Activating Circular Services in the Electric and Electronic Sector

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Deliverable 4.1. Framework for setting up and running the demonstrations

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1. Executive Summary

The purpose of Deliverable D4.1 is to establish a common framework for the C-SERVEES demonstrations that includes laying the background by introducing the four demonstrators to be used: washing machine, laser printer (including toner cartridges), ALM (Access Link Monitor) and TV set, and describing their features, current business models and current process flowcharts. Methodological support is also developed in the form of evaluation tools to help industrial partners to measure the performance of the circular economy business models (CEBMs) to be developed.

The outcome of the work carried out up to this point in WP4, resulting from the interactions with manufacturers and WP2/WP3 leaders as well as WP4 partners is presented in this deliverable and aims to establish a baseline for all demonstrators that includes:

- Description of the demonstrator: product, model, characteristics, materials, reason of choice.
- Description of the current business model (BM) for the selected demonstrator.
- Description of process flows belonging to the selected product: background for a Material Flow Analysis (MFA) of the demonstrator systems.
- Proposal for introducing new circularity improvements in the current BM, considering all life-cycle stages: design and production, distribution and use, end-of-life.
- Proposal of evaluation tools that enable the measurement of the CEBM performance along the demonstration period, according to the objectives defined for each demonstrator. The tool presented here is based on Key Performance Indicators (KPIs) that need to be defined for each of the demonstrations, which is the work being carried out at present in WP2. Thus, in this deliverable a proposal for tools and template are given, to be completed and modified depending on the results of WP2 (product specific CEBMs for the demonstrators).

To present a better overview of the background concerning CEBMs in the Electric and Electronic (E&E) sector, this deliverable includes a section describing current CE (Circular Economy) practices and initiatives for E&E products belonging to the same categories as the ones chosen for C-SERVEES.

In order to collect all relevant information to be included in this deliverable, frequent interactions (online meetings, e-mail exchanges, general meetings) have been maintained with the demonstration leaders (manufacturers): Arçelik (washing machine and TV set), ADVA (ALM) and Lexmark (laser printer). In addition, available options for circularity measures currently implemented in the E&E sector, in particular for the type of products selected in C-SERVEES, have also been researched and discussed.

Content

2. Acronyms and abbreviations

B2B	Business to business
B2C	Business to customer
BSC	Balanced Scorecard
CE	Circular Economy
CI	Circularity Indicators
CEBM	Circular Economy Business Model
EEA	European Environment Agency
EEE	Electric and Electronic Equipment
EoL	End of life
E&E	Electrical and Electronic
GPP	Green Public Procurement
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MFA	Material Flow Analysis
PSS	Product Service Systems
REF-CIRCMODE	Circular Economy Business Reference Model
SLCA	Social Life Cycle Assessment
WEEE	Waste Electrical and Electronic Equipment
WIP	Work Implementation Plan
WP	Work Package

3. Introduction

This deliverable D4.1 presents the results of Task 4.0.1, "Setting up the demonstrations", which focuses on the development of a common framework for the four demonstrations to be carried out in WP4. The objectives of the deliverable are the following:

(1) Presenting a generic view on circular economy business models and strategies applied to EEE and examples of current CEBMs in the E&E sector.
(2) Developing an evaluation tool to assess the performance of the CEBMs during the demonstration period. It is conceived as methodological support for the leaders of each demonstration, and as such it is designed as a generic template that can fit any of the four different CEBMs in the C-SERVEES and can be later extrapolated and adapted to any CEBM in the sector. The evaluation tool is supported by the Circularity Indicators (CIs) to be explored in Layer 5 of the REF-CIRCMODE and validated through the LCA, LCC and S-LCA carried out in WP5.
(3) Presenting and describing the four C-SERVEES demonstrators: washing machine, laser printer and toner cartridges, ALM and TV set.
(4) Establishing a baseline for all demonstrations in terms of what the manufacturer (industrial partner responsible for the demo) is doing already (current business model) and their current process flowcharts.

The information presented here concerning product description and BM canvas aims to provide an overview of the demonstrators and will be further explored, expanded and developed in the product specific C-SERVEES CEBMs which will be prepared and delivered in the scope of Task 2.2, so that they can be later implemented through the demonstration activities in Tasks 4.1, 4.2, 4.3 and 4.4.

Based on the REF-CIRCMODE developed in WP2 (D2.1) and the exploration of ICT functionalities carried out in WP3 (D3.1), the aim of WP4 at this stage is to implement Layer 2 of the REF-CIRCMODE in order to develop a detailed action plan including all innovative activities to be explored during the demonstration period, according to the strategic circularity objectives determined in Layer 1. This process is being carried out at present and will be finalised by mid-January 2020 with the development of finalised CEBMs for the demonstration products and comprehensive action plans for each demonstration.

The agenda for the finalisation of the action plan is given below:

Meeting date	Location	Demonstrator	Manufacturer
28-29th November 2019	Meiningen (Germany)	ALM	ADVA
17-18th December 2019	Budapest (Hungary)	Laser printer	LEXMARK
7-8th January 2020	Istanbul (Turkey)	Washing machine	ARÇELIK
9-10th January 2020	Istanbul (Turkey)	TV set	ARÇELIK

The purpose of Deliverable D4.1 is to describe Task 4.0 activities up to the starting point of the demonstrations, in accordance with WP4 Implementation Plan. Task 4.0.1 has been led by GAIKER with the participation and collaboration of all WP4 partners. The duration of this task was from Month 1 to Month 18 (May 2018 - October 2019). Task 4.0.1 associated steps are shown in Table 1.

Table 1. Actions for Task 4.0.1. Setting up the demonstrations.

Action	Partner(s)	Status	End
A4.0.1	All WP4 partners	started	M18
Description	This action encompasses all activities required to establish a common framework for setting up and running the demonstrations and to ensure the correct application of all operating principles along each life-cycle phase: design & production, distribution & use, EoL. It has required close cooperation with the rest of task leaders and also inputs from other partners, as well as WP2 regarding the development of specific CEBMs for each of the demos. As a final result, this task has produced Deliverable 4.1 which is due M18.		
Steps			
An initial description of the selected target product has been required from each industrial partner in order to define model, technical specifications and any other information of interest to help in the definition and feasibility of eco-innovative actions to be implemented. GAIKER requested this information from the industrial partners during the first WP4 meetings which were held by phone individually.			
An assessment has been carried out individually with each industrial partner in order to establish a baseline for the current linear/circular business models for each target product defined. This baseline will help to build upon the current system and evolve towards a circular economy-oriented model according to the principles and framework developed in WP2. GAIKER has maintained individual conversations (via phone call) with all industrial partners.			
Periodic online meetings have be maintained between LOU, CIRCULARISE and GAIKER in order to share the progress concerning i) feedback received from industrial partners ii) ICT tools developed within C-SERVEES, iii) information relative to the development of specific CEBMs for the target products, and iv) definition of demo activities according to all relevant inputs. GAIKER is acting as leader in the technical integration of the WP2, WP3 and WP4, organising and coordinating joint actions.			
LOU and GAIKER have contributed to WP3 workshops with the industrial partners by suggesting specific points in the agenda and persons/skills which they would like to see included in the workshops, as well as attending whenever possible/relevant.			
GAIKER in collaboration with LOU (WP2), CIRCULARISE (WP3) and all industrial partners and WP4 partners is working on the definition of new CEBMs for the target products, identifying circular economy standards, principles and Key Performance Indicators for each demonstrator. GAIKER has also been working on the methodological support to industrial and SME partners to establish the common framework for the demonstrations (vision fundamentals, templates, protocols and guidelines).			
GAIKER in collaboration with all task leaders and WP4 partners will define collaborative actions needed among partners and work on the activation of an interactive permanent platform.			
GAIKER has prepared deliverable 4.1 “Framework for setting up and running the demonstrations” due M18.			

4. Generic framework for a CEBM in the Electric & Electronic Sector

4.1. The concept of Circular Economy

The Circular Economy (CE) is an economic development strategy that seeks economic growth in a sustainable way. Specifically, it pursues the following fundamental objectives:

- **Optimise the use of resources** (materials, energy, time...). Efficiency is sought at all levels, that is, to use the minimum possible resources to get the best possible results.
- **Minimize the extraction of virgin resources**. In Circular Economy, a large part of raw materials is obtained from discarded products. Reintroducing products and their materials into the economic system avoids the need to extract these resources from nature.
- **Prevent the generation of negative externalities**. It is intended that the elements that are outsourced (such as waste, emissions, etc.) and impact negatively both in the environment and the economic system, need to be reduced to maximum and managed properly.
- **Promote and increase the resilience of the system**. A self-sufficient system can respond better to unforeseen events that may occur. For this, it is necessary to minimize dependence on non-renewable and scarce sources (fossil fuels, critical raw materials…) and prevent their impact in the environment.

To achieve these objectives, the Circular Economy tries to maintain resources (products, its parts, its materials and / or its energy) within closed cycles the maximum time possible: once discarded, they are collected and processed for recovery and reintroduction into the economic-productive network. The concept of CE evolves around the fact that natural resources are finite, and they will eventually be depleted, being in that way closely related to sustainable development. It is based on nature processes in which there is no waste since the “waste” resulting from one process serves as “nutrients” for the next, giving as result a closed cycle.

The practical applications of Circular Economy in economic systems and modern industrial processes gained importance from the end of the 70s although it already existed prior to that date. In fact, this concept has an origin strongly rooted in time and has evolved over the years, so it is not possible to assign it to an exact date or author. It derives from some more specific approaches such as from “cradle to cradle” (C2C), "biomimicry", “industrial ecology” and the "blue economy" among others.

Even though nowadays the concept of CE is rather widespread and discussed both in the literature and media, its implementation at a global scale, as well as at the microeconomic level, is still poor and focused mainly on recycling rather than on re-use, re-manufacture or refurbishment.

According to the EU (European Commission, 2015), the transition to CE is an essential contribution towards the development of a sustainable, low carbon, resource efficient and competitive economy. Today, "a Europe that effectively uses resources" is one of the seven flagship initiatives that are part of the Europe 2020 strategy (European Commission, 2010).

There is not an established definition for a circular economy, but a simple definition is given below (Mentink, 2014):

A circular economy is an economic system with closed material loops

The main purpose of the CE is to achieve economic growth without compromising the environmental and social sustainability goals, by slowing, narrowing and ideally closing the material flow loops in the economic system and striving towards a zero-waste economy where waste is not discarded but converted into inputs for other economic activities.

To achieve this goal, CE embraces strategies oriented to extend the lifetime of products and maximize the time the value of a product spends within the circles of reuse, remanufacturing and recycling, in that particular order. While the most desirable strategy is to make the product redundant by abandoning its function or offering it by means of a service, for any product to embrace circularity the priority is to avoid consuming virgin raw materials, followed by sharing and reuse, repair or refurbish, then remanufacturing and finally recycling. When the material cannot be recycled anymore, valorisation (energy generation and recovery) would be preferable to landfilling.

CE has gained much positive publicity and is being actively promoted by the EU since 2015, as well as by many other public organisations and institutions. According to the European Environment Agency (European Environment Agency, 2016) there are seven enabling factors of CE: (1) eco-design; (2) repair, refurbishment and remanufacture; (3) recycling; (4) economic incentives and finance; (5) business models; (6) eco-innovation; and (7) governance, skills and knowledge. The C-SERVEES demonstrations focus on the development of new CEBMs where several or all the mentioned concepts can be applied for a single product.

CE contemplates the whole product life cycle, from the design until de end-of-life, and in fact the design phase of the product is very carefully considered as the first strategy to be taken into account to facilitate product reuse and material utilization from the earliest stage. Table 2 lists the available strategies for CE considering the life cycle phase level at which they operate and the priority from the sustainability perspective.

Table 2. Circular Economy strategies for product recovery management.

Strategy	Objective	Life cycle phase	Result	Priority
Reduce	Avoid or reduce the consumption of raw materials	Design	New product	1
Share	Make product use more intensive	Use	Shared product	2
Reuse	Maintain the functional product in use	Use	Cleaned used product	3
Repair	Return the defective product to a usable state	Use	Repaired product	4
Refurbish	Restore the defective / old product to a specified quality level	Use	Refurbished product, upgrade possible	5
Remanufacture	Restore the damaged product to the quality level of a new product including new parts or components	Use	Remanufactured product, upgrade possible	6
Recycle	Process product materials to obtain usable resources	End-of-life	Secondary raw materials	7
Recover	Valorisation at the end of life	End-of-life	Energy	8

It is also important to note that circular economy is closely related to new cultures of responsible consumption, abandoning the classic "own, consume and discard" patterns and embracing sharing the use of the function, service and value of physical products.

Public procurement is also key in the transition process to a circular economy. Including 'circular principles' in procurement practices from the first stages of a procurement to the end of product life can help public sector buyers to progress in the achievement of sustainability goals. The EU Action Plan for the Circular Economy (2015) recognises public procurement as a key driver in the transition towards the circular economy, and it sets out several actions which the European Commission will take to facilitate the integration of circular economy principles in Green Public Procurement (GPP).

Circular procurement can be defined as the process by which public authorities purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across their whole life-cycle[1]. Circular public procurement also has a role to play in achieving the Sustainable Development Goals, defined by the United Nations 2030 Agenda for Sustainable Development. In addition, several countries, regions, and cities have been developing their own circular economy strategies, and public purchasing is often emphasised by these as an essential tool for encouraging the transition to a circular economy.

International initiatives such as the 10YFP Sustainable Public Procurement Programme, ICLEI's Procura + campaign (now Network), the Sustainable Purchasing Leadership Council (SPLC), and the International Green Purchasing Network (IGPN) amongst others, have built a suite of resources and expanded expertise and capacity with member organizations and others on GPP.

4.2. Business Models and their transition towards circularity

A business model (BM) is defined as the basis of how an organization creates, delivers and captures value (Osterwalder & Pigneur, 2010). This definition is reflected in a representation of the business model as a system supported by four pillars:

1. Value proposition: value created by a company with its product/service
2. Infrastructure management or Supply chain: how is the value proposition created, including own processes and relationships with the partners, suppliers, etc.
3. Customer interface: who are the customers and how does the company deliver value to them
4. Financial model: costs and benefits associated to the previous pillars and how to capture the value created

Table 3 shows how the three activities (creation, delivery and capture) within BMs are separated into these four pillars (value proposition, supply chain, customer interface and financial model). In practice, they are either expanded to nine basic components or 'building blocks' (Osterwalder & Pigneur, 2010) such as the ones shown in Figure 1 or converted into four basic questions (Frankenberger, et al., 2013) (Kok, et al., 2013).

Table 3. Typical nomenclatures used to identify activities and pillars in BMs and their relationship with basic components and questions

Activities of BM or CEBM	Pillars of BMs	Basic components (Osterwalder & Pigneur, 2010)	Basic questions (Frankenberger, et al., 2013)
• **Create value**	• Value proposition	• Value Proposition	• **What?** - the value proposition
• **Create value**	• Supply chain	• Key Activities • Key Resources • Key Partners	• **How?** - activities, processes, resources and capabilities

[1] Public Procurement for a Circular Economy (EU, 2017)

• **Deliver value**	• Customer interface	• Customer Segments • Channels • Customer Relationships	• **Who?** - customer segments
• **Capture value**	• Financial model	• Cost Structure • Revenue Streams	• **Why?** - revenue model

According to Osterwalder and Pigneur's terminology, the building blocks for the BM creation are 'value proposition', 'key partnerships', 'key activities', 'key resources', 'channels', 'customer relationships', 'customer segments', 'revenue streams' and 'cost structure', and they can be organized in a business model canvas as depicted in Figure 1.

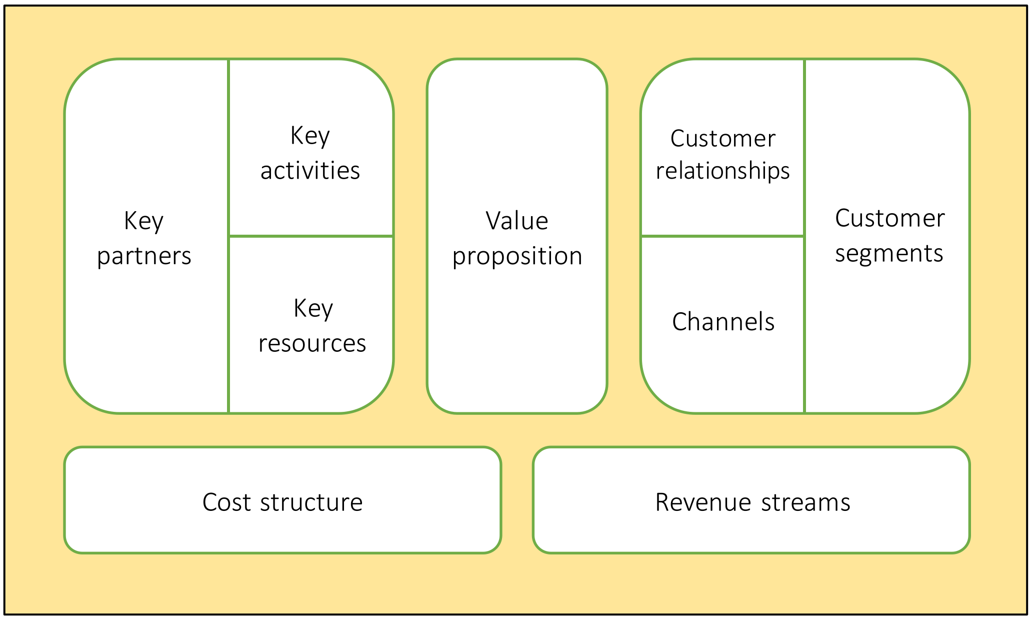


Figure 1. Business model canvas (Osterwalder & Pigneur, 2010)

In order to understand what a BM is, the following observations are important:

- BMs are models of a company, and not of an entire sector or industry.
- BMs are systems of interrelated components and, as such, if one component changes, others often (have to) change as well. For example, making a new product (Value proposition) may require new processes and resources (Key Activities and Key Resources).
- BMs can be used as communication tools by the companies to explain their ventures.
- BMs are not business strategies. The strategy is the company's plan to create and defend a value proposition in the market and the BM represents how this strategy is executed.
- BMs are not static; they need to evolve over time in order to adapt to the business environment.

According to the BM definition given above, a circular economy business model (CEBM) could be defined as **the basis of how an organization creates, delivers and captures value with and within closed material loops**. The primary goal of CEBMs is to help companies create value through using resources in multiple cycles and reducing waste and consumption. In the best-case scenario, waste is avoided completely (closed loop CEBM) and only renewable energy is used. The converted CEBM canvas is represented in Figure 2 and it includes two conceptual elements reflecting the key differences between a linear BM and a CEBM: slowing or closing resource loops, and sustainable inputs (using renewable energy, recycled or recyclable materials).

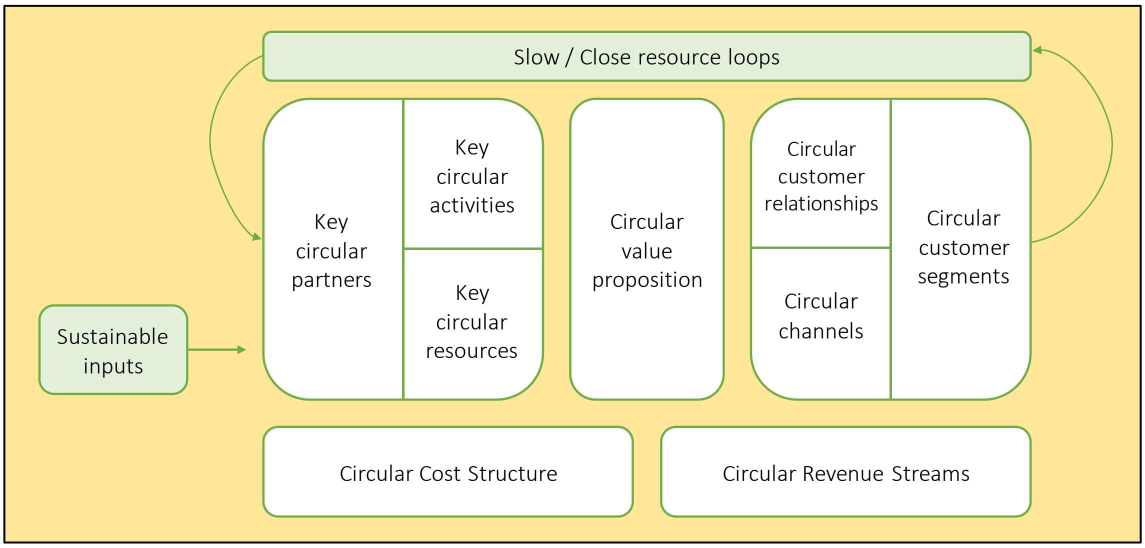


Figure 2. Circular Economy Business Model canvas (Danish EPA, 2018)

The canvas components in the CEBM have been converted to their corresponding circular components according to the Layer 1 of REF-CIRCMODE, as described in D2.1.

In order to transition from "linear" or "traditional" business models towards CEBMs, changes need to occur in the entire value chain, starting from the use of fewer and preferably renewable raw materials, to designing and making products that have a longer lifespan and are easy to repair, disassemble or can be upgraded a number of times during their lifecycle, up to the optimization of end-of-life processes in order to reuse waste materials and avoid disposal. Implementing this vision requires business and revenue models that ensure that companies benefit from products that are designed and maintained in line with principles of circularity.

As part of the work carried out during WP2 (D2.1), CEBMs archetypes and involved strategies were examined for their relevance to the E&E sector (Table 4).

Table 4. Main CEBM strategies relevant to the E&E sector.

Business models	Description	Resource impact	Relevant to E&E sector
Circular supply chain	Use materials sourced from waste or biomass	Reduce use of primary materials and scarce materials	Relevant to all material use Particularly relevant to critical raw materials
Recovery and recycling	Recover materials from waste	Ensuring recovery of materials for use in subsequent production cycles	Already commonplace Relevant to all material use Particularly relevant to critical raw materials
Building products to last	Repair and maintenance of products Reuse through second ownership / resale	Prolong use phase of products More intensive use of products Fewer products required	Relevant to slowing replacement cycles of products
Sharing platforms	Enabling collaboration on using and sharing products and ownership	Fewer products required Reduce use of primary materials and scarce materials	More intensive use of products
Products as a service	Purchase or subscription of a solution rather than product (pay per use)	Reduce use of primary materials and scarce materials	Provision of an appliance or product Provision of a solution (e.g. lighting, pay-per-lux)

As shown in Table 4, there are five archetypical CEBMs that companies can leverage, singly or in combination, to generate resource productivity improvements in innovative ways that also cut costs, generate revenue and enhance customer value and differentiation:

1. Circular supplies: This CEBM is relevant for companies dealing with scarce resources as fossil fuels or critical raw materials which are replaced with renewable, recyclable or biodegradable ones.
2. Sharing platforms: This CEBM is centred on the sharing of products and assets that have a low ownership or use rate. Companies that leverage this model can maximize the use of the products they sell, enhance productivity and value creation.
3. Product as a service: Through this CEBM customers use products through a lease or pay-for-use arrangement versus the conventional buy-to-own approach. This model is attractive for companies that have high operational costs and ability to manage maintenance of that service and recapture residual value at the end of life.
4. Product life extension: This CEBM helps companies to extend the lifecycle of their products and assets to ensure they remain economically useful. Material that otherwise would be wasted is maintained or even improved, such as through remanufacturing, repairing, upgrading or re-marketing. By extending the lifespan of the product for as long as possible, companies can keep material out of the landfill and discover new sources of revenue.
5. Resource recovery: This CEBM leverages technological innovations and capabilities to recover and reuse resource outputs that eliminates material leakage and maximizes economic value. Examples include closed loop recycling, industrial symbiosis and Cradle-to-Cradle (C2C) designs, where waste materials are re-processed into new resources or by-products are exchanged.

In Table 5, the five archetypical CEBMs are linked to their key actions and their descriptions. Figure 3, taken from the presentation "Circular Economy Business Models for the Manufacturing Industry", shows the positioning of CEBMs along the circular value chain comprising: raw materials extraction, product manufacture, distribution, sales, use phase, end of life (EoL), reverse logistics and effective recycling and material loops closing (The Finnish Innovation Fund Sitra & Accenture, 2019).

Table 5. CEBMs archetypes and associated key actions

Type of CEBM	Key action	Description
Circular supply chain	Reform use of resources	Use of renewable energy, bio-based or potentially complete recyclable materials
Sharing platforms	Improve capacity use	Increased usage rates through collaborative models for usage, access or ownership
Product as a service	Sell result-oriented solutions	Offering of products for use with retention of product ownership which incentivises increase in resource productivity along the whole life cycle
Product life extension	Extend life cycles	Extension of life cycle through repair, maintenance, upgrade resale and remanufacturing
Recovery and recycling	Recover value in waste	Recover of usable resources or energy from waste or by-products

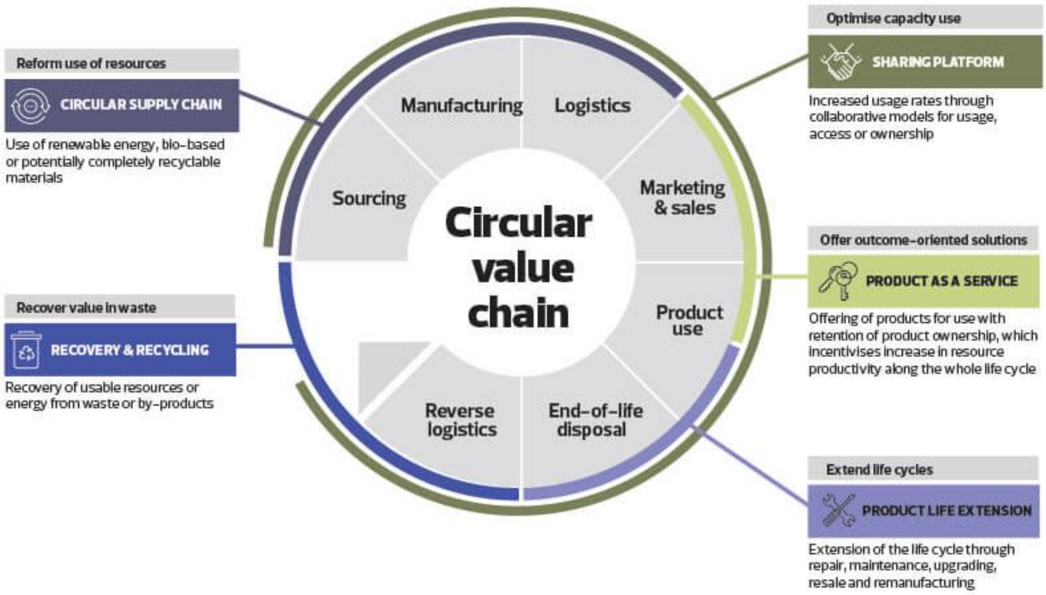


Figure 3. Five archetypical CEBMs and their positioning along the circular value chain (source: http://www.kasvuakiertotaloudesta.fi/)

All CEBMs work to preserve materials, components and products by reusing, repairing, refurbishing or remanufacturing and remarketing. Among the above mentioned, product-service systems (PSS) receive special attention since they have many features aligned with resource reduction. The PSS models' goal is to utilize the entire lifetime of a product and maximize the utilization rate. In addition, these businesses reshape the consumption patterns towards **sharing and renting instead of owning**, which result in better management at the end-of-life as the **ownership is retained by the company who offers the service** and who is responsible for the end-of-life treatment.

As mentioned before, one of the main concerns for the success of CEBMs is the social dilemma, i.e. the concern that the consumers might not be satisfied with the sustainable products and services, either because the price is not sufficiently attractive, or the expected service does not meet their standards, or because they are reticent to abandon ownership, etc. Therefore, the desired positive influence on society would not be reached. For this reason, CEBMs should aim at developing products and services that, beside sustainability, have some other **appealing factors for the consumers**.

Delivering value to customers is one of the key pillars involved in the creation of any BM. In the Circular Economy Playbook for Finnish SMEs (The Finnish Innovation Fund Sitra & Accenture, 2019) the authors identify three key areas of development for a CEBM: customer value delivery, resource handling and organisation and collaboration. Each of these must translate into practice in order to achieve the desired goal. Table 6 explores the three key areas and their relationship to know-how and tools, technologies and processes, to propose associated practices that are linked to the development of CEBMs.

Table 6. CEBMs key areas of development

Key action	Description	Know-how	Practice
Customer value delivery	Design solutions to deliver customer outcomes	Ability to put customer needs and requirements at the centre of product	• Iterative design / rapid prototyping • Open collaboration / co-creation • Data analytics
	Design products for circularity	Ability to design products for long-life cycles and sustainable material	• Life cycle assessment • Circular design criteria
	Sell outcomes and life cycle services	Ability to leverage customer insights in selling value-adding solutions	• Customer-centric sales process • Outcome-based offerings and pricing models • Product-life extension support
Resource handling	Source recycled or recyclable material	Ability to specify and source materials that can easily be regenerated and recycled	• Circular resource Marketplace • Industrial symbiosis • Supplier code of conduct
	Produce, remanufacture	Ability to handle waste in production, incl.	• Material flow management • Digital production

	and recycle products	material flows and remanufacturing	• Remanufacturing reprocessing and recycling
	Take back products at end of life	Ability to establish return systems that ease and facilitate disposal of products end-of-life	• Reverse logistics network • Condition tracking and monitoring • Return incentives
Organisation and collaboration	Deploy technologies and data for delivering outcomes	Ability to manage and derive valuable insights from real-time data	• Smart products • Data analytics and visualisation • Data monetisation
	Orchestrate ecosystem of partners	Ability to manage increasing number of ecosystem partners to jointly closet the loop	• Collaboration platforms • Co-innovation
	Transform culture and steering	Ability to develop and motivate circular competences and outcomes	• Circular economy targets and incentives • Cross-functional collaboration and knowledge sharing

The approach followed in the C-SERVEES project to develop new CEBMs based on the existing BMs for the demonstration products has gone beyond these three key areas, examining in detail every component (and related subcomponents) of the BM canvas in order to analyse their relevance to the manufacturer and to the strategic objectives defined in the first step of the REF-CIRCMODE implementation plan. As outcome of this in-depth exploration, a comprehensive action plan will be generated which contemplates many of the practical measures described in Table 6.

The implementation of new CEBMs would not be possible in many cases without the support of innovative new technologies, especially digital ones (e.g. the internet of things). Table 7 identifies enabling technologies for the development of CEBM, categorized according to the maturity stage and type: digital, physical or biological. Note that many of them involve engineering, for example robotics, machine learning, digital twin etc.

Table 7. Enabling technologies for CEBM

Maturity stage	Technology	Type of technology
Emerging	Artificial intelligence	Digital
	Digital Twin	Digital
	Nanotechnology	Physical
	Energy harvesting	Physical
In development	Conversational Systems	Digital
	Blockchain	Digital
	Robotics	Physical

	New materials	Physical
	Bio-based material	Biological
Mature	Internet of Things & Industrial Internet	Digital
	Machine Learning	Digital
	Augmented Reality / Virtual Reality	Digital
	Big Data	Digital
	Machine Vision	Digital
Scale-up	3D Printing	Physical
	Radio-frequency identification (RFID)	Digital
	NIR Spectroscopy	Physical
	Bioenergy	Biological
	Secondary data	Digital

The C-SERVEES project incorporates some of the above-mentioned enabling technologies, such as blockchain or RFID (developed by WP3 and applied in WP4) and 3D Printing and NIR spectroscopy (developed and applied in WP4).

Finally, Table 8 shows a list of practices that companies should consider when trying to implement their strategic circularity goals. They are categorized by key company department or area: R&D, Procurement, Production, Sales, Waste management, Finance.

Table 8. Strategies and practices supporting the circular economy by company department and activity (WBCSD, 2018)

Activity	Department	Circular economy strategy or practice
Design	**Research, Innovation or Design**	Biomimicry Cradle to Cradle® Design for disassembly/deconstruction Design for flexibility Design for maintainability/reparability Design for recoverability/recyclability Design for the environment (eco-design) Green chemistry Integrated design process Life cycle thinking Lifetime extension & durability Regenerative design Standardization Systems thinking
Buy	**Procurement**	Bio-based resources Biodegradable resources Compostable resources Critical raw material substitutes Rare earth metal substitutes Reclaimed resources Recycled resources

		Renewable resources Reused/reusable resources Safe chemicals Services (not products)
Make	Production and Manufacturing	Additive manufacturing Dematerialization Jidoka (autonomation) Kaizen (continuous improvement) Kanban (just-in-time) Lean manufacturing Poka Yoke (error-proofing) Prefabrication Refurbishing Remanufacturing Resource efficiency Six Sigma
Sell	Sales and Marketing	Co-branded services Digitization and virtualization Leasing Pay-per-service unit Sharing platforms
Dispose	Waste Management	Cascading Compatibilizers Composting Deconstruction and disassembly Energy recovery Feedstock recycling Industrial symbiosis Recycling Repurposing Reverse logistics Secondary material marketplaces Selective extraction Take-back program Waste to Energy
Finance	Finance and Accounting	Assess creditworthiness risk Assess ESG risk Assess linear risk Crowdfunding Emphasize relationship-based financing Extend investment time horizon Factoring Green bonds Impact loan Incentivize end-of-life returns Integrate circular value in models Integrated client approach Natural capital valuation Prioritize cash flow Purchase order finance Stranded asset management Supply chain financing

4.3. CEBM strategies for the Electric & Electronic Sector

4.3.1. Circular economy business models and washing machines

A fine insight of circular economy around washing machines can be found in the Ellen MacArthur Foundation site (Ellen MacArthur foundation, 2012), the following text is based on it. The site contents relevant data associated to these large household appliances as the occurrence of washing machines in Europe (homes own more washing machines than cars!), typical values of mass per machine (70-80 kg including 30-40 kg of steel), standard size (850 × 595 × 470 mm) and the fact that available models vary very much in price, lifetime and performance. Regarding to customer segments they range from the single-person home (110 washing cycles/year) to commercial use in laundromats (1500-3000 washing cycles/year).

Washing machines, see Figure 4, have similar components but their longevity ranges from 2000 washing cycles for entry-level machines to 10000 for high-quality machines. The common break points in washing machines are the motor, the pump and the plumbing. The industry average for domestic washing machines is set in 250 washing cycles/year and warranty periods are typically 1-2 years. Users frequently incline to purchase the lowest-cost machine and get 2000 washing cycles in a 10 years period. Customer groups with low usage intensity opt for lower-quality machines. High-end machines cost users 0.12 € /washing cycle and low-end machines 0.27 €/ washing cycle. The costs associated to a home using one high-end machine a 20-year period are lower than if the same household uses a series of low-end machines to do the same number of washes during the same period. The trade-offs between high- and low- quality machines also have implications for material and energy consumptions. Given similar material compositions and production processes, replacing five 2000 cycle machines with one 10000 cycle machine yields almost 180 kg of steel savings and more than 2.5 t of CO_2 emissions avoided.

Energy efficiency improvements introduced in new machines are not available to customers owning old machines, which translates into less savings for these end-users, but such gains (associated to water temperature, spin rate and washing cycle time) can be made accessible to users of “built-to-last” machines by means of new washing programmes, automatic load detection, sensor technologies, and auto dosing systems associated to software, electronics, and sensors. These are components that could be reintegrated into machines postproduction without substantial changes in their structure, thus allowing their owners to benefit from the associated improvements and money savings.

Updating and upgrading washing programmes after the first sale can be a way to achieve energy efficiency improvements without replacing the whole machine. Once realised the decrease in the economic and environmental impacts associate to durable washing machines, manufacturers should consider offering high-end washing machines in a usage- or performance-based model and costumers abandoning the low-cost segment. This could enable average users to profit from low per-cycle costs of high-end machines within a shorter period, in this situation a 5-year leasing agreement would remove the high initial cost. Concerns associated to that shift form linear to circular as the increase of total cost of ownership, the decrease of sales due to the substitution of existing models by longer-lasting machines, the reluctance of costumers to accept new contract schemes or the financial risk that will be assumed by the manufacturers by financing of upfront production has been raised (Ellen MacArthur foundation, 2012).


Figure 4. Washing machines: inner parts (left), commercial uses (right)

CEBM associated to washing machines

Pay-per-wash model: During 1999-2000 in Gotland (Sweden), Electrolux offered customers per-wash options based on smart metering. The manufacturer installed its high-quality washing machines in customer homes, connected to a dedicated measuring device installed at the power outlet. This enabled tracking of not only the number of washing cycles but also the programme (e.g., cold vs. hot wash). When the project was started, 7000 smart meters were installed, mainly around the city of Visby. Since it was calculated that up to 90 % of the environmental impact can be attributed to the use stage of a washing machine, the pay-per-use method would give a financial incentive to do fewer washes. In addition, Electrolux chose their most energy efficient machine for the trial. Electrolux completed a pilot scheme based on a pay-per-use system with washing machines. Instead of selling or renting out the appliances they were paid by the consumers according to how much the appliances are used. The business model included providing a washing machine to the consumer and charging approximately 1.00 €/per wash at 1.0 kWh/wash cycle, rather than charging for the washing machine. The machine remained the property of Electrolux, although the consumer paid for the installation that was about 45.00 €. A 24-hour repair service was guaranteed as well as new machine after 1000 wash cycles. The intention was then to refurbish the used machines at the Electrolux refurbishment facility. The partners in the project were Vattenfall a major electricity production/distribution company, GEAB the local electricity company based in Gotland and one Electrolux Home store on Gotland. The usage of the washing machine was monitored by a smart electricity meter installed in the washers and connected to the electricity and telephone networks. Each month the households received a bill listing the washing expenses as part of their regular electricity bill from GEAB. This business model was discontinued after the utility provider discontinued the smart metering. Without this element, Electrolux was unable to assess customer-specific usage and charge the customer accordingly. Further, customer acceptance was rather low; the advantages (e.g., free servicing, easy trade-in for upgrades, high-end machines with hardly any upfront costs) were not marketed adequately.

Refurbishing model: ISE, a specialty washing machine company producing professional washing machines (10000 to 12000 cycles) in sizes comparable with domestic models, collects used heavy-duty washing machines from hotel or laundromat customers. After refurbishment, it sells these machines to the domestic market at a discount price.

Lease model: Several market participants have discovered the potential of offering leasing contracts for washing machines to commercial users as well as to private households. Specialty leasing providers such as Appliance Warehouse of America offer a wide range of products and contract specifications to meet customer demands. Home appliance manufacturers such as BSH (Bosch Siemens Hausgeräte) provide leasing to customers under a "full service" scheme, which includes warranties that cover the whole contract time frame. This provides the customer not only with increased flexibility in terms of timing but also with better service levels and added convenience. In such a setting, third-party financing companies may take up an intermediary role, matching manufacturer and customer incentives and handling administrative tasks.

Companies associated to CEBM and washing machines

Bundles (The Netherlands), see Figure 5, leases high-end Miele washing machines at a fair price and flexible and high quality services.

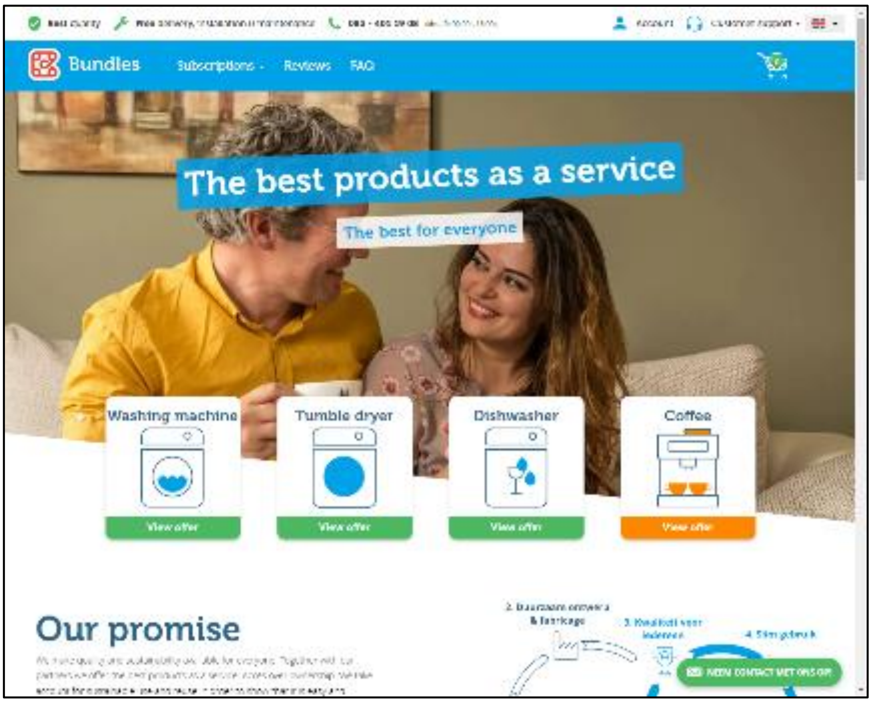


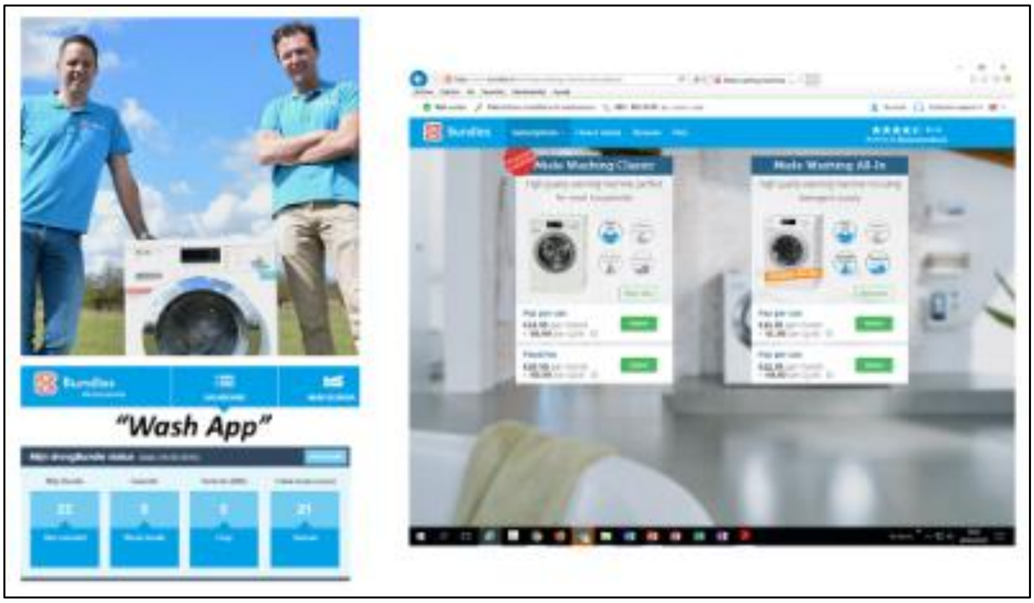
Figure 5. BUNDLES website [source: https://bundles.nl/en/washing-machine-rental/]

Company: Bundles

Location: The Netherlands

Business innovation: Bundles offers a service to produce clean laundry in homes on a pay-per-wash basis, so customers pay for the performance, not the product. It links quality washing machines and dryers to the Internet and works with the customer to reduce overall washing costs. It charges customers a monthly subscription fee and usage on a per-wash basis, while the company retains ownership of the appliances.

Signals of success: It has received approximately 800000 € in financing from Rockstart Accelerator and crowdfunding initiatives. It operates 166 appliances from the brand Miele at 130 households across The Netherlands. The company has four employees and generated approximately 25000 € in revenues in 2015.



https://www.circle-economy.com/case/bundles/#.XaYVdzZMrct

Homie (The Netherlands), see Figure 6, offers a pay-per-wash service.

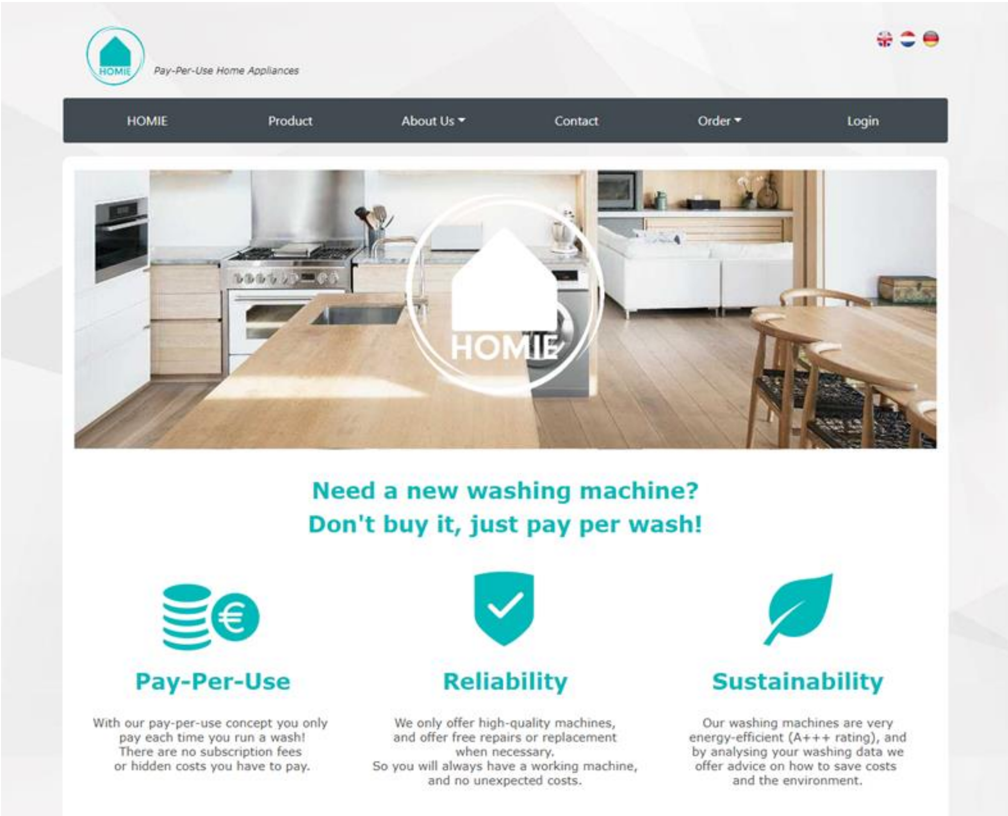
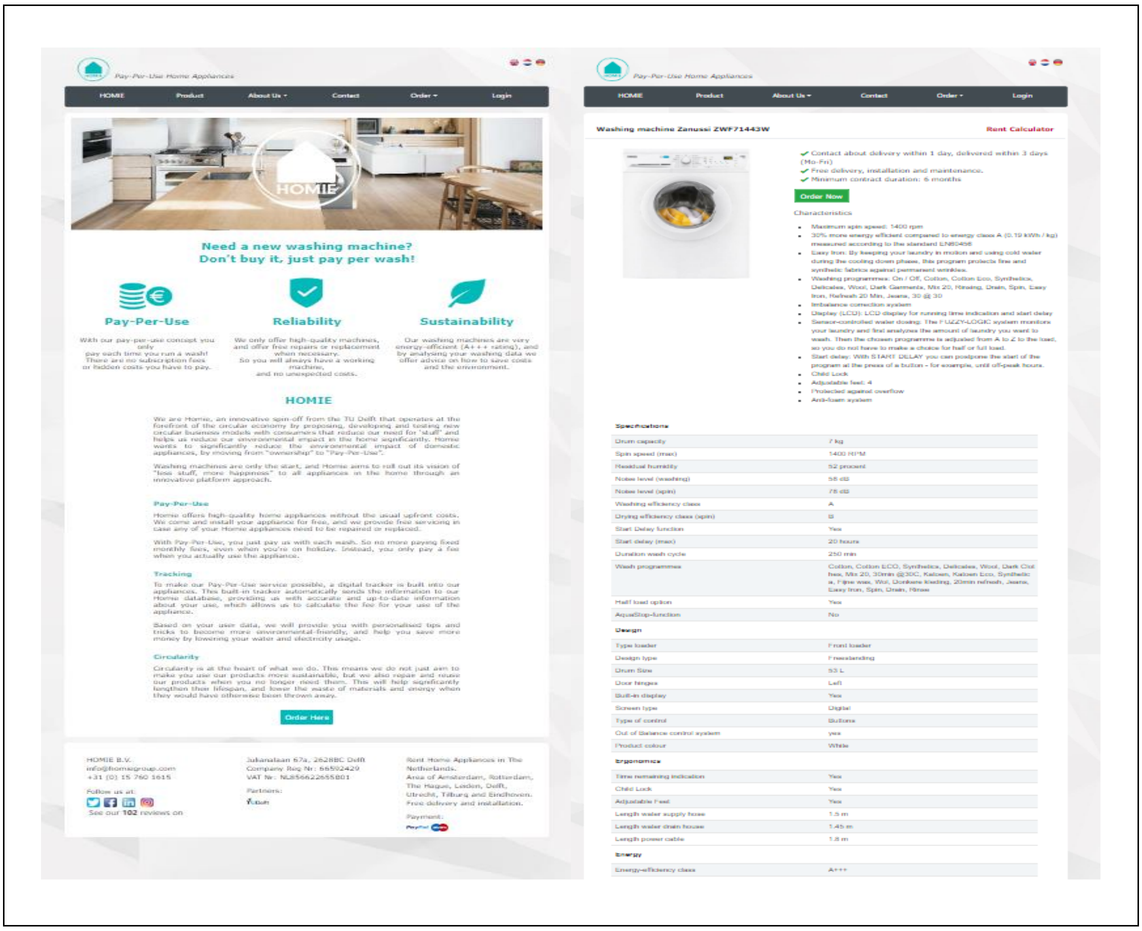


Figure 6. HOMIE website [source: https://www.homiepayperuse.com/]

Company: Homie
Location: The Netherlands
Business innovation: Homie is an innovative spin-off from the TU Delft that operates at the forefront of the circular economy by proposing, developing and testing new circular business models with consumers that reduce our need for 'stuff' and helps us reduce our environmental impact in the home significantly. Homie wants to significantly reduce the environmental impact of domestic appliances, by moving from "ownership" to "Pay-Per-Use". Homie offers high-quality home appliances without the usual upfront costs. We come and install your appliance for free, and we provide free servicing in case any of your Homie appliances need to be repaired or replaced. With Pay-Per-Use, you just pay us with each wash. So, no more paying fixed monthly fees, even when you're on holiday. Instead, you only pay a fee when you actually use the appliance. To make our Pay-Per-Use service possible, a digital tracker is built into our appliances. This built-in tracker automatically sends the information to our Homie database, providing us with accurate and up-to-date information about your use, which allows us to calculate the fee for your use of the appliance. Based on your user data, we will provide you with personalised tips and tricks to become more environmentally friendly, and help you save more money by lowering your water and electricity usage. Circularity is at the heart of what we do. This means we do not just aim to make you use our products more sustainable, but we also repair and reuse our products when you no longer need them. This will help significantly lengthen their lifespan and lower the waste of materials and energy when they would have otherwise been thrown away.



4.3.2. Circular economy business models and printers

Printers are peripheral devices under the control of computers that can make a persistent representation of texts, graphics or photos on paper. Currently many printers can also work as copying machines or digital cameras to print directly without using a computer and even work reversely as scanners converting printed images or documents into digital formats being in fact office multifunction devices (MFDs). Initially, the printing technology was based on typewriters that was low in speed and quality. The development of line printers and dot matrix systems, that could mix text and graphics, increased speed and performance but still high-quality documents as blueprints were made by plotters. The introduction of laser printing, that is an electrostatic digital printing process, allowed the fast production of high-quality text and graphics and medium-quality photos by using a laser beam back and forth over a negatively charged cylinder called a “drum” to define a differentially charged image. The drum collects electrically charged powdered, the toner, and transfers the image to paper, which is then heated in order to permanently fuse the text, imagery, or both, to the paper. The toner, a mixture of fine plastic particles, carbon black and other substances, is contained in toner cartridges that are consumables of the laser printers. When colour printing is needed liquid inkjet and solid ink printers are used. To print, the inkjet printers propel droplets of liquid ink on pages meanwhile the solid ink printers melt coloured-waxes (cyan, magenta, yellow and black) and spray them on a rotating oil coated drum that transfer them to the pages. Typically, inkjet printers are the customer choice and solid ink printers are the professional option.

CEBM associated to laser printers and toner cartridges

As complex equipment, printers offer a wide range of opportunities for circular economy either extending their service life (by means of repair, refurbishment or remanufacture operations) or closing the components and materials loops (by means of reuse and recycling activities) or using fewer resources per product (by means of eco-design that optimise use of materials during manufacture and energy and consumables during use).

Printers remanufacturing: Remanufacturing consists on returning the old machines to a condition equivalent to new. Selected units to remanufacture are carefully taken back and inspected, cleaned, repaired (old parts are substituted) and software is updated and reset. The result is a fully functional product that can be sold and in which up to 90 % (weight basis) of the raw materials input has been saved.

Printers refurbishment: Refurbishment consists on a process that is less extensive than remanufacturing since it is limited to cleaning of the equipment, substitution of damaged parts and replacement of consumables. The result is a temporary extension of life as a second-hand equipment allowing both the access of customers to quality products at lower cost and the diversion of units that still can work from the end of life treatments.

Printers recycling: Recycling consists on a process in which materials on waste products are processed to separate secondary materials that can be incorporated into new products. In the case of WEEE recycling covers classification (the collected product are inspected and classified by practical categories: metal rich, small size, IT equipment, etc.), depollution (hazardous elements as batteries or substances as mercury or components as screens having a surface greater than 100 cm^2 are removed or disassembled involving manual work), shredding (the depolluted products are shredded in order to open them and liberate inner parts and materials using fully automated operations) and separation (materials are concentrated based on size, density or magnetic behaviour differences to separate copper, iron/steel, aluminium, plastics, etc. fractions that can be sold using fully automated operations). Approved WEEE recyclers fulfil requirements detailed Directive 2012/19/EU on WEEE.

Ownership and pay-per-printing models: Office equipment, such as printers and copy machines, is an archetype of using equipment as a service. Despite private customers usually own their printers, companies, instead of purchasing them, contract tailored printing services considering the number of printed pages per time unit (typically month or year), required quality (dots per inch) and speed (page per minute). Under this model printers remain property of the manufacturer that monitor them continuously. Mounted sensors in printers collect both alerts and data allowing predictive maintenance and performance improvement resulting in energy and consumables savings and extension of product life.

Printer cartridge collection programmes: toner cartridges are special consumables since many designs go beyond a simple container of toner or ink and incorporate more complex elements (as the cleaning blade, the control chips or the drum that transfer the toner to the paper) that can be used again if the cartridge is refilled.

Companies associated to CEBM and laser printers and toner cartridges

In 1990 the Japanese company Canon introduced a toner cartridge recycling programme that has been expanded from Japan to China, Europe and North America. By the end of 2017 up to 394000 tonnes of cartridges have been collected globally using this system. Canon also offers remanufactured multifunction devices as well as refurbished products as printers, Figure 7. The company maximizes value from its manufactured capital by collecting used equipment from the market, remanufacturing it and re-selling it with the same high-quality guarantee as original products. In reusing at least 80 % of the materials, Canon also reduces product greenhouse gas emissions associated with raw materials, parts and manufacturing by more than 80 % compared to a newly manufactured product. By capturing the components and materials directly, Canon offers customers a high-quality product with fewer environmental impacts at a competitive price.

Figure 7. Printers remanufacturing and refurbishment by Canon (source: https://www.wbcsd.org/Programs/Circular-Economy/Factor-10/Resources/8-Business-Cases-to-the-Circular-Economy)

The experience of Canon shows how companies can generate revenue from existing products by taking a circular economy perspective on their products, services and operations. Specifically, businesses have demonstrated positive contributions to their bottom line by remanufacturing, refurbishing and turning products into services.

The Japanese company Ricoh has its GreenLine™ Series of remanufactured equipment that allows the access to like-new MFPs (Multi-Function Printers) and printers with the added benefit of enjoying cost and environmental savings as compared to purchasing new equipment. The company has defined a 10-steps remanufacturing process (initial disassembly, cover removal, cover refresh, chassis disassembly, parts replacement, reassembly, troubleshooting & testing, software/firmware updates, final inspection, packaging) in which every selected unit is inspected, restored and tested, see Figure 8. This process assures industry-standard certifications (ISO 9001, ISO 14001 and UL Remanufactured) and equivalent product warranties as brand-new devices.

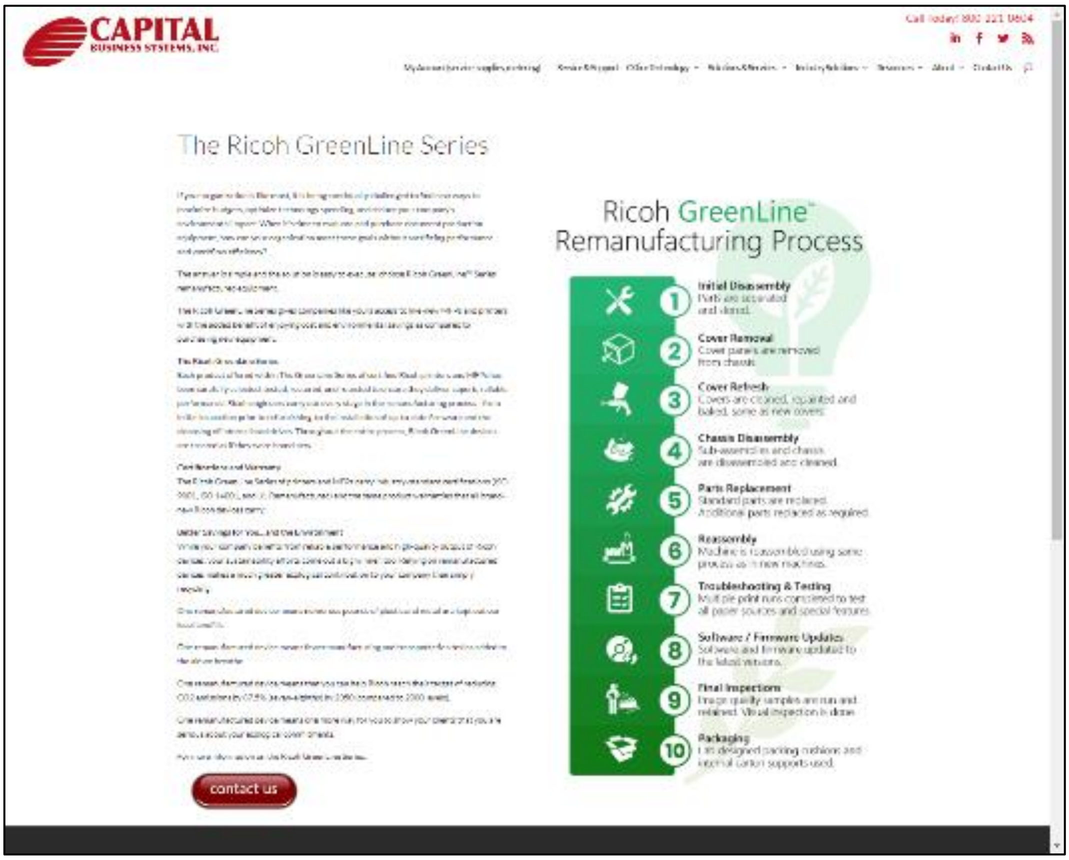
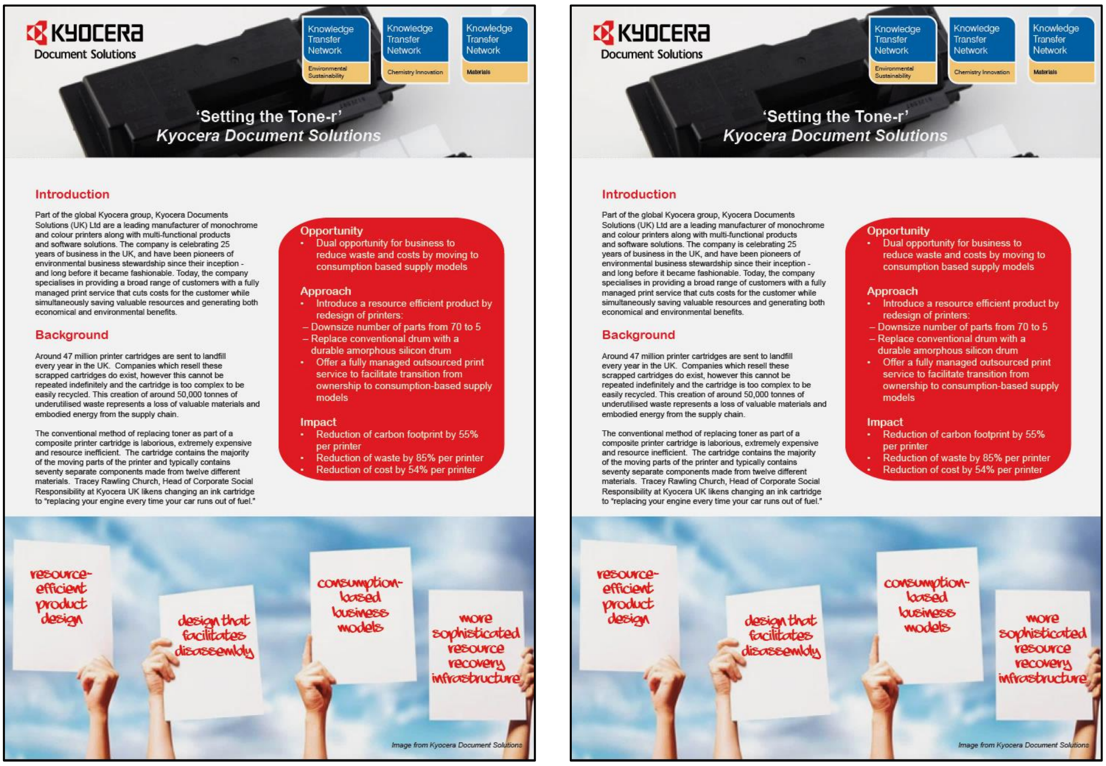


Figure 8. Remanufactured printers and remanufacturing process of Ricoh (source: https://www.capitalmds.com/ricoh-greenline/)

Printer remanufacturing made by Ricoh contributes to mitigate environmental impacts more than recycling since plastics and metals, that constitute the equipment, are kept in use and emission associated to product recycling or manufacturing and transport are avoided. In summary, a remanufactured device contributes to reduce CO_2 emissions and help companies using it to show its customers that are making serious environmental commitments.

The Japanese company Kyocera is a well-known example of design for disassembly. The company has redesigned its laser printers including concepts as “number of component parts downsizing” and “cartridge free” that have resulted in a 55 % carbon footprint reduction, an 85 % reduction in waste and a cost saving of 54 % per printer, Figure 9. Built with disassembly in mind, Kyocera printers can be taken apart with a single screwdriver and the use of metal fixings is minimised in favour of "clip together" components. In addition, plastic parts are embossed with a material code to identify the correct recycling process and a symbol to indicate the point where pressure may be applied to separate them.



KYOCERA
Document Solutions

Knowledge Transfer Network — Environmental Sustainability
Knowledge Transfer Network — Chemistry Innovation
Knowledge Transfer Network — Materials

‘Setting the Tone-r’
Kyocera Document Solutions

Introduction

Part of the global Kyocera group, Kyocera Documents Solutions (UK) Ltd are a leading manufacturer of monochrome and colour printers along with multi-functional products and software solutions. The company is celebrating 25 years of business in the UK, and have been pioneers of environmental business stewardship since their inception - and long before it became fashionable. Today, the company specialises in providing a broad range of customers with a fully managed print service that cuts costs for the customer while simultaneously saving valuable resources and generating both economical and environmental benefits.

Background

Around 47 million printer cartridges are sent to landfill every year in the UK. Companies which resell these scrapped cartridges do exist, however this cannot be repeated indefinitely and the cartridge is too complex to be easily recycled. This creation of around 50,000 tonnes of underutilised waste represents a loss of valuable materials and embodied energy from the supply chain.

The conventional method of replacing toner as part of a composite printer cartridge is laborious, extremely expensive and resource inefficient. The cartridge contains the majority of the moving parts of the printer and typically contains seventy separate components made from twelve different materials. Tracey Rawling Church, Head of Corporate Social Responsibility at Kyocera UK likens changing an ink cartridge to “replacing your engine every time your car runs out of fuel.”

Opportunity
- Dual opportunity for business to reduce waste and costs by moving to consumption based supply models

Approach
- Introduce a resource efficient product by redesign of printers:
  – Downsize number of parts from 70 to 5
  – Replace conventional drum with a durable amorphous silicon drum
- Offer a fully managed outsourced print service to facilitate transition from ownership to consumption-based supply models

Impact
- Reduction of carbon footprint by 55% per printer
- Reduction of waste by 85% per printer
- Reduction of cost by 54% per printer

Figure 9. Printer and cartridges eco-design for disassembling by Kyocera (source: https://connect.innovateuk.org/documents/3005437/0/Kyocera%20Case%20Study%20February%202014?version=1.0)

One concern of Kyocera is that in current WEEE regulations, targets are set according to the volume of waste collected and processed without considering the value of materials recovered. As generally EEE is not designed for disassembly, and there is no labelling scheme to enable products designed for disassembly to be easily identified, any WEEE is most likely to be shredded producing material cross contamination and hence low-quality recycled plastics. The way to take advantage of this design for disassembling is to involve recyclers able to identify the products implementing this feature and the technology to separate parts and produce high-quality recycled materials.

The American company HP is running its HP’s Instant Ink program. The program is an IoT enabled subscription model with 5 printing plans (pages/month) for individuals and small businesses [free 0.00 USD (15), occasional 2.99 USD (50), moderate 4.99 USD (100), frequent 9.99 USD (300), business $19.99 (700)] that increases cartridge recovery and recycling. The model uses connected printers to send customers replacement cartridges, along with pre-paid envelopes for returning used cartridges, before the customer runs out of ink, Figure 10.

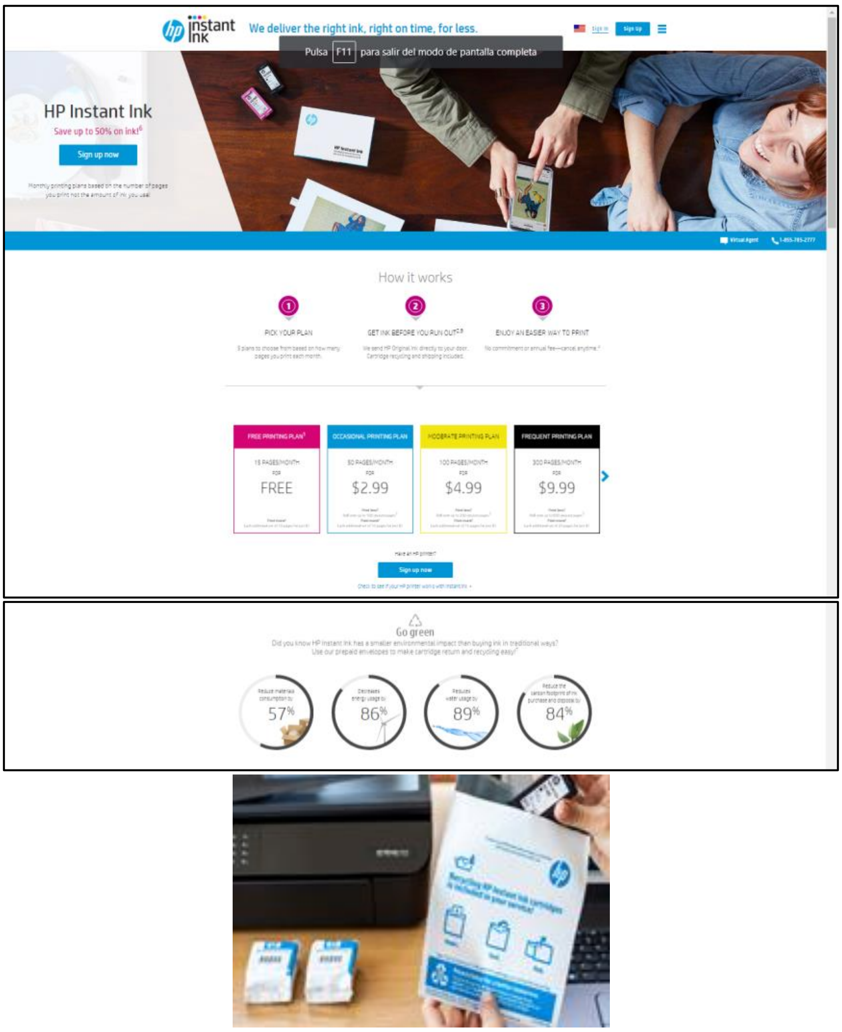


Figure 10. Ink jet printing subscription model by HP and envelope used in reverse logistic (source: https://instantink.hpconnected.com/us/en/l/)

The model successfully demonstrates a component recovery and recycling programme in the consumer electronics sector, as it enables HP to put their cartridges through multiple uses. Subscribers to the service pay a monthly fee based upon the number of pages they print. The connected printer notifies HP when the cartridge is about to run dry and signals to deliver a new one without the subscriber having to interact. Empty cartridges are collected and returned to HP as part of a 'closed-loop' recycling programme. The environmental impacts avoided by this printing program are reduction in materials consumption by 57 %, decrease of energy usage by 86 %, reduction of water usage by 89 %, reduction of the carbon footprint of ink purchase and disposal by 84 %.

The American company Lexmark, a world class provider of printing solutions supplying ink, toner and paper, is running the LCCP (Lexmark Cartridge Collection Program) since 1991. The program is designed to ensure that empty Lexmark print cartridges are properly recovered, reused or recycled; resulting in less solid waste and fewer resources consumed. The Cartridge or Equipment Collection Programs are available in more than 60 countries, are free to the consumers and designed to be easy to use, see Figure 11.

Figure 11. Ecobox and steps in the LCCP (Lexmark Cartridge Collection Program) (source: https://www.lexmark.com/en_us/products/supplies-and-accessories/collection-and-recycling-program/lccp.html)

In Europe, since 2017, the collected cartridges, up to 45 % of the ones put on market by Lexmark, are consolidated, sorted and shipped to a manufacturing facility in Żary (Poland) were applying a "zero waste approach" cartridges are prepared for reuse and materials separated for recycling, see Figure 12.

Figure 12. Lexmark print cartridges reuse and recycling facility in Żary (Poland) (source: https://csr.lexmark.com/sustainability-emea.php)

To support its LCCP in Europe Lexmark has a collaboration agreement with Syncreon and has joined the CER (Conseil Européen de Remanufacture/European Remanufacturing Council) and the CE100 Network of the Ellen MacArthur Foundation that respectively provides specialised support, remanufacture knowledge and evaluations of and recommendations for closed loops. Besides the circular activities around print cartridges, Lexmark also has a deep commitment with printer remanufacturing and refurbishment.

4.3.3. Circular economy business models and IT equipment

Dematerialization: In "A new circular vision for electronics – Time for a global reboot", the Platform for Accelerating the Circular Economy (PACE), a public-private collaboration dedicated to bringing about the circular economy in the EE sector, stresses the potential of cloud computing and the internet of things (IoT) to "dematerialize" the electronics industry. The rise of service business models and better product tracking and take-back could lead to global circular value chains. In the Netherlands, Signify (formerly Philips Lighting) sells lighting as a service. These are examples of electronics as a service.

Leasing and renting: Current leasing and rental models, with monthly contracts say for smartphones and even some televisions, allow global consumers to access the latest technology, particularly products with short lifespans and without high up-front costs. This new ownership allows the manufacturer to ensure that the resources are used optimally over a device's lifecycle. Instead of a one-off transaction, the business model shifts to one of an ongoing service, and the subscription economy. This builds a much closer and stronger customer relationship. This has already occurred with household modems in some countries. For example, Fairphone, a circular mobile phone company in the Netherlands, has launched "Fairphone-as-a-Service" and Dell in the US already has "PC as a Service".

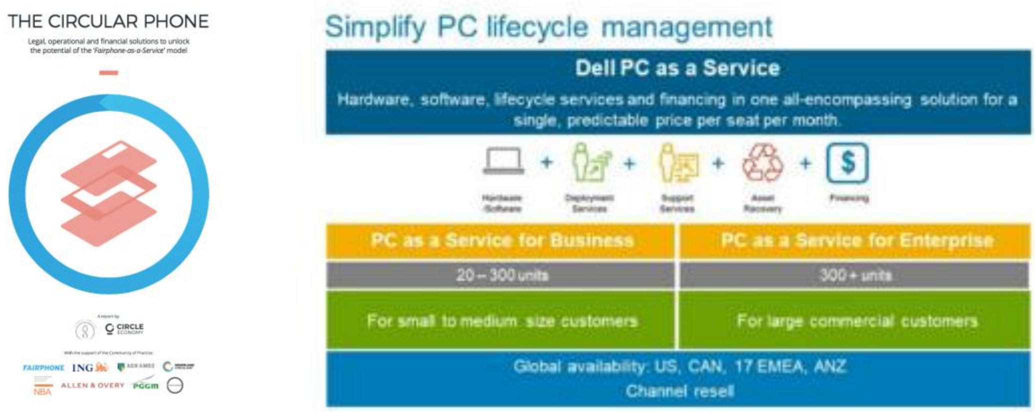


Figure 13. Fairphone-as-a-Service and Dell PC as a Service, examples of IT equipment renting/leasing models.

Extended lifetime: Agito Medical, is a provider of preowned medical equipment which has specialised in extending the life span of used medical equipment through its purchasing, refurbishment, remarketing and reselling. The company co-operates with medical equipment manufacturers (OEMs), clinics, hospitals and laboratories worldwide, and maintains an online database of available equipment and spare parts with its clients so they can find the products they need at better prices. This circular business model is an affordable alternative to new equipment for less privileged customers. Aside from direct sales, Agito Medical offers service contracts on CT and MRI equipment, such as delivering spare parts and engineering maintenance services. These services secure a maximum possible uptime of the equipment and prolong the lifespan of the entire system and prevent waste.

Repair, reuse and recycling: Having signed the “Capital Equipment Pledge” initiated by PACE, Cisco (provider of Network and Communication Equipment and Services) has significantly reduced the environmental impact of used electronic products through its end-of-life programs. The Takeback and Recycle Program is designed to harvest and reuse the materials contained in the equipment collected. Products are disassembled and then processed to retrieve materials such as steel, aluminium, copper, plastics, shredded circuit boards, and cables. These materials are returned to the market where they are made into new products. The program is open to all users of Cisco equipment and equipment branded by companies acquired by Cisco.

Recover-E® is a shared responsibility program that is firmly rooted in the circular economy, the products and the materials they contain can remain valuable and reusable for as long as possible. The Recover-E® Program was established in 2013 as a joint initiative between Royal HaskoningDHV and SiSo, who set up the Recover-E® Foundation for the sustainable reuse of depreciated ICT equipment. By involving everyone from product owner and user, to the collector and the recycler in this approach, there is no waste. Transparency is increased in the chain by encouraging each player to contribute to and take responsibility for the solution.

The Nordic Waste Prevention Group under the Nordic Council of Ministers initiated in 2015 a project named “Moving towards a circular economy – successful Nordic business models” which had the overall objective of making the circular economy-thinking more mainstream in the Nordic countries and hereby accelerate the development of circular economy in the Nordic countries. As a result of the work done by this group, a report was published gathering 18 remarkable experiences of Nordic businesses which are part of the Nordic circular economy (Kiørboe, et al., 2015).

The business model of the Swedish company, Godsinlösen, is based in recycling and reselling damaged insured goods, operating in collaboration with insurance companies and policy holders. On request by insurance companies, Godsinlösen retrieves damaged goods from this companies and ensures that they are reused or recycled, as effective and transparent as possible in line with environmental standards. Redeemable goods are sold in Returhuset, a retail store owned by the company. A large share of the products are mobile phones, laptops and tablets. The net income from this aftermarket is shared between the insurance company and Godsinlösen. This business model thus allows the service provided by Godsinlösen to be mainly self-financed, and often creates a profit to the insurance company. All activities aim to close material loops by repairing EEEs.

Mazuma Mobile is an online mobile phone re-use and recycling service allowing consumers to unlock the cash value of their mobile phones – offering same day payments. If necessary, the handsets are refurbished by an external partner, and then sold to emerging markets and to insurance dealers and retailers in the UK. The majority of phones received can be re-used, provided they are refurbished. Phones that do not work are recycled for secondary raw materials (techUK, 2015).

Samsung UK has the strategy to bring customer support interaction closer to their customers by providing Support Centre locations across the UK. These repair centres offer full on-site repair facilities for all Samsung smartphones and tablets. All repairs are carried out by fully trained staff using genuine Samsung parts. However, Samsung research found that 30 % of all repairs in support centres could have been fixed by remote management support. The Samsung Smart Tutor app was developed to give customers dedicated support from a qualified expert who can check devices remotely to examine and improve performance.

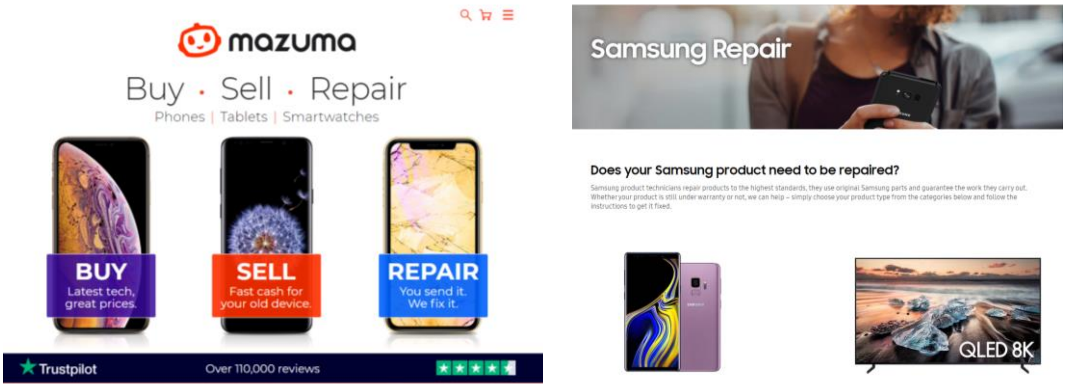


Figure 14. Mazuma mobile and Samsung Repair offer mobile phone refurbishment operation services.

Closed-loop systems recycle and re-use materials repeatedly, reducing the need for virgin materials while avoiding the creation of waste. A key component of closed-loop systems is the idea that recycling comes from the same product or same industry. The Dell computers closed-loop system uses plastics derived from the computers that the company takes back.

4.3.4. Circular economy business models and TVs

According to YouGov research 30 % of people purchase a new TV at least once every five years, with a quarter of people recycling their old TV and 24 % giving their old TV to a friend or family member. Yet 12 % simply threw their old TV away and 8 % still have their old device stored in their house, which could be recycled.

CEBMs associated to TVs

TV rental/lease: TV rental businesses have been operating for decades, and nowadays still a large number of companies offer TVs and other home appliances based on pay-per-week or pay-per-month systems. Many offers as well refurbished or reconditioned items, at a lower cost. While the cost of these services is usually not attractive to home users who can afford buying the item upfront, there are a number of cases where the deal can be interesting (short-term renting periods for example, or shared use). However, the renting option is more interesting for business or organisations who need to use TVs for a short period of time (conferences, meetings, trainings, etc.) and many corporate customers who offer the TV services as part of their business (hotels, stadiums, hospitals, etc.).

For example, Panasonic will start a fixed-rate rental service in Japan for home appliances in 2020, and also expand on a trial TV rental program launched in February 2018 with plans to collect customer data from a wider variety of products. Profits from the subscription model are not yet fully proven though, which is why the model has to be tested for different markets and adapted to the consumer’s needs. Panasonic will use the program to gather data such as what TV channels users watch and when, to use in crafting sales promotions and developing new products and services.

Details such as prices will be set based on knowledge gleaned from Panasonic's existing TV rental service. The company offers a range of seven TV models, with screens from 49” to 65” and display options such as ultra-high-resolution 4K or organic light-emitting diode technology, for monthly fees ranging from 28 € to 120 €. Users can sign three- or five-year contracts, after which they can choose to pay a fee and keep using the set or switch it out for a new one. A 55” OLED TV that retails for about 2800 €, for instance, can be rented for a monthly fee that starts at 81 € and then falls to 65 € from the second month. Customers will be able to sign up for rental services at 2500 of Panasonic's affiliated retail stores throughout Japan. The company hopes interacting with customers more in person will help to sell them other products.

TV refurbishment / recycling: Discarded LCD TVs is the fastest-growing stream of electronic waste in the EU, with an estimated 25000 discarded since 2004 and a growth rate of up to 28 per cent every five years (Hislop & Hill, 2011). Among the challenges of recycling LCD TVs are: they come in large number of different sizes, design and configurations, making automated disassembly impractical; their screens often contain mercury, which presents a hazard during the disassembly process, but few are labelled as such; the liquid crystals used in the screens could be recovered, but it is hard to identify which type has been used in any particular model; a variety of adhesives are used, varying sometimes even within the same model type, so it is hard to identify the right solvent to use to separate components; the economics are challenging: the indium used in the screens is a metal identified as critical by many commentators, but prices are low compared to precious metals, and the amount per device is low, making recovery uneconomic. The new generation of LED screens are non-hazardous, and easier to dismantle with automated systems although, unfortunately, there is still the risk of contamination from the historic legacy of toxic LCDs that are not spotted as they go through the machinery.

Company: Veolia
Location: Shropshire, UK
Business innovation: At Veolia, state-of the-art facilities can give flat screens and monitors a second, third or even a fourth life. At their RoboTele facility in Bridgnorth, Shropshire, they dismantle and recycle over half a million screens every year. That's the equivalent of more than 2500 tonnes of Waste Electrical and Electronic Equipment (WEEE) that is turned into a resource to make new products. The process uses robots to remove each screen without damaging the surrounding case. A second robot safely traps the mercury inside the tubes by injecting a wax mixture, before they are cut and removed for further recycling. Using a shredding line, they can extract non-ferrous metals such as copper and aluminium and any plastics are segregated by hand and sent to a recycler to be turned into plastic granules to make new TV frames. Finally, the circuit boards containing gold, silver and platinum are removed by hand and sent to a specialist third party to extract the precious metals and make new circuit boards for new TVs and computers. This allows Veolia's recycling to go full circle, closing the loop again and again. According to the company, using advanced robotics technology, 'ROBOTELE', the plant has the capacity to collect approximately 300000 obsolete TVs and monitors each year, through its nationwide network of Household Waste Recycling Centres.
Signals of success: During the run up to the FIFA World Cup in 2018, Veolia received 65 % (10500 units) more flat screen TVs at its recycling facility in Shropshire (UK) as compared to the amount received in 2017. The tonnage of flat screens and monitors processed at ROBOTELE has quadrupled since it became operational in October 2016.

Source: https://www.veolia.co.uk/press-releases/tvs-moscow-recycling-bin

5. Methodological support for the demonstrations

5.1. CEBMs Performance Assessment

To determine whether a CEBM is attaining the desired objectives, organisations need to measure their performance by means of indicators. Key Performance Indicators (KPIs) have a long and diverse history, but they are traditionally divided into two main categories:

1. financial or cost-based indicators measuring the financial performance of a business
2. nonfinancial or non-cost-based indicators measuring the operational performance

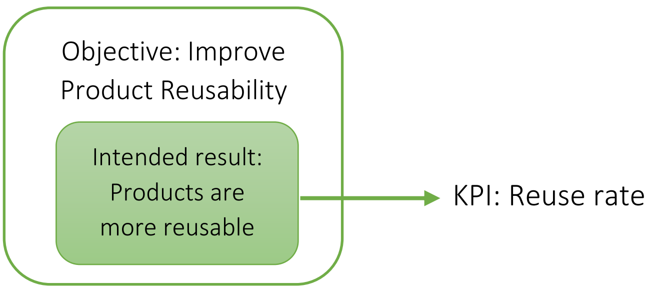
Since the 1980s, nonfinancial indicators have been gaining popularity as opposed to the conventional financial indicators due to the growing complexity of organizations and the constantly changing market expectations.

In order to select a meaningful set of KPIs to measure the performance of any BM, it is important to understand what they are and how they should be used.

5.1.1. Key Performance Indicators

KPIs are the critical (key) indicators of progress toward a desirable outcome. The selection of relevant KPIs is therefore a crucial step in order to perform a valid assessment. Several rules apply when selecting KPIs:

- They must be expressly quantifiable (number, percentage, rate of…). They are not initiatives, actions or tasks (e.g. "redesign the components").
- Before starting to measure anything, the objectives pursued by the strategy must be clear, therefore it is essential to define first the strategy, then the objectives.



- It is important not to confuse goals / objectives with KPIs. The objective is the desired outcome or result. KPIs are the metric or indicator that tells whether the objective is being achieved.

- KPIs require a comparative context to be meaningful. It is important to set targets for each KPI which define the desired level of performance, and/or to have a scale defining if the level of performance is good, average or poor. Many measures are best expressed as ratios: percent completion, fraction of the total possible, efficiency (output/input), productivity (output/cost), etc.
- Having a framework to organize the KPIs helps to understand the results. Frameworks can be built are different levels, some are high-level strategy and others are at operational level. They are useful to contextualize KPIs and relate them to processes and articulate cause-effect stories.
- KPIs should allow the analysis of the process at a meaningful level. If the KPI is set at too high level, it may not be possible to detect which processes are contributing and in which measure, which in turn makes it difficult to extract conclusions and take corrective actions.
- KPIs should be simple to understand and use and stimulate continuous improvement.

Table 9. SMART criteria for KPI selection

SPECIFIC	Must be defined in a clear and precise form
MEASURABLE	Must be measured by metrics in order to quantify results
ACHIEVABLE	Must be in accordance with available resources and time
RELEVANT	Must be aligned to your goal and strategy
TIME-BOUND	Must have an allotted period of time to complete

5.1.2. Choosing a framework: The Balanced Scorecard

The KPIs need to be defined after setting the strategy and objectives of the CEBM and are usually incorporated into measurement systems to facilitate their application. The aim is to convert strategy into a consistent combination of indicators. Both in literature and in practice, one of the most well-known Strategic Performance Measurement System is the Balanced Scorecard.

The Balance Scorecard (BSC) is a tool for strategic planning and management developed by the US management consultancy firm Nolan, Norton & Co. in 1990. The tool aims to explore the overall performance evaluation of the organization in line with the strategy adopted. It can be used to communicate, plan, prioritize and monitor projects, products or services. It is one of the most widely employed frameworks for KPIs as it can be adapted to different organizational patterns, characteristics and life cycles.

The BSC covers four dimensions: Financial, Customer, Internal Processes and Growth, each of them containing their own set of descriptors.

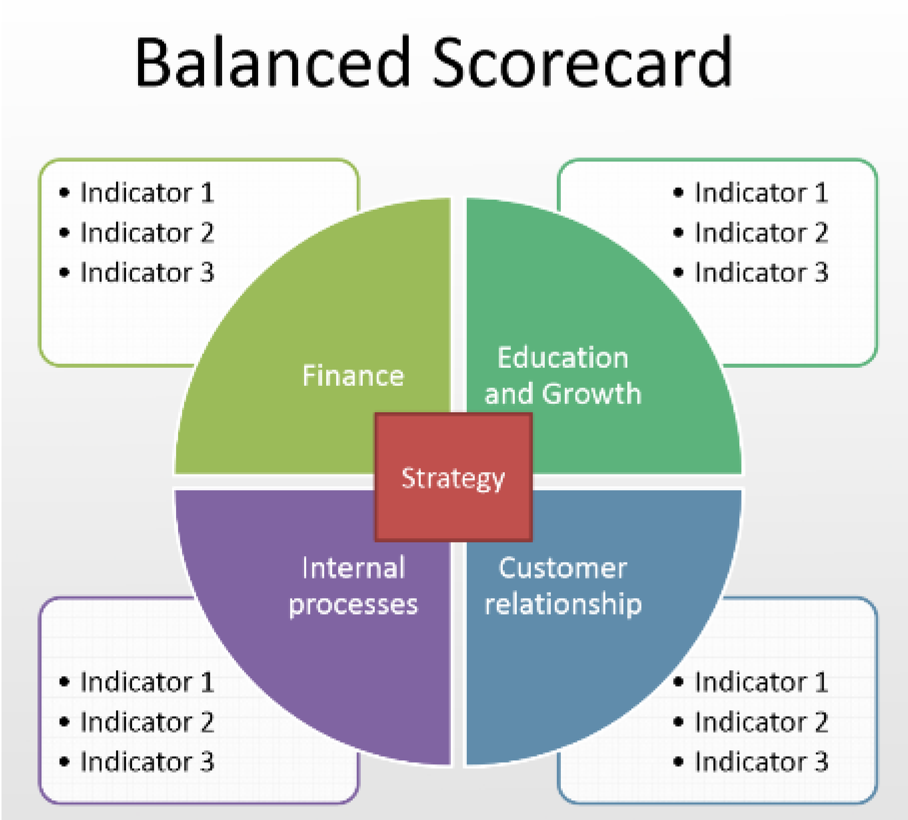


Figure 15. Typical Balanced Scorecard model (BSC Designers)

(1) Financial perspective

The financial perspective represents the financial performance of the organizational operations. It relates to the interests of the shareholders and the financial impact of strategic objectives. Usually, means pursuing solely revenue growth, increasing productivity, cost reduction and financial risk management.

Examples of criteria or KPIs related to this dimension are:

- Revenue growth
- Productivity
- Return of capital employed
- Cost management

(2) Customer perspective

The customer perspective represents the way a company can create value to the customer through policy and action. It can be categorized into market share, customer acquisition, customer retention, customer satisfaction and customer profitability.

Examples of criteria or KPIs related to this dimension are:

- Customer satisfaction
- Customer continuation rate
- Market share

(3) Internal business process perspective

The internal process perspective relies on the analysis of the BM's value chain: innovation process, operational process, post-sales process. It translates into organizing internal processes optimally in order to meet the client's needs.

Examples of criteria or KPIs related to this dimension are:

- Innovation process
- Business process
- Service
- Information system capabilities

(4) Learning and growth perspective

The learning and growth perspective deals with the improvement in the competitiveness of the organization and its human resources to accept the challenges to be faced in the future. This perspective has three major components: employee's capabilities, information system's capabilities and motivation, empowerment and alignment.

Examples of criteria or KPIs related to this dimension are:

- Employee satisfaction
- Employee continuation rate
- Employees' ability
- Internal communication

For the last two decades, environmental and social issues have gained increasing strategic relevance for businesses, since they very often represent risks (e.g. negative press coverage or consumer boycotts) or opportunities (e.g. positive effects on corporate reputation, differentiation through eco-products). Thus, the original BSC has been modified into versions that explicitly consider environmental, social or ethical issues, including a fifth layer or dimension to the BSC, or integrating these into the four existing dimensions. These versions are often referred to as sustainability balanced scorecards (SBSCs).

The aim of the BSC is always to support strategy implementation. The main challenge is to create a balance between the different dimensions and select KPIs with clear cause-effect that represent all relevant aspects of the BM and can be quantified effectively to determine the success of the selected strategy. Each initiative, KPI or objective should be assigned to a responsible person or team who will periodically measure its performance and is in charge of establishing and/or enforcing correcting measures in case they are needed.

5.2. C-SERVEES CEBMs assessment

5.2.1. Key Performance Indicators

During the development of Task 2.1, CIs relevant for the E&E sector were explored and defined for each of the life cycle stages of E&E products, as shown in Figure 16.

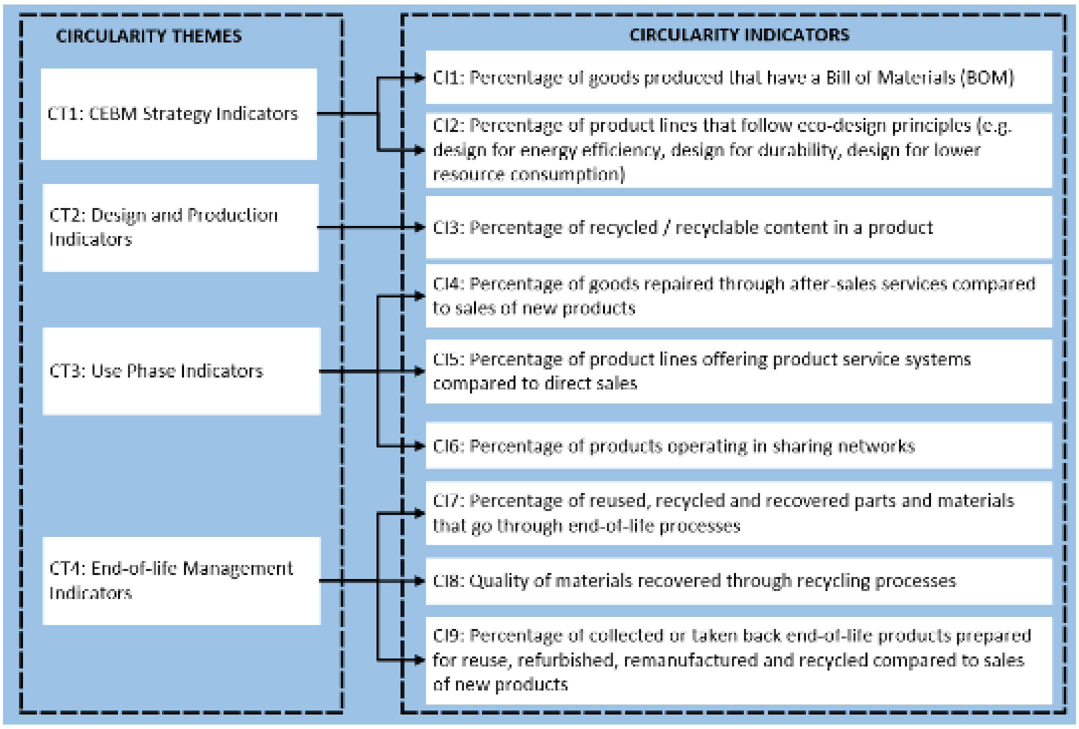


Figure 16. REF-CIRCMODE Layer 5: Circularity Indicators (Deliverable D2.1)

According to the circularity themes already defined for the C-SERVEES, each CEBM should have a set of CIs for 1) CEBM Strategy, 2) Design and Production phase, 3) Use Phase and 4) End-of-Life Management.

CT1 - CEBM Strategy

The purpose of these CIs would be to measure the rate of development, effectiveness or success of the selected strategy in the company. Suitable indicators for this category are shown below (in green the CIs identified within Task 2.1):

- Percentage of goods produced that have a Bill of Materials (BOM) (CI1).
- Percentage of product lines that follow eco-design principles (CI2).
- Number of products or services associated to the CEBM.
- Product recyclability rate (%, efficiency, number and diversity of components, ease of separation…).
- Product repairability rate.
- Product remanufacture rate.
- Product durability and reutilization rate.
- Number of collaborations, contractual or service level agreements or purchase policies related to the structure of the CEBM.

- Percentage of invoices/euros generated in the purchase of products or services related to circular economy.
- Number of internal tools developed to assess circular economy (LCAs, SLCAs, LCCs).
- Investment (€) in activities or processes related to the CEBM.
- Employment generated by the CEBM.

CT2 - CEBM Design and Production Phase

The purpose of these CIs would be to measure the implementation rate of CE-related production and design changes relevant to the CEBM strategy. Suitable indicators for this category include:

- Percentage of recycled/recyclable content in a product (CI3).
- Percentage of recycled materials used during the productive process in substitution of raw materials.
- Number of eco-designed parts or components.
- Reduction in total energy consumption or per unit of product.
- Reduction of total water consumption or per unit of product.
- Recovery rate of waste and packaging from productive processes.
- Percentage of renewable energies in the energy mix.
- Percentage of recycled materials in the products/components received from providers.

CT3 - CEBM Use Phase

The purpose of these CIs would be to measure the effectiveness of the selected CEBM strategy in terms of prolonging the functional use time of the product. Suitable indicators for this category include:

- Percentage of goods repaired through after-sales services compared to the sales of new products (CI4).
- Percentage of product lines offering product-service systems compared to direct sales (CI5).
- Percentage of products operating in sharing networks (CI6).
- Increase in the functional use time of the product.
- Reduction in total energy consumption per functional lifetime of product.
- Reduction of total water consumption per functional lifetime of product.
- Amount in euros of the income related to reuse or repair of products.

CT4 - CEBM End-of-Life Management

The purpose of these CIs would be to measure the improvement in the end-of-life management operations related to CE. Suitable indicators for this category include:

- Percentage of reused, recycled and recovered parts and materials that go through end-of-life processes (CI7).
- Quality of materials recovered through recycling processes (CI8).
- Percentage of collected or taken back end-of-life products prepared for reuse, refurbished, remanufacture and recycled compared to sales of new products (CI9).

- GHG emissions avoided through recycling practices.
- Collaboration agreements or contracts with recyclers.
- Cost savings due to waste reduction, correct classification or reselling of waste.
- Waste valorisation rate.

5.2.2. The C-SERVEES CE Balanced Scorecard

In order to provide a methodological support tool to measure the performance of the C-SERVEES CEBMs during the demonstration period, a modified version of BSC has been developed in the framework of WP4. It relies on the basic structure on the BSC to include all relevant KPIs / CIs related to each of the four CEBMs, categorizing them into two groups: Business Performance Indicators and Business Circularity Indicators.

Business model performance indicators

These are general performance indicators for the CEBM, in accordance to the four original dimensions of the BSC: financial, internal, customers and learning. They relate to the general strategy chosen for the CEBM and measure the success of the implemented actions, changes or approaches based on the definition of the CEBM carried out in WP2. Examples are provided within each dimension, although the definitive indicators will be selected once the product specific CEBMs have been finalised and according to the strategic goals set for each CEBM.

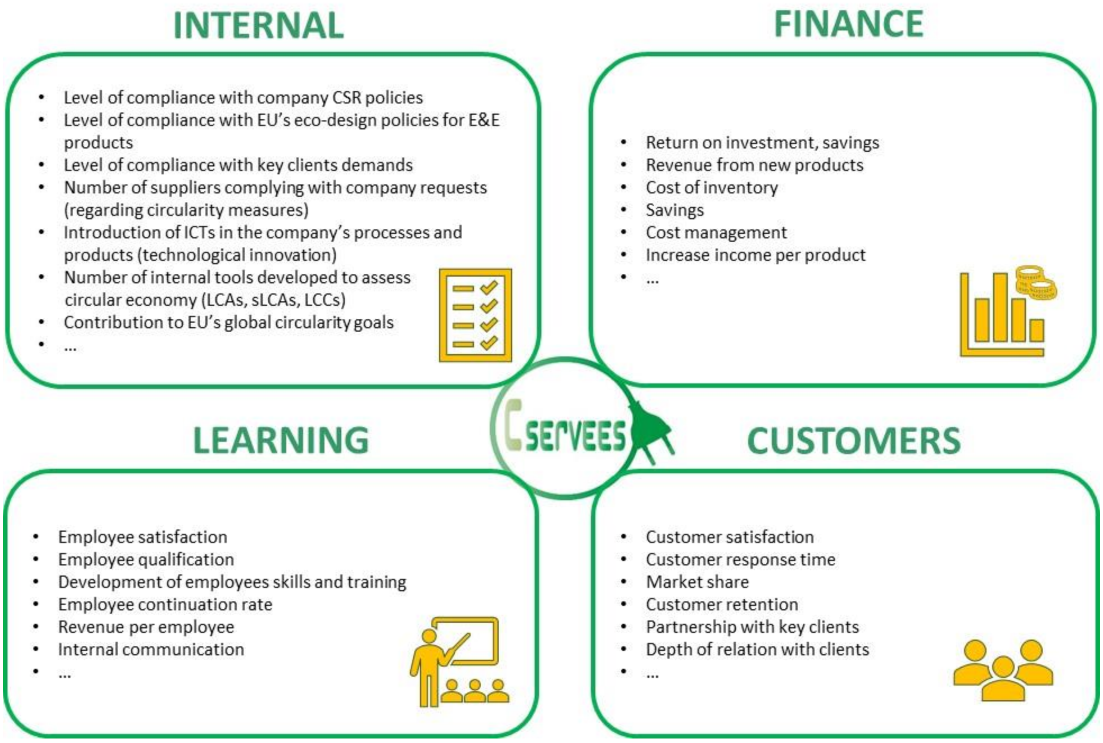


Figure 17. Preliminary list of CEBM Performance Indicators for C-SERVEES demonstrations

The internal dimension is derived from the global sustainability strategy of the company, which in turn can be conditioned by and aligned to the current EU policies for sustainability in the E&E sector. The internal dimension is therefore directly related to the selected CEBM strategy, defined by Layer 1 of the REF-CIRCMODE and the CIs in this dimension should reflect how the strategy goals are being met along the demonstration period. The KPIs in this dimension should reflect how the CEBM objectives (strategic CEBM goals) are aligned to the strategic objectives and goals of the company regarding their sustainability and CE roadmap.

The financial dimension comprises KPIs that reflect the state of the CEBM in economic terms. This is closely related to the economic analysis of the CEBMs that will be carried out during WP5. The KPIs should be selected to measure every finance aspect of the CEBM in terms of revenues vs. costs and invest vs. return.

The learning dimension relates to measures that show how training and social related aspects add value to the CEBM. The KPIs should show if the CEBM is improving internal communications, employee satisfaction, productivity, etc. This is also closely related to the social LCA to be carried out in WP5.

The customer dimension concerns metrics that evaluate all customer-related aspects for the CEBM: customer satisfaction, number of new customers acquired, market share, customer response time, etc.

Business model circularity indicators

These are specific circularity indicators for the CEBM strategy, categorized into the three circularity themes each demonstration will be covering: CEMB design and production phase, CEBM use phase and CEBM end-of-life management. These set of indicators should provide quantified measurement of the performance of the CEMB in terms of circularity, i.e. how effective the internal processes and measures implemented are being to achieve the success of circularity goals set by the CEBM.

Once the strategy of the CEBM has been defined, it must be translated into actions needed to achieve the desired strategy. Depending on the type of strategy, they may fall into any or all of the three phases in the product’s life cycle: design and production, distribution and use, or end-of-life management. **¡Error! No se encuentra el origen de la referencia.** shows some examples of CEBM strategies with their operational goals and CIs specifically aligned to each life cycle phase.

The complete list of relevant CIs for each demonstration will be defined once the action plan has been finalised. Figure 18 shows a preliminary list of tentative CIs according to the Circularity Themes CT1-CT4 described above.

Table 10. Examples of circularity indicators for the CEBM assessment.

STRATEGY	STRATEGY CIs	DESIGN & PRODUCTION CIs	USE CIs	END-OF-LIFE CIs
Building products to last	- Increase the repairability of the product	- Number of eco-designed parts in the product to make it more easily repairable	- Number of hours spent in repair operations	- Number of products reaching end-of-life per year
Product as a service	Implement PSS for the product	- Increase in production rates attributed to the PSS - Cost of unit produced for PSS	- Number of products in use	- Number of products returned

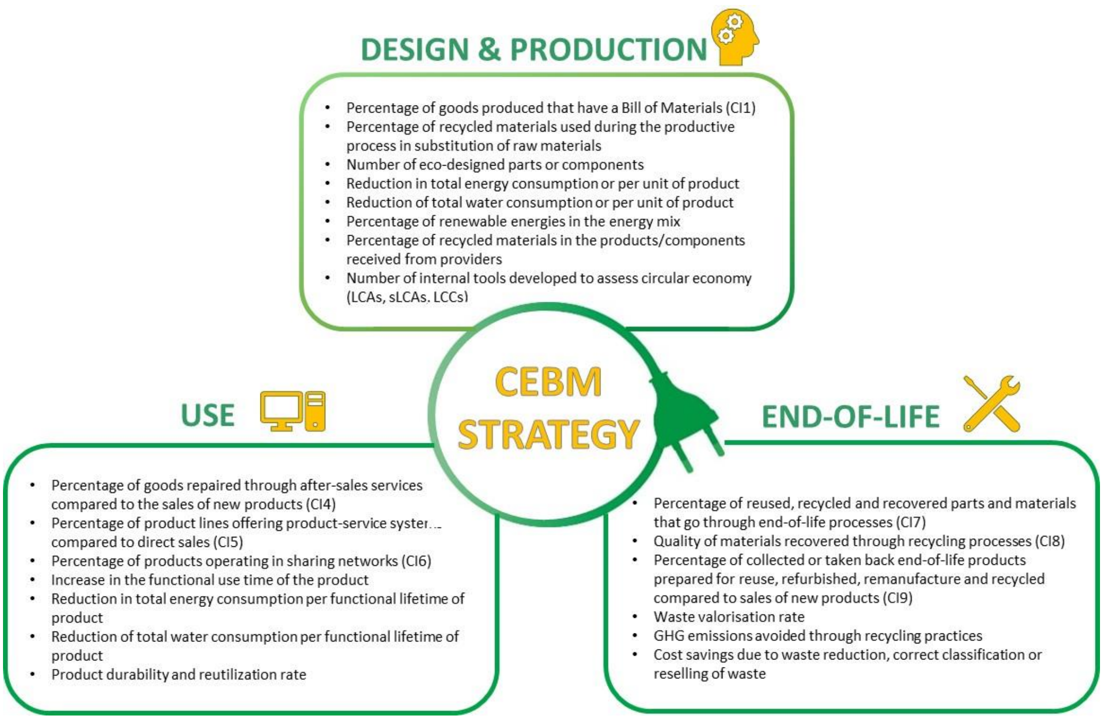


Figure 18. Preliminary CEBM Circularity Indicators for C-SERVEES demonstrations

The design & production dimension relates to the impact of the changes introduced to the design of the product or the production processes due to the CEBM strategy. For example, if the "building products to last" strategy necessitates the eco-design of a certain part of the product to make it more easily repairable or upgradeable, the CI in this dimension could include the quantification of the product repairability or upgradeability rate, which can be evaluated before and after the changes were implemented.

The use dimension concerns the impact of the changes introduced by the CEBM to the use phase of the product, for example measuring the extent to which the product's functional lifetime is prolonged and all associated operations to achieve this goal. It may also measure the improved energy efficiency of an eco-designed product or the number of repair operations needed.

The end-of-life dimension is related to the improvements achieved through end-of-life management processes as a result of the CEBM implementation. It measures the performance of recycling and recovery operations, once the functional period of the product is spent.

5.3. Procedure for C-SERVEES demonstrations evaluation

According to the methodology developed in the REF-CIRCMODE (D2.1) and using the evaluation tool proposed here, the evaluation process of the C-SERVEES demonstrations would comprise the following steps:

1. Definition of the CEBM strategy for the selected product, according to the research carried out and provided in D2.1 (Table 4).
   - Circular supply chain (use materials sourced from waste).
   - Recovery and recycling (recover materials from waste).
   - Building products to last (repair and maintenance or reuse through second ownership).
   - Sharing platforms (using and sharing products and ownership).
   - Product as a service (purchase or subscription of a solution rather than a product).

2. Definition of the strategic goals to be tackled under the C-SERVEES timeframe (from the overarching strategy goal set developed in the product-specific CEBMs (D2.2 – D2.5 to be delivered by Month 21).

3. Definition of the specific action plan for the demonstration based on the strategic goals including all activities to be developed in the demonstration period.

4. Definition of the C-SERVEES KPIs and development of framework (evaluation tool) containing both General Business Indicators and Circularity Indicators, by choosing the most relevant KPIs for each of the dimensions involved. This evaluation tool will be customized for each of the demonstrations, according to their chosen strategies and objectives. The evaluation tool must be supported by the product specific CEBM (D2.2 – D2.5) and the initial LCA, LCC and S-LCA carried out in WP5, which together with the preliminary exploration carried out in WP4 will allow to determine the most relevant KPIs to include in the framework for each of the demonstrators.

5. Establishment of an evaluation procedure: assign each of the KPIs to specific persons/teams involved in the demonstration and set periodic evaluation dates.
   - Assign responsible team/person to KPI.
   - Establish target for each KPI.
   - Define periodic evaluation dates.
   - A proposal for evaluation template is given in Table 11.

6. Periodic operational meetings between all partners involved in the demonstration, to share and discuss performance and actions to be carried out for the consecution of the set objectives and the strategic goal.

Table 11. Evaluation sheet for the C-SERVEES demos (proposal).

	Dimension	KPI / CI	Responsible	Evaluation date	Target	Result	Corrective measures
GENERAL BUSINESS INDICATORS	Financial						
	Internal						
	Customer						
	Learning						
CIRCULARITY INDICATORS	Design & Production						
	Use						
	End-of-life						

5.4. C-SERVEES demonstrations overview

The following table shows a global overview of the C-SERVEES demonstrations according to the steps already given towards the definition of a product specific CEMB and associated action plan for the demonstration activities. This will be further refined with the completion of the BM exploration and definition of detailed action plan for each demonstration.

Table 12. Development plan for the C-SERVEES demonstration activities (preliminary).

	ARÇELIK	**LEXMARK**	**ADVA**	**ARÇELIK**
Demonstration product	Washing machine	Laser printer	ALM	TV set
Strategic goal for the demo	Increase circularity by means of eco-design and explore leasing opportunities	Increase circularity by implementing / enhancing take back and refurbishment operations	Improve the circularity and recycling process of the ALM by means of eco-design	Increase circularity by means of eco-design and implement leasing for the first time
CEBM archetype	Circular supply chain Sharing platforms Product as a service Building products to last Recovery and recycling	Circular supply chain Sharing platforms Product as a service Building products to last Recovery and recycling	Circular supply chain Sharing platforms Product as a service Building products to last Recovery and recycling	Circular supply chain Sharing platforms Product as a service Building products to last Recovery and recycling
Action plan (demo objectives)	• Select sustainable raw materials • Increase recycled content in selected parts/components • Implement leasing • Improve repair and reuse	• Improve logistics to recover EoL products • Improve refurbishment operations • Improve recycling process	• Implement eco-design for recycling • Improve logistics to recover EoL products • Improve recycling process	• Expand functional life through eco-design and customization • Increase recycled content in selected parts/components • Implement leasing
ICT functionalities (to be explored)	• Equipping products with a unique identifier and digital twin on blockchain • Tokenisation of product materials in order to allow tracking • Connecting suppliers on blockchain • Allowing smart questions on the product materials	• Equipping products with a unique identifier and digital twin on blockchain • Tokenisation of product materials in order to allow tracking • Connecting suppliers on blockchain • Allowing smart questions on the product materials • APP for takeback • Retrieving of product status information	• Equipping products with a unique identifier and digital twin on blockchain • Tokenisation of product materials in order to allow tracking • Connecting suppliers on blockchain • Allowing smart questions on the product materials	• Equipping products with a unique identifier and digital twin on blockchain • Tokenisation of product materials in order to allow tracking • Connecting suppliers on blockchain • Allowing smart questions on the product materials

6. Assessment of existing scenarios/baseline for each demonstrator

In order to develop a common framework for the demonstrations according to the WP4 WIP, a series of steps have been taken to determine the baseline scenario for each C-SERVEES demonstration product.

- Collect information on the selected product: physical dimensions and weight, technical characteristics (energy class, power consumption, noise…), specifications (colour, functionalities…).

- Collect information on the current BM for the product, based on the Osterwalder and Pigneur BM canvas template. In order to facilitate information collection and ensure all canvas components were fully described, a guidance document with questions was provided to the manufacturers. The current business models for the four demonstration products are presented below, adapted from the original canvas model for schematization and confidentiality purposes.

- Develop a Process Flow Chart for data collection regarding the material flows along the value chain of the selected products. The initial step has been to prepare a schematic of the process charts including all the material flows involved in the life cycle of the demonstration product, from the manufacture until the end-of-life treatment. Once the flows are determined, the second step is to quantify each of them in order to study the Material Flow Analyses for the four demonstrators.

6.1. Washing machine demonstration

6.1.1. Product description

The selected washing machine is Arçelik 9123 WF (7150370100), with a 9 kg capacity, max spinning 1,200 rpm, energy efficiency class A^{+++} (-30 %) and connectivity features. It is manufactured in Çayırova (Istanbul) and currently sold in the Turkish market. Arçelik is selecting this model for its smart home technology, which allow the users to access the HomeWhiz app from their mobile phones or tablets and control the smart features introduced in the product (switch on and off, program selection, user instructions etc.).

By using connected products, Arçelik will have a chance to collect data and learn customer usage habits in order to improve their customers' experience and offer maintenance and repair services to extend product life.

The chosen washing machine has almost 10 % recycled material and Arçelik aims to increase it further, improving the circularity of the product.

Table 13. Technical specifications of the washing machine demonstration product.

Model	Arçelik 9123 WF
Image	
Prod. num.	7150370100
Colour	White
Dimensions	840 mm × 600 mm × 610 mm
Weight	75 (±4) kg
Capacity	9.0 kg
Max. spin speed	1,200 rpm
Fascia	Grundig
Dynamic group	Large
Energy class	A^{+++} (-30%)
Energy consumption per year	152 kWh
Water consumption per year	10999 L

Number of programs	16
Recycled content	9,79 %
Features	HomeWhiz, ProSmart (Brushless Motor with 10-year guarantee) Wifi and BLE Steam Function Anticrease+

Table 14. General part breakdown of the washing machine demonstrator.

WASHING MACHINE					
Part/component	**Material(s)**	**Contains recycled material? Yes/No**	**type and % of recycled material**	**Potential for eco-design Yes/No**	**Potential for customization Yes/No**
Tub (plastic part)	PP with additive (Arçelik formula)	Yes	5 % recycled content	Yes	Yes
Tub (plastic part)	PP with additive (Arçelik formula)	Yes	5 % recycled content	Yes	Yes
Tub (plastic part)	PP with additive and %10 rPET (Arçelik formula)	Yes	5 % recycled content	Yes	Yes
T5ransport safety sleeve	PP with additive	Yes	100 %	Yes	No
Front door glass	glass	Yes	---	No	No
Rubber parts (gasket)	EPDM	Yes	10 %	Yes	Yes
Control panel front door plastic part	ABS - white	No	-	Yes	Yes
Control panel front door plastic part	ABS - grey	Yes	100 %	Yes	Yes
Styrofoam	EPS	No	-	Yes	No
Packaging	LDPE	No	-	Yes	No
Motor board	PC/ABS	Yes	40 %	Yes	No
Shock Absorber, hose holder	PA6.6	No	-	Yes	No
Front door cover	PMMA	No	-	Yes	No

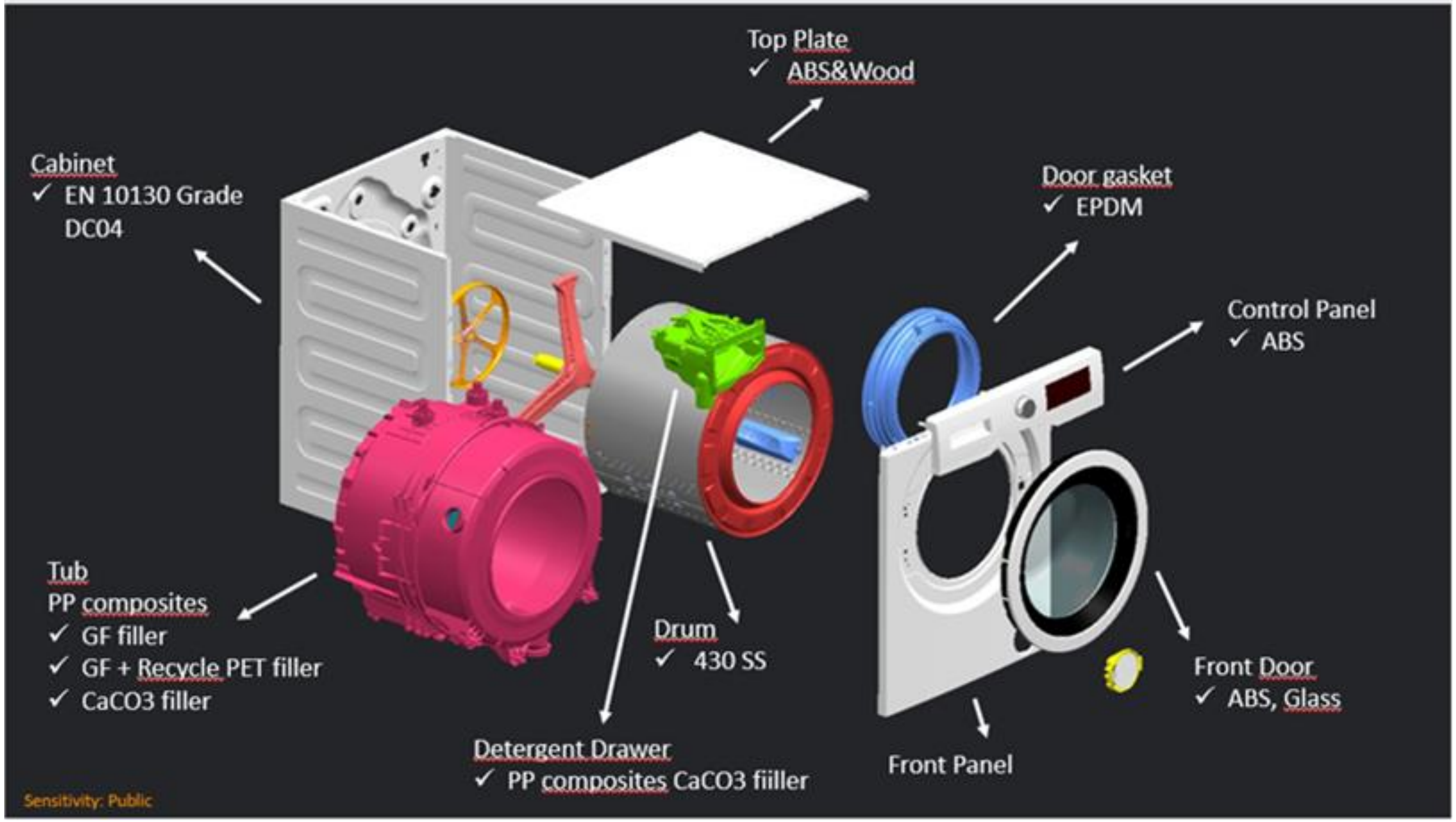


Figure 19. Exploded view of the washing machine used as demonstration product.

6.1.2. Current business model description

Table 15. Current business model of the washing machine demonstrator

Value proposition	Products	Sustainable products	Quality products	Wide selection of models	Innovative products				
	Services	After-sales services							
Value delivery	Target customers	B2B customers							
	Value delivery processes	Direct sales	Online sales	Retailers	Subsidiaries	Marketing	Social media		
Value creation	Partners and stakeholders	Suppliers (raw materials, parts)	3rd party manufacturers	Design consultants	University	Production Technology consultants	Test labs		
	Value creation processes	Design & Development	Quality control	Maintenance & technical services	Customer services	Marketing & Sales	Sourcing	Logistics	
Value capture	Revenues	Direct product sales	Spare parts sales	Investment incentives	Energy incentives	Single transaction payments			
	Costs	Labour	Manufacturing	Materials	Depreciation	Warranties	Transportation, logistics	Waste management	

6.1.3. Process flow chart

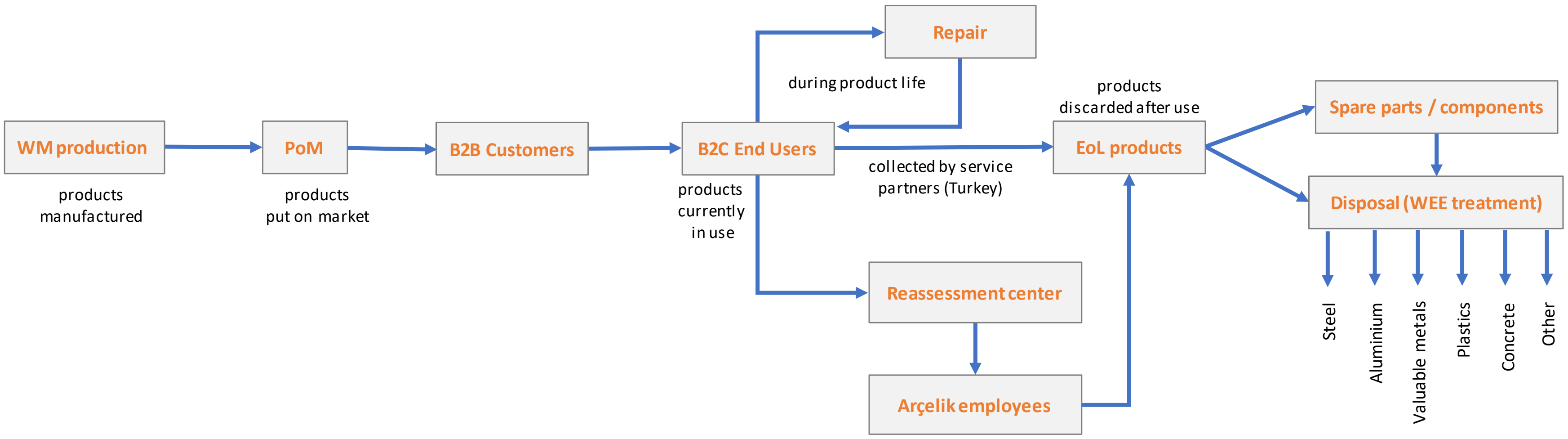


Figure 20. Process flow chart of the washing machine used as demonstration product

6.2. Printer & toner cartridge demonstration

6.2.1. Product description

Lexmark has identified a selected number of printer models to include in the demonstration. All of them are laser multifunction printers suitable for refurbishment operations. Two example models are described below.

Table 16. Priority models for the Lexmark demonstrator printers.

XS950de	XM5163	XM5170	XM7163
XS955de	XM5170	XM7155	XM7170

Table 17. Technical specifications of the laser printer demonstration products.

MODEL	XS950de	XM7155
Image		
Technology	Colour LED	Laser monochrome
Functions	Colour copying, colour faxing, colour printing, colour scanning, colour network scanning	Copying, faxing, printing, scanning
Display	Lexmark e-Task 10-inch (25 cm) class colour touch screen	Lexmark e-Task 10.2-inch (25.9 cm) colour touch screen
Size	762 × 640 × 685 mm	1133 × 663 × 734 mm
Packaged size	870 × 848 × 769 mm	1327 × 870 × 762 mm
Weight	116.0 kg	86.0 kg
Packaged weight	125.0 kg	111.0 kg
Recommended monthly page volume	5,000 – 33,000 pages	5,000 – 35,000 pages

Cartridges	35,000*-page Extra High Yield Cartridge	35,000*-page Extra High Yield Cartridge
Electricity consumption	6,2 kWh per week (ENERGY STAR Certified)	7,1 kWh per week (ENERGY STAR Certified)
Average power	1 W (hibernate) 16.5 W (sleep) 675 W (printing) 810 W (copying) 125 W (scanning)	0.63 W (hibernate) 3.2 W (sleep) 676 W (copying)
Noise level	24 dBA (idle) 52-55 dBA (operating)	30 dBA (idle) 57 dBA (operating)
Country of origin	China	China

6.2.2. Current business model description

Table 18. Current business model of the laser printer and toner cartridge demonstrator

<table>
<tr><td rowspan="2">Value proposition</td><td>Products</td><td colspan="6">Laser printer</td><td colspan="4">Toner cartridges (consumable)</td></tr>
<tr><td>Services</td><td colspan="7">Printing services</td><td colspan="3">Maintenance, repair, control</td></tr>
<tr><td rowspan="2">Value delivery</td><td>Target customers</td><td colspan="7">B2B customers</td><td colspan="3">B2B resellers</td></tr>
<tr><td>Value delivery processes</td><td colspan="6">Contracts with clients</td><td colspan="4">Channel partners/resellers</td></tr>
<tr><td rowspan="2">Value creation</td><td>Partners and stakeholders</td><td colspan="2">Component suppliers</td><td colspan="2">Raw material suppliers</td><td colspan="2">Contract manufacturers</td><td>Technical services</td><td colspan="2">Service partners</td><td>Technical support</td></tr>
<tr><td>Value creation processes</td><td colspan="3">Eco-design of products</td><td colspan="2">Software development</td><td colspan="2">Marketing and sales</td><td colspan="3">Distribution and take-back</td></tr>
<tr><td rowspan="2">Value capture</td><td>Revenues</td><td colspan="7">Service contracts (per printed page)</td><td colspan="3">Single transaction payment</td></tr>
<tr><td>Costs</td><td>Labour</td><td colspan="4">Distribution (transport)</td><td colspan="2">Services (maintenance, support)</td><td>Sales</td><td colspan="2">Logistics</td></tr>
</table>

6.2.4. Process flow chart

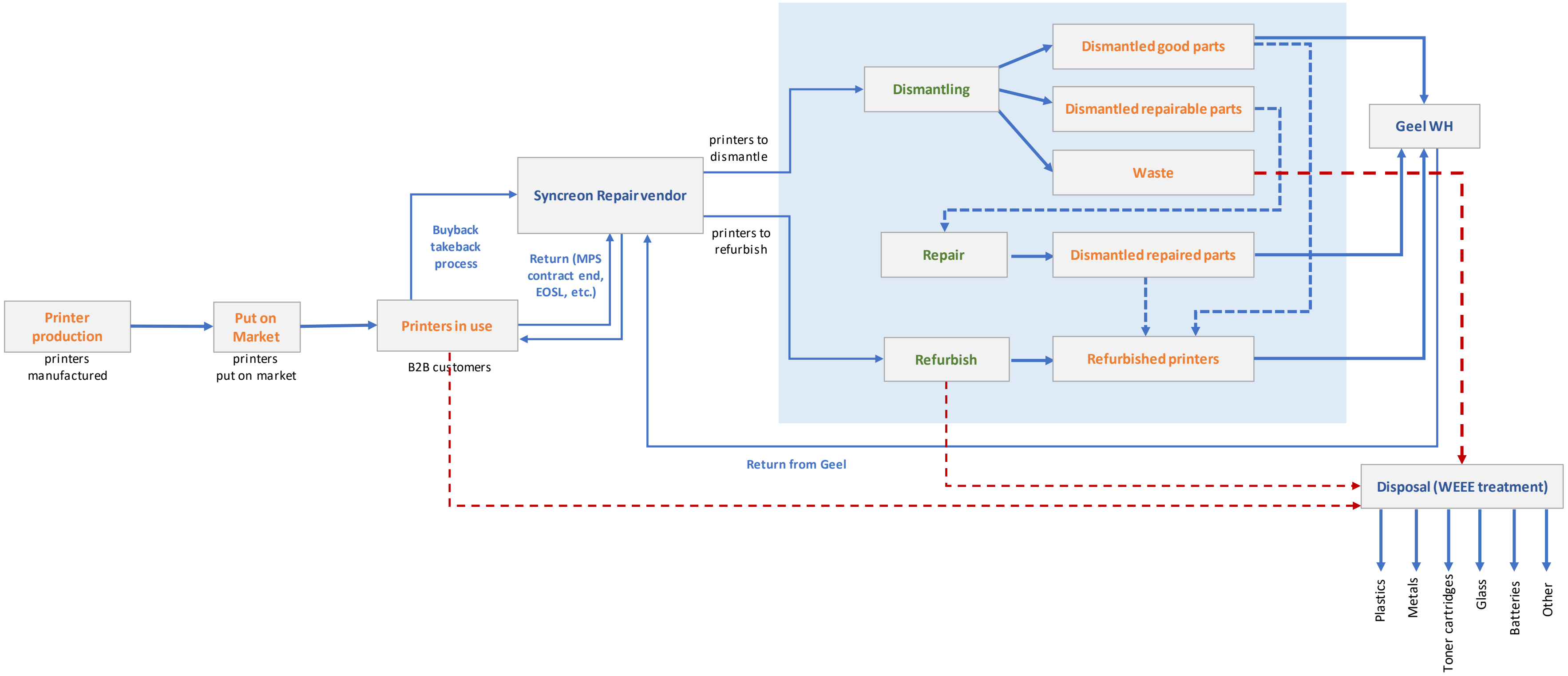


Figure 21. Process flow chart of the laser printer and toner cartridge used as demonstration product

6.3. ALM demonstration

The product selected for this demonstration belongs to the ALM line (Advanced Link Monitoring) for optical networks, a relatively new and still upraising product line. It splits into an (electrically) active unit and passive fibre-optic sensors for various monitoring tasks, including fibre surveillance, access control and novel fire sensors. More than 100 passive sensors plus the respective smaller number of active units will be used for the demonstration in C-SERVEES.

The novelty in the ALM product line makes it suitable for the demonstration purposes, since it makes it simpler to introduce changes on the product line. It also extends the lifetime scope of the project, especially for the sensors, to 30+ years, thus defining the upper bound of lifetime considered in the project. Furthermore, the material composition and the entire LCA in general of the active ALM units do not massively differ from other product lines. Hence, results derived in the project for the active units will also be applicable in good extent to other ADVA products.

6.3.1. Product description

The product line considered is the ALM (Access Line Monitoring) product, which provides the following functionalities:

- Real time information on fibre integrity.
- Fast and easy localization of user traffic.
- Remote passive fire detection in sites that are accessed with a fibre.

Two ALM variants are considered for the demonstration: 16ALM and 64ALM.

Table 19. Technical specifications of the ALM demonstration products

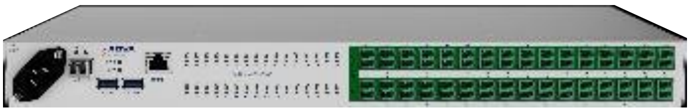
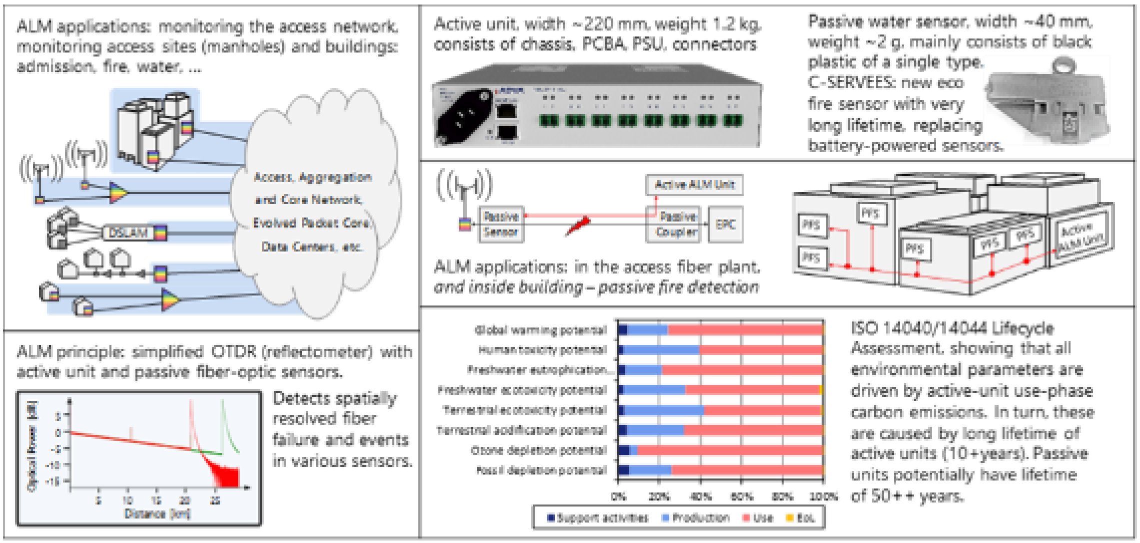
MODEL	16ALM / 64ALM
16ALM	
64ALM	
Product ref. codes	1043709841-02, 1043709842-02, 1043709846-01, 1043709847-01
Colour	Grey
Size	44 × 215 × 213 mm
Weight	< 2 kg
Packaged weight	11.6 kg
Average power	13 W (maximum)
Country of origin	Hungary

Figure 22. Overview of the demonstration product: applications, operating principle, characteristics and summarized LCA results.



