samsung Electronics (KR-L30), Schneider Electric (KR-L32), Siemens (KR-L35), SONY (KR-L38) |
| | Upgrading / Updating / Upcycling | ASUS (KR-L11), Electrolux (KR-L13), HP (KR-L20), HP Enterprise (KR-L23), Samsung Electronics (KR-L29), SONY (KR-L38) |
| | Others | Philips (KR-L27, KR-L28) |

## C. Pattern Coding Results for Value Delivery

*Appendix C. shows the pattern coding results for value delivery of this study.* Tables C1 and C2.

**Table C1**
[Singapore].

| BM Dimensions | | CEBM design options found in Singapore | Cases |
|---|---|---|---|
| **Value Delivery** | ***Target customers*** | General consumers-centric | Apple (SG-L2), Brother (SG-L7, SG-L8), Canon (SG-L9), Electrolux (SG-L17, SG-L19), Epson (SG-L20), LG Electronics (SG-L44), Miele (SG-L45) Mitsubishi (SG-L47), Samsung Electronics (SG-L55) |
| | | Industry-centric | ABB (SG-L1), Bosch (SG-L6), Ericsson (SG-L24), HP Enterprise (SG-L35), Kaer (SG-L41), RESQ (SG-L52), Schneider Electric (SG-L56), Toshiba (SG-L59, SG-L61, SG-L64) |
| | | Industry and general consumers | Dell (SG-L11), Fuji Xerox (SG-L26), Hitachi (SG-L28), HP (SG-L32), Lexmark (SG-L42), Panasonic (SG-L48), Philips (SG-L51), Ricoh (SG-L54). |
| | ***Value delivery processes*** | Offering long-lasting products | Miele (SG-L45, SG-L46) |
| | | Digital technology-based solutions | ABB (SG-L1), Electrolux (SG-L17), HP (SG-L32), Kaer (SG-L37), Lexmark (SG-L42), Philips (SG-L51), RESQ (SG-L52), Schneider Electric (SG-L56), Ricoh (SG-L63) |
| | | Lifecycle / Integrated solutions | HP Enterprise (SG-L35), Kaer (SG-L37, SG-L39), Lexmark (SG-L42), Schneider Electric (SG-L56, SG-L58) |
| | | Specific results and corresponding services (Results-oriented services) | HP (SG-L32), Kaer (SG-L37, SG-L39, SG-L41), Lexmark (SG-L42), Philips (SG-L51), Ricoh (SG-L63) |
| | | Own labeling / certification | Schneider Electric (SG-L56), Anonymous company (SG-L67) |
| | | Others | Philips (SG-L51), RESQ (SG-L52) |

**Table C2**
[South Korea].

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| **Value Delivery** | ***Target customers*** | General consumers-centric | Samsung Electronics (KR-L5), Apple (KR-L7, KR-L50, KR-L51, KR-L52), ASUS (KR-L11), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), Electrolux (KR-L13, KR-L14, KR-L52), LG Electronics (KR-L24, KR-L42), Samsung Electronics (KR-L29, KR-L42, KR-L46, KR-L48), SK Magic (KR-L37), SONY (KR-L38), Cuckoo Electronics (KR-L41), Osang healthcare (KR-L44), Electrolux (KR-L44), i-river (KR-L48) |
| | | Industry-centric | Hyundai Electric (KR-L1, KR-L2) LS Electric (KR-L3), Samwha Electric (KR-L4), Heidelberger (KR-L16, KR-L51), HP Enterprise (KR-L23), Philips (KR-L26), Schneider Electric (KR-L32) |
| | | Industry and general consumers | Fuji Xerox (KR-L15, KR-L51), HP (KR-L20, KR-L46), Philips (KR-L28, KR-L44), Siemens (KR-L35, KR-L44), Sindoh Richo (KR-L36, KR-L48), GE (KR-L50, KR-L52) |

(*continued on next page*)

**Table C2** (*continued*)

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| | ***Value delivery processes*** | Product / Service platforms | Coway (KR-L12), Fuji Xerox (KR-L15), LG Electronics (KR-L24), Samsung Electronics (KR-L29), Schneider Electric (KR-L32), Osang healthcare (KR-L44), Philips (KR-L44), Siemens (KR-L44), i-river (KR-L48), Anonymous company B (KR-L49) Anonymous company F (KR-L49), GE (KR-L50), Apple (KR-L50, KR-L51, KR-L52) |
| | | Home visiting service | Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), SK Magic (KR-L37), Cuckoo Electronics (KR-L41) |
| | | Providing a membership | Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), SK Magic (KR-L37), Cuckoo Electronics (KR-L41) |
| | | Lifecycle / Integrated solutions | ASUS (KR-L11), Fuji Xerox (KR-L15), HP Enterprise (KR-L23), Schneider Electric (KR-L32, KR-L34, KR-L44), Sindoh Richo (KR-L48), Heidelberger (KR-L51), Apple (KR-L52) |
| | | Specific results or functionalities | Fuji Xerox (KR-L15), HP (KR-L20), Philips (KR-L28), Sindoh Richo (KR-L48) |
| | | Others | Electrolux (KR-L13, KR-L52), Schneider Electric (KR-L32), |

## *D. Pattern Coding Results for Value Creation*

*Appendix D. shows the pattern coding results for value creation of this study.* Tables D1 and D2.

**Table D1**
[Singapore].

| BM Dimensions | | CEBM design options found in Singapore | Cases |
|---|---|---|---|
| **Value Creation** | ***Partners and Stakeholders*** | Local government | Brother (SG-L8), Canon (SG-L9), Electrolux (SG-L18), Epson (SG-L20), Panasonic (SG-L48) |
| | | Other companies in the same industry | Brother (SG-L8), Canon (SG-L9), Electrolux (SG-L18), Epson (SG-L20), Panasonic (SG-L48) |
| | | Suppliers | Apple (SG-L2, SG-L5), Mitsubishi (SG-L47) |
| | | Waste management companies | ABB (SG-L1), Dell (SG-L11), Electrolux (SG-L19), HP (SG-L30), Lexmark (SG-L42), LG Electronics (SG-L43, SG-L44), Miele (SG-L45), Samsung Electronics (SG-L55), Toshiba (SG-L60, SG-L64) |
| | | Others | Dell (SG-L16), HP Enterprise (SG-L36) |
| | ***Value creation processes*** | Designing with durability | Apple (SG-L2), Ericsson (SG-L24), HP (SG-L32), HP Enterprise (SG-L34), Miele (SG-L45), Schneider Electric (SG-L56) |
| | | Increase of recyclability and disassembly of products | Bosch (SG-L6), Brother (SG-L8), Dell (SG-L12, SG-L15), Epson (SG-L20), Ericsson (SG-L24), Fuji Xerox (SG-L25), HP Enterprise (SG-L34, SG-L35), Lexmark (SG-L42), LG Electronics (SG-L43, SG-L44), Miele (SG-L45, SG-L46), Mitsubishi (SG-L47), Ricoh (SG-L54), Samsung Electronics (SG-L55) |
| | | Maintaining or repairing products, components | Bosch (SG-L6), Dell (SG-L14, SG-L15), Kaer (SG-L37) |
| | | Optimizing specific outcomes | HP (SG-L32), Kaer (SG-L38), Lexmark (SG-L42), Philips (SG-L51), Ricoh (SG-L63) |
| | | Recycling, refurbishing or remanufacturing products, components | Bosch (SG-L6), Canon (SG-L9), Dell (SG-L14, SG-L15), Fuji Xerox (SG-L25), HP (SG-L29, SG-L32), HP Enterprise (SG-L33, SG-L35), Philips (SG-L50) |
| | | Upgrading or upcycling products, components (Design for upgradeability) | Dell (SG-L12), Ericsson (SG-L24), HP Enterprise (SG-L35, SG-L36), Philips (SG-L49), Schneider Electric (SG-L56) |
| | | Use of advanced technologies | ABB (SG-L1), Kaer (SG-L37), RESQ (SG-L52), Anonymous company (SG-L67) |
| | | Using used products, components, materials as input | Canon (SG-L9), Dell (SG-L14, SG-L15), HP (SG-L29), Lexmark (SG-L42), Mitsubishi (SG-L47) |
| | | Designing to enable easy-repair | Dell (SG-L12, SG-L15), Ericsson (SG-L24), HP (SG-L32), HP Enterprise (SG-L35), Miele (SG-L45, SG-L46), Samsung Electronics (SG-L55) |

**Table D2**
[South Korea].

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| **Value Creation** | ***Partners and Stakeholders*** | Collaboration with other industries | Apple (KR-L50) |
| | | Local government or NGOs | ASUS (KR-L11), LG Electronics (KR-L42) |
| | | Suppliers | Apple (KR-L7, KR-L10), ASUS (KR-L11) |

(*continued on next page*)

**Table D2** (*continued*)

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| | | Waste management companies | Electrolux (KR-L14), HP (KR-L18), SONY (KR-L38), Samsung Electronics (KR-L42), LG Electronics (KR-L42) |
| | | Independent contractors | LS Electric (KR-L3), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), Sindoh Richo (KR-L36), SK Magic (KR-L37), Cuckoo Electronics (KR-L41) |
| | ***Value creation processes*** | Designing with circular concepts in general (reusability, easy-dismantling, upgradability etc.) | Hyundai Electric (KR-L2), Apple (KR-L7), ASUS (KR-L11), HP (KR-L20), HP Enterprise (KR-L23), LG Electronics (KR-L25), Philips (KR-L26), Samsung Electronics (KR-L29), Schneider Electric (KR-L32), Siemens (KR-L35), Sindoh Richo (KR-L36), Coway (KR-L43, KR-L51) |
| | | Digital capabilities | LG Electronics (KR-L24), Osang healthcare (KR-L44), Siemens (KR-L44), Anonymous company B (KR-L49), Anonymous company E (KR-L49), Anonymous company F (KR-L49), GE (KR-L50), Heidelberger (KR-L51) |
| | | Increase of recyclability | Samwha Electric (KR-L4), ASUS (KR-L11), HP Enterprise (KR-L22, KR-L23), LG Electronics (KR-L25), Samsung Electronics (KR-L29), SONY (KR-L38) |
| | | Optimizing specific outcomes | Fuji Xerox (KR-L15, KR-L51), HP (KR-L20), Philips (KR-L28), Sindoh Richo (KR-L48), Heidelberger (KR-L51) |
| | | Refurbishing/remanufacturing/ recycling of products and components | ASUS (KR-L11), Coway (KR-L12, KR-L45, KR-L47), HP (KR-L17, KR-L20), HP Enterprise (KR-L21, KR-L23), Philips (KR-L27), Samsung Electronics (KR-L29) |
| | | Development of initiatives/programs/materials | Anonymous company (KR-L6), ASUS (KR-L11), Samsung Electronics (KR-L29), Sindoh Richo (KR-L36), SONY (KR-L38, KR-L40) |

## *E. Pattern Coding Results for Value Capture*

*Appendix E. shows the pattern coding results for value capture of this study.*
Tables E1 and E2.

**Table E1**
[Singapore].

| BM Dimensions | | CEBM design options found in Singapore | Cases |
|---|---|---|---|
| **Value Capture** | ***Revenues*** | Leasing/subscription fee | RESQ (SG-L52), Anonymous company (SG-L66) |
| | | Payments per use/results | HP (SG-L32), Kaer (SG-L37, SG-L38, SG-L39, SG-L40, SG-L41), Lexmark (SG-L42), Philips (SG-L51), Ricoh (SG-L63) |
| | | Resource efficiency-related solutions | ABB (SG-L1), Bosch (SG-L6), HP Enterprise (SG-L35) |
| | | Sales of used products and resources | Canon (SG-L9), Ericsson (SG-L24) |
| | ***Costs*** | Product/service maintenance costs | HP (SG-L32), Kaer (SG-L38, SG-L39, SG-L40, SG-L41), Philips (SG-L51), Schneider Electric (SG-L58) |
| | | Processing costs for collected EoL materials | Apple (SG-L2), Canon (SG-L10), Epson (SG-L20, SG-L21), Fuji Xerox (SG-L26), Hitachi (SG-L27, SG-L28), HP (SG-L32), Panasonic (SG-L48), Samsung Electronics (SG-L55), Toshiba (SG-L59, SG-L60, SG-L61) |
| | | Reduction of material input costs | ABB (SG-L1), Apple (SG-L2, SG-L3, SG-L4), Bosch (SG-L6), Brother (SG-L7, SG-L8), Canon (SG-L9), Dell (SG-L11, SG-L12), Electrolux (SG-L17, SG-L19), Epson (SG-L20), Ericsson (SG-L22, SG-L24), Fuji Xerox (SG-L25), Hitachi (SG-L27, SG-L28), HP (SG-L31, SG-L32), HP Enterprise (SG-L35), Lexmark (SG-L42), LG Electronics (SG-L43, SG-L44), Miele (SG-L45), Mitsubishi (SG-L47), Panasonic (SG-L48), Philips (SG-L49, SG-L51), Ricoh (SG-L53, SG-L54), Samsung Electronics (SG-L55), Toshiba (SG-L59, SG-L61), Anonymous company (SG-L67) |
| | | Reduction of disposal costs | ABB (SG-L1), Bosch (SG-L6), Brother (SG-L7, SG-L8), Dell (SG-L11), Electrolux (SG-L17, SG-L19), Ericsson (SG-L22, SG-L24), Fuji Xerox (SG-L25, SG-L26), Hitachi (SG-L27, SG-L28), HP (SG-L31, SG-L32), Lexmark (SG-L42), Miele (SG-L45), Mitsubishi (SG-L47), Panasonic (SG-L48), Philips (SG-L49, SG-L51), Ricoh (SG-L54), Samsung Electronics (SG-L55), Toshiba (SG-L59) |

**Table E2**
[South Korea].

| BM Dimensions | | CEBM design options found in South Korea | Cases |
|---|---|---|---|
| **Value Capture** | ***Revenues*** | Efficient product and service operation | HP Enterprise (KR-L23), Apple (KR-L50) |
| | | Payments per use/results | HP (KR-L20, KR-L46), Philips (KR-L28), Electrolux (KR-L44, KR-L52), Fuji Xerox (KR-L51), GE (KR-L52) |
| | | Rental / Lease fees | ASUS (KR-L11), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51) SK Magic (KR-L37), Cuckoo Electronics (KR-L41), Electrolux (KR-L44) |
| | ***Costs*** | Product/service maintenance costs | ASUS (KR-L11), Coway (KR-L12, KR-L43, KR-L44, KR-L45, KR-L47, KR-L51), Fuji Xerox (KR-L15), HP (KR-L20), LG Electronics (KR-L24), Philips (KR-L28), Schneider Electric (KR-L34, KR-L44), SK Magic (KR-L37), Cuckoo Electronics (KR-L41), Electrolux (KR-L44), Heidelberger (KR-L51) |
| | | Processing costs for collected EoL materials | Apple (KR-L7), ASUS (KR-L11), Coway (KR-L12, KR-L47), Fuji Xerox (KR-L15), HP (KR-L20), LG Electronics (KR-L24, KR-L25, KR-L42), Philips (KR-L28), Samsung Electronics (KR-L29, KR-L31, KR-L42), Siemens (KR-L35), Sindoh Richo (KR-L36), SK Magic (KR-L37), SONY (KR-L38) |
| | | Reduction of material input costs | Hyundai Electric (KR-L1, KR-L2), LS Electric (KR-L3), Samsung Electronics (KR-L5, KR-L29, KR-L31, KR-L42), Anonymous company (KR-L6), Apple (KR-L7, KR-L8, KR-L9), ASUS (KR-L11), Coway (KR-L12), Electrolux (KR-L13, KR-L14), Heidelberger (KR-L16, KR-L51), HP (KR-L19, KR-L20), HP Enterprise (KR-L23), LG Electronics (KR-L24, KR-L25), Philips (KR-L26, KR-L28), Siemens (KR-L35), Sindoh Richo (KR-L36), SK Magic (KR-L37), SONY (KR-L38, KR-L39, KR-L40), Schneider Electric (KR-L44) |
| | | Reduction of disposal costs | Hyundai Electric (KR-L2), Apple (KR-L7), ASUS (KR-L11), Coway (KR-L12), Electrolux (KR-L13, KR-L14), HP (KR-L19, KR-L20), LG Electronics (KR-L24, L25), Philips (KR-L26), Samsung Electronics (KR-L29), SONY (KR-L38) |

*F. A Morphological Box of CEBM Design Options (Singapore)*

**Appendix F:** represents a morphological box of CEBM design options for Singapore (The number of cases is indicated in parentheses).

| BM Dimensions | | CEBM design options in the EEE sector (Singapore) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Value Proposition** | **Products** | Ease-to-repair products (1) | Durable products (6) | Recycled products (3) | Refurbished products (1) | Remanufactured products (1) | | | | |
| | **Services** | Community initiative to increase consumer awareness (7) | Digital technology-based maintenance/monitoring (6) | Take-back / Trade-in (15) | Repair / Maintenance (11) | Product as a service (5) | Upgrading / Updating / Upcycling (5) | Extended warranty (5) | Others (3) | |
| **Value Delivery** | **Target customers** | General consumers-centric (9) | | Industry-centric (8) | | Industry and general consumers (8) | | | | |
| | **Value delivery processes** | Offering long-lasting products (1) | Digital technology-based solutions (9) | Lifecycle / Integrated solutions (4) | Specific results and corresponding services (5) | Own labelling / certificate (2) | Others (2) | | | |
| **Value Creation** | **Partners and stakeholders** | Local government (5) | Other companies in the same industry (5) | Waste management companies (9) | Suppliers (2) | Others (2) | | | | |
| | **Value creation processes** | Designing with durability (6) | Increase of recyclability and disassembly of products (13) | Designing to enable easy-repair (6) | Maintaining / repairing products, components (3) | Using used products, components, materials as input (5) | Recycling, refurbishing or remanufacturing products, components (7) | Upgrading / upcycling products, components (Design for upgradeability) (5) | Optimising specific outcomes (5) | Use of advanced technologies (4) |
| **Value Capture** | **Revenues** | Payments per use/results (5) | | Leasing/subscription fee (2) | Resource efficiency-related solutions (3) | Sales of used products and resources (2) | | | | |
| | **Costs** | Product/service maintenance costs (4) | Processing costs for collected EoL materials (9) | Reduction of material input costs (23) | Reduction of disposal costs (17) | | | | | |

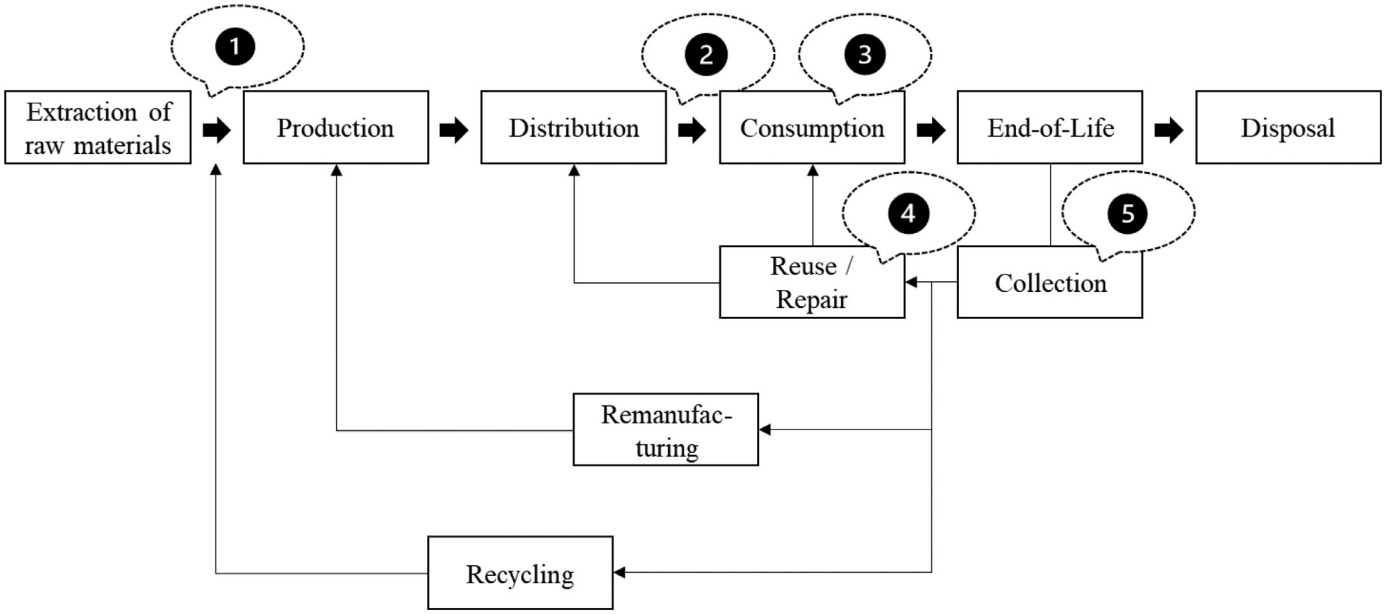
*G. A Morphological Box of CEBM Design Options (South Korea)*

**Appendix G:** represents a morphological box of CEBM design options for South Korea (The number of cases is indicated in parentheses).

| BM Dimensions | | CEBM design options in the EEE sector (South Korea) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Value Proposition** | **Products** | Easy-to-repair products (1) | Durable products (6) | Recyclable / Reusable products (3) | IoT-based products (1) | Modular products (1) | Remanufactured products (2) | Refurbished products (3) | | | |
| | **Services** | Community initiative to increase consumer awareness (3) | Consultancy (7) | Digital technology-based maintenance / monitoring (8) | Extended warranty (3) | Product as a service (5) | Rental / Leasing service (5) | Repair / Maintenance (17) | Take-back / Trade-in (9) | Upgrading / Updating / Upcycling (6) | Others (1) |
| **Value Delivery** | **Target customers** | General consumers-centric (13) | Industry-centric (7) | Industry and general consumers (6) | | | | | | | |
| | **Value delivery processes** | Product / Service platforms (13) | Home visiting service (3) | Providing a membership (3) | Lifecycle / Integrated solutions (7) | Specific results or functionalities (4) | Others (2) | | | | |
| **Value Creation** | **Partners and stakeholders** | Collaboration with other industries (1) | Local government or NGOs (2) | Independent contractors (5) | Suppliers (2) | Waste management companies (5) | | | | | |
| | **Value creation processes** | Designing with circular concepts in general (12) | Digital capabilities (8) | Increase of recyclability (6) | Optimising specific outcomes (5) | Development of initiatives/programs /materials (5) | Refurbishing/remanufacturing/ recycling of products and components (6) | | | | |
| **Value Capture** | **Revenues** | Efficient product and service operation (2) | Rental / Lease fees (5) | Payments per use/results (5) | | | | | | | |
| | **Costs** | Product/service maintenance costs (11) | Processing costs for collected EoL materials (12) | Reduction of material input costs (18) | Reduction of disposal costs (10) | | | | | | |

*H. Practical Considerations for Adopting CEBMs in the EEE Sector*

*Appendix H. presents summarized practical considerations that EEE producers can put into practice for the adoption of CEBMs in the EEE life cycle, based on the findings and discussions of this study.*




**Appendix Fig. H1.** The Life Cycle of Electrical and Electronic Equipment (EEE).

1 **Product design stage:** Application of circular product design guidelines, ensuring that relevant partners and stakeholders comply with the guidelines for the circularity of their products.
   - Design for recyclability, repairability, reusability, and upgradability
   - Design for durability
   - Design for ease of repair and maintenance
   - Design for modular products
   - Design that can utilize digital technologies

2 **Before sales stage:** Determination of business models that can increase resource efficiency and achieve environmental benefits, such as:
   - Result-oriented PSS (servitization) strategy: customer/product type, service duration, and unit cost etc.
   - Rental/leasing business model: subscription fees, rental/leasing period, and hiring of independent contractors for maintenance etc.

3 **Product use stage**: Offering a variety of services to meet customers' needs with value capture.
   - Services: Personalized membership and home visitation service (for rental/leasing business models), extended warranty, consultancy, use of digital technology-based solutions (e,g, online platforms), and joint events with a local government or community etc.
   - Value capture: Payments per unit of service or performance-based contracts (for result-oriented PSS), rental or lease fees (for rental/leasing business model)

4 **Product use stage (in case maintenance or repair is required)**: Consideration of predictive maintenance and repair system as part of a circular economy approach.
   - Providing a real-time monitoring or remote maintenance/repair service through digital technologies to extend the life of products.
   - Digitally-enabled offerings, such as real-time monitoring, predictive maintenance, and online repairing allow EEE manufacturers to have new opportunities in the areas of maintenance, repair, and field operations, boosting servitization through digitalization in the EEE sector.

5 **Product collection stage**: Building a partnership with waste management companies and environmental NGOs for take-back or trade-in schemes.
   - Strategic alliance with local waste management companies for efficient logistics and competitive costs.
   - Collaboration with environmental NGOs to promote take-back or trade-in programs.

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