Activating Circular Services in the Electric and Electronic Sector

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Executive Summary

The present document constitutes the Deliverable 6.1 "Guidelines for the ecodesign of the electrical and electronic equipment" in the framework of the C-SERVEES project. The deliverable reports the outcomes of Task 6.1 "Ecodesign guidelines".

The purpose of this deliverable is to provide replicable ecodesign guidelines for the sustainable production of electrical and electronic equipment (EEE).

The Guidelines provide key elements for effective implementation of ecodesign, as well as ecodesign strategies addressing the main environmental issues and practical examples that demonstrate how these are relevant to sustainable EEE development.

The present Guidelines include the following content:

- Introduction to the ecodesign of EEE, including key aspects and ecodesign principles, the role of ecodesign in the E&E sector, overview of C-SERVEES project as well as the aim of Guidelines;
- Methodological approach for the integration of ecodesign into EEE production;
- Description of the identified ecodesign strategies for EEE and their validation through examples of successful implementation of ecodesign strategies and best practices from E&E industry;
- Application of ecodesign strategies to C-SERVEES case studies.

Starting from literature review, a list of ecodesign strategies for environmentally compatible design of EEE were identified.

An online survey was addressed to C-SERVEES partners to collect feedbacks on the identified strategies and information about the ecodesign measures implemented in C-SERVEES demos.

All the ecodesign strategies were detailed including environmental benefits. Several cases studies from E&E sector were analysed, taking into account environmental and economic implications associated with them.

Finally, the C-SERVEES demonstration products (i.e., washing machine, laser printers and toner cartridges, ALM products and TVs and displays) developed within the project were analysed as practical examples of the implementation of the ecodesign approach to EEE. The ecodesign solutions that were applied (or explored) in the four demonstration products are in accordance with the generic strategies for eco-design in the E&E sector and seem promising in terms of contributing significantly to strengthening the circular economy in the E&E sector.

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Acronyms and abbreviations

EEE	Electrical and electronic equipment
DT	Digital Twin
ICT	Information and Communication Technology
IT	Information Technology
IoT	Internet of Things
WEEE	Waste of Electrical and Electronic Equipment (WEEE)
EoL	End of Life
EU	European Union
E&E	Electrical & Electronic
LCA	Life Cycle Assessment
EPS	Expanded Polystyrene
NOC	Network Operation Center
CA	Civic Amenity
CPU	Central Processing Unit
RAM	Random Access Memory
CIRCMODEs	Circular Economy Business Models
B2B	Business to Business
NGO	Non-Government Organisations
ALM	Advanced Link Monitoring
DfE	Design for Environment
XRF	X-Ray Fluorescence
QR	Quick Response

1 Introduction

The electrical and electronic equipment (EEE) industry is one of the largest and fastest growing domains in the European economy. It covers the production of a wide variety of products and devices, such as Information and Communication Technology (ICT) equipment, household appliances, lighting equipment, electrical tools, medical devices, etc.

The growth of consumer products and EEE industry have led to negative effects on the environment. The EEE products entail significant environmental impacts in all stages of the product life cycle, from the extraction of raw materials up to their end of life. This mainly depends on the increased complexity of devices and their increased use.

In particular, the amount of waste of electrical and electronic equipment (WEEE) is growing rapidly at the EU and the global level. According to the latest Global E-Waste monitor, the volume of e-waste generated worldwide in 2019 was 53.4 million metric tonnes (12 Mt in Europe), up 21% in five years. This trend is expected to continue, a 57.4 million tonnes of e-waste is estimated by 2021 [1].

WEEE is a complex mixture of both valuable and hazardous materials and substances. They are one of the major contributors of the environmental and health impacts if they are not managed properly. In addition, electronical and electronics devices contain rare and expensive resources, which can be recycled and re-used if the waste is effectively managed.

This makes more challenging to recover all the materials for technical and economic reasons, specially the WEEE plastics since the plastics fraction is composed of a complex mix of many polymers [2].

Therefore, the WEEE prevention and the improvement of the collection, treatment, and recovery of electrical and electronic equipment at the end of their life are essential to achieve the sustainable production and consumption objectives set out by WEEE Directive. New approaches in the design, manufacturing, use and end of life of EEE are required to contribute to the circular economy and increase the resource efficiency.

In this framework, eco-design is a key tool for the sustainable production of the EEE, considering and incorporating environmental aspects into the product development process with the aim of reducing the environmental impacts [3].