6.3.2. Current business model description

Table 20. Current business model of the ALM (Access Line Monitoring) demonstrator

Value proposition	Products	Cost-effective products	Small products	Energy-efficient products	Long lasting products		
	Services	Maintenance, repair, control					
Value delivery	Target customers	B2B customers (mainly wholesale carrier market, but also other sectors)					
	Value delivery processes	Dedicated accounts	Strategic long-term contracts	Sales and Business Development			
Value creation	Partners and stakeholders	Component suppliers	Contract manufacturers	OEMs, VARs	Investors	Recyclers	Strategic customers
	Value creation processes	Eco-design (R&D)	Marketing and sales	Support services			
Value capture	Revenues	Direct products sales, including software and services					
	Costs	Labour	Components, goods and services	Compliance, audits			

6.3.3. Process flow chart

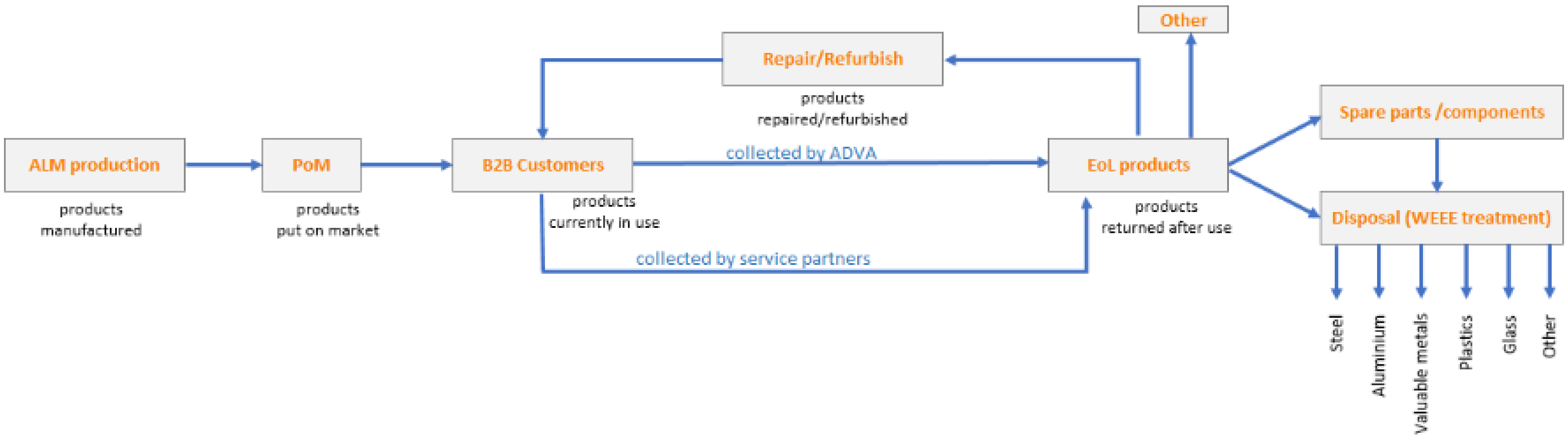


Figure 23. Process flow chart of the ALM (Access Line Monitoring) used as demonstration product

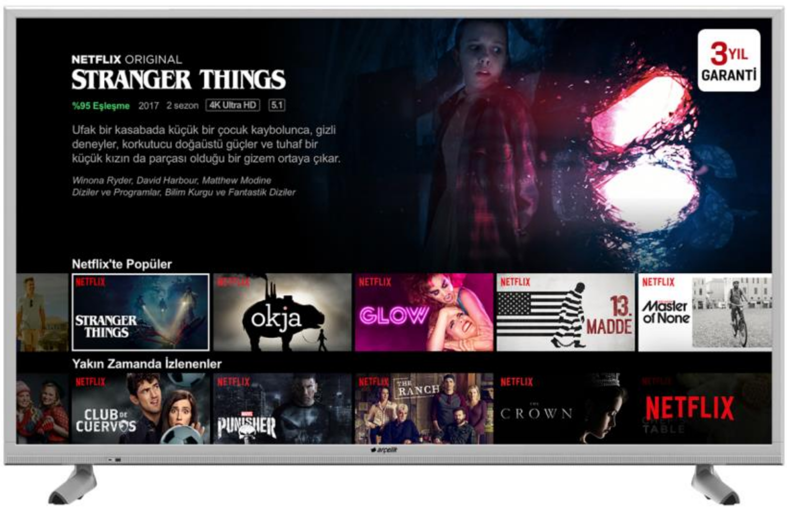
6.4. TV set demonstration

6.4.1. Product description

The product selected for this demonstration is a 43” smart-TV, model SYU000 from brand Arçelik. This product is currently on sale in Turkey and the EU. The reasons of choice are:

- Energy level (A^+).
- Convenient size for hospitality customer (43”).
- Connectivity features.
- Enclosure and stand of TV free of halogenated plastics.
- Amount of recycled plastic in back cover of TV approximately 40 %.
- Printed Circuit Board surface area and number of electronics components decreased by design.
- Compliance with new draft eco-design requirements for electronic displays and Energy Labelling of electronic displays.
- Thickness of optical sheet in TV panel decreased by using laminated raw material.
- Improvements to connectors to decrease return failure products from customer.

Table 21. Technical specifications of the TV demonstration product.

MODEL	A43L 8900 5A
Image	
Product name	SYU000
Brand	ARÇELİK
EAN code	8690769025028
Product ref. code	A43L 8900 5A
Colour	M. Grey
General description	43" ESEENCE NX - JG MUS - ARÇELİK, 43"/108 cm, UHD (3.840x2.160), 50 Hz, HEVC/H.265, Smart
Technical information	Picture Features: Picture Noise Reduction, MPEG Noise Reduction, Dynamic Contrast Colour System: Multisystem

	USB Supported Files: .mp3, .m4a, .aac, .jpg, .jpe, . bmp, .png, .mov, .mpg, .mpe, .vob, .dat, .trp, .ts, .avi, .mp4, .mkv, .div Guarantee term: 3 years
Size	625 × 231 × 976 mm
Weight	9.2 kg
Packaged weight	12 kg
Energy class	A^+
Electricity consumption	Annual On-Mode Energy Consumption (EP): 80 kWh Stand-by Power Consumption(W) (EP): 0.45 W Nominal Power Consumption (EP): 55.1 W [J/s] Networked Stand-by Power Consumption: 1.95 W
Packaging	Carton Craft flekso 2-Colour 71.0 x 15.5 x 105.7 (cm)
Country of origin	Turkey

Table 22. General part breakdown of the TV demonstrator

TV-Set						
Part/component	Material(s)	Contains recycled material? Yes/No	% of recycled material	Potential for eco-design Yes/No	Potential for customization Yes/No	Corresponding number in Figure 12
Plastic back cover	PC+ABS	Yes	40 %	Yes	No	600
Plastic Front Cover	PC+ABS+%10GF	No		Yes	No	300
Plastic Midframe	PC+%10GF	No		Yes	No	57
Plastic stands	PC+ABS	No		Yes	Yes (limited)	716
Plastic Stand Holder	PC+ABS+%15GF	Yes	10 %	Yes	No	717
Metal back cover	ECC / EGI (Electrogalvanized Sheet)	No		Yes	No	643
Metal T-con board cover(optional)	DX52+Z100B	No		Yes	No	-
Styropor for packaging	EPS	Yes	5 %	-	No	-
Carton for packaging	Carton	Yes	100 %	Yes	No	-
Lens Plastic	PC-NAT-I-HB	No		Yes	No	323
Main Board AV Braket Plastic	PC+ABS	No		Yes	No	633
Speaker	-	No				428
Main Board		No				110
Power Board		No				190
Remote control	Plastic or Metal	No				987
User Manual	Paper	No				901

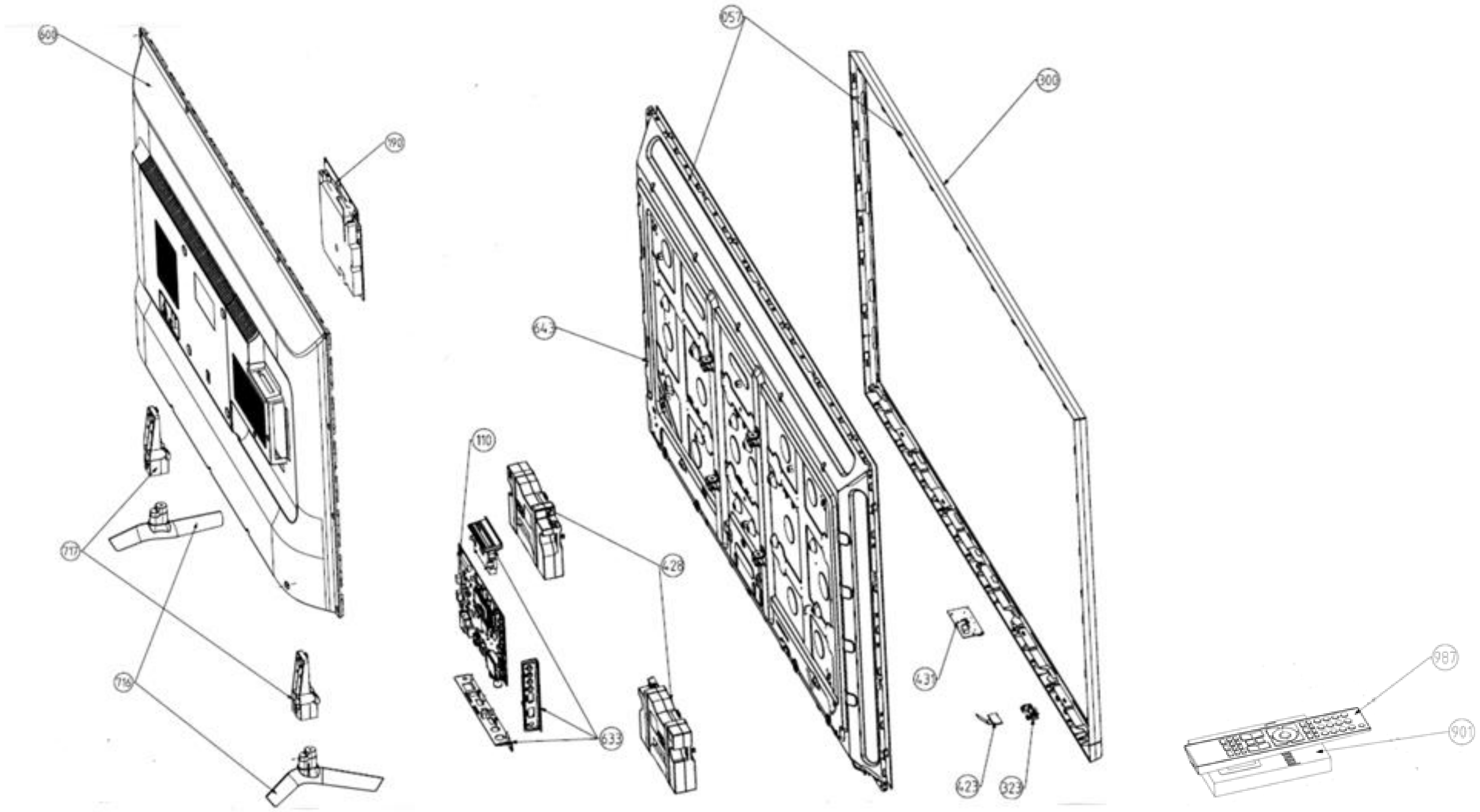


Figure 24. Exploded view of the TV used as demonstration product

6.4.2. Current business model description

Table 23. Current business model of the TV demonstrator

<table>
<tr><td rowspan="2">Value proposition</td><td>Products</td><td colspan="5">Durable products</td><td colspan="3">Energy efficient products</td><td colspan="2">Quality products</td><td colspan="3">Good price-performance products</td></tr>
<tr><td>Services</td><td colspan="13">After-sales services</td></tr>
<tr><td rowspan="2">Value delivery</td><td>Target customers</td><td colspan="10">B2B customers mainly</td><td colspan="3">B2C customers</td></tr>
<tr><td>Value delivery processes</td><td colspan="5">Corporate direct sales</td><td colspan="2">Marketing</td><td>Tenders (B2B)</td><td>Dealers</td><td colspan="3">Online sales</td><td>Social media</td></tr>
<tr><td rowspan="2">Value creation</td><td>Partners and stakeholders</td><td colspan="5">Suppliers (parts and components)</td><td colspan="2">3rd party manufacturers</td><td>Operators</td><td>3rd party providers</td><td colspan="3">Standard committees</td><td>Test labs</td></tr>
<tr><td>Value creation processes</td><td colspan="2">Design & Development</td><td colspan="3">Test & Verification</td><td colspan="2">Quality control</td><td>Installation</td><td>Maintenance & services</td><td>Marketing & Sales</td><td colspan="2">Sourcing</td><td>Logistics</td></tr>
<tr><td rowspan="2">Value capture</td><td>Revenues</td><td colspan="3">Direct sales</td><td colspan="4">Software sales</td><td colspan="2">Maintenance revenues</td><td>Government incentives</td><td colspan="3">Single transaction payments</td></tr>
<tr><td>Costs</td><td>Labour</td><td colspan="3">Manufacturing</td><td colspan="2">Materials</td><td colspan="2">Transportation</td><td>Warranties</td><td>Depreciation</td><td>Services</td><td colspan="2">Waste management</td></tr>
</table>

6.4.3. Process flow charts

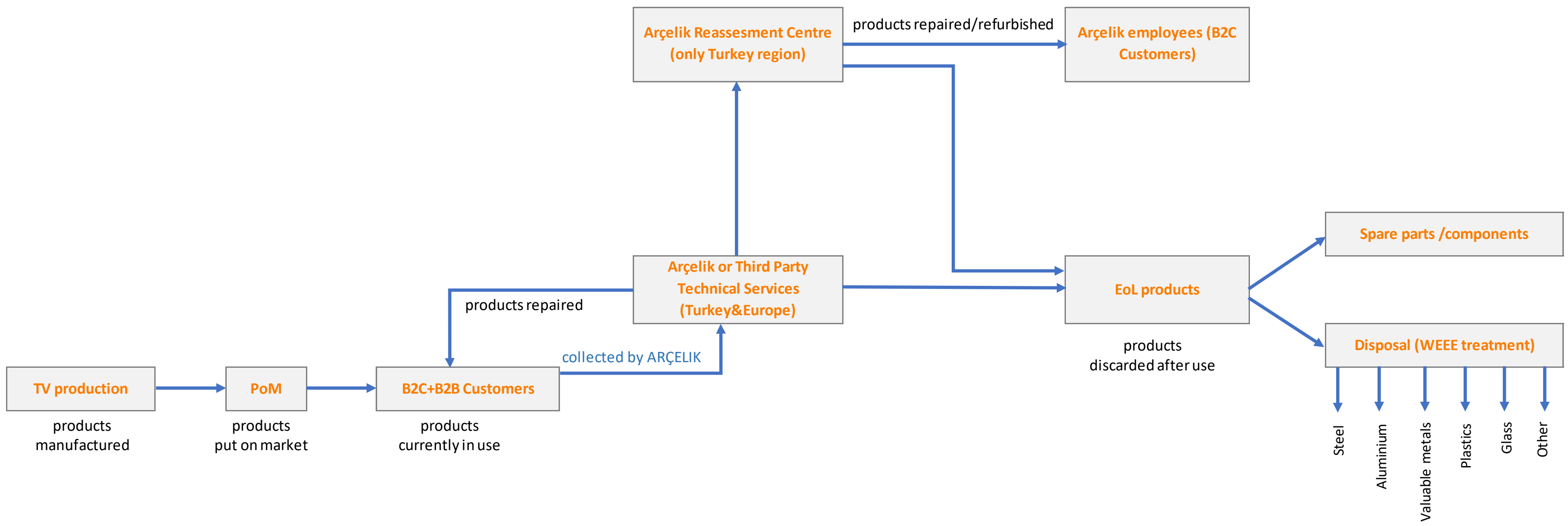


Figure 25. Process flow chart of the TV used as demonstration product

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Annex – BM template guide

<table>
<tr>
<td rowspan="2"><u>Key Partners</u>

• Who are the main strategic allies?
• What is your value chain?
• Who is supporting with strategic resources and activities?
• Which internal activities could be externalised with the less quality loss and at the less cost?</td>
<td><u>Key Activities</u>

• Which are the main activities and processes involved in this business model? (design, manufacture, research, maintenance services…)</td>
<td rowspan="2"><u>Value Proposition</u>

• What do you offer your clients in terms of products and services?
• What are the clients paying for?
• Why do your clients select your company?
• Do you provide targeted offers depending on customer segments?
• What differentiates you from other competitors?
• Do you have any eco-labels?</td>
<td><u>Customer Relationships</u>

• How is your relationship with the clients built?
• Do you have a strategy to manage client relationships?
• Can your customer also be your supplier?</td>
<td rowspan="2"><u>Customer Segments</u>

• B2B/B2C?
• Who are the clients?
• Can you describe the different types of clients your business is focused on?
• How do different client's segments differ?</td>
</tr>
<tr>
<td><u>Key Resources</u>

• Which are the most important and most costly resources in your business model? (raw materials, people, networks, ICTs, premises, know-how…)</td>
<td><u>Channels</u>

• How do you reach and make new clients?
• Which channels do you use to interact with your clients?
• Do you use ICT platforms or tools?</td>
</tr>
</table>

<table>
<tr>
<td><u>Cost Structure</u>

• How is the cost structure in your business?
• Which are the main costs involved in your business model?
• What is the proportion of fixed/variable costs in your business?</td>
<td><u>Revenue Streams</u>

• Which is your revenue structure? How do you earn money in your business?
• Which type of revenues do you receive? (single transaction payments, subscription payments, services, etc.)
• Do you receive economic incentives through regulation?</td>
</tr>
<tr>
<td><u>Environmental Cost Structure</u>

• Which are the costs related to environmental impacts? (materials, energy use, water consumption, waste management)
• Have you performed an LCA of your processes or products?
• Do you have a Mass Flow Analysis of your processes?</td>
<td><u>Environmental Revenue Streams</u>

• Are there any revenues related to environmental management practices? (from secondary materials sales, recycled materials/parts…)
• Do you receive revenues from second-used products?
• Green procurement? Corporate Social Responsibility?</td>
</tr>
</table>