1.1 Role of ecodesign in the E&E sector

Ecodesign plays a key role in the EEE sector for the prevention and mitigation of the environmental pollution by acting on the resource protection, energy saving and management of the end-of-life of EEE in early phase by their proper design.

The most significant environmental impact of these products from a life-cycle perspective is the energy consumption during their use. For this reason, energy efficiency is required for all energy-related products as washing machine, ICT, lighting, heating, and others. Ecodesign can help to significantly improve the energy efficiency.

Other relevant environmental issues for EEE are related to materials used in manufacturing and e-waste management at the end of their life.

E&E products consist of different materials. Some of them are hazardous not only for the environment but also for the human health. Therefore, their use should be reduced or eliminated [3]. Ecodesign can help in the selection of materials at the design stage, reducing the use and subsequently the depletion of critical raw materials (e.g., rare earths, precious metals, cobalt, tantalum, indium, gallium) and limited resources and the same time increasing the probability of reuse and recycling at the end of life.

Furthermore, ecodesign can contribute to the reduction of WEEE by increasing the product's durability and designing for easy disassembly and recycling.

In general, ecodesign is become ever more important for the development of more innovative and sustainable EEE products. It allows to integrate environmental criteria to basic requirements of product design, such as: function, reliability, costs, performance, aesthetic.

Ecodesign involves the improvement of efficiency of products, while ensuring at the same time high levels of safety and quality.

The implementation of ecodesign strategies offers several benefits in terms of environmental, economic, and social impacts. Ecodesign contributes to the sustainability development and the achievement of environmental goals in accordance with current policies and regulations on environment protection. In addition, optimisation of the use of resources, production process and transport can significantly reduce the economic impact. Furthermore, the application of environmental aspects into product design can improve the image of the company and make the products even more attractive for consumers, considering the increased environmental awareness.

1.2 C-SERVEES Project

C-SERVEES project aims to boost a resource-efficient circular economy in the electrical and electronic (E&E) sector through the development, testing, validation, and transfer of new Circular Economic Business Models (CEBMs) based on systemic eco-innovative services, such as: eco-leasing of EEE, product customisation, improved WEEE management, and ICT services to support the other eco-services (Figure 1.1).

ICT tools are being developed as the driver of the proposed eco-innovative services to take full advantage of the potential and the synergies between circular economy and Industry 4.0.

The techno-economic, environmental, and social viability of the new CEBMs is going to be validated through demonstrations dealing with four target products each belonging to a different EEE category: washing machine (large household appliances), printers and laser toner cartridges (IT equipment), ALM products (telecommunication equipment) and TV sets and displays (consumer electronics equipment).

Furthermore, key enabling tools are going to developed for boosting the replicability and transferability of circular economy products and services across EU, developing ecodesign guidelines for EEE and recommendations on policies to overcome current legislative barriers, as well as a framework for standardizing the circular economy.

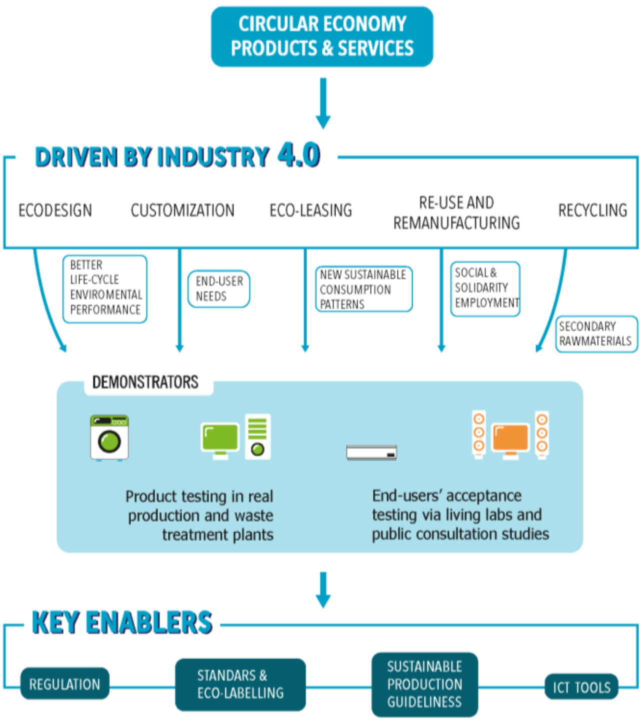

Figure 1.1 – Overview of C-SERVEES Project

1.3 Ecodesign Guidelines

The present Guidelines have been developed in the framework of C-SERVEES Project. They are the result of the activities carried out in Task 6.1, with the interaction of C-SERVEES partners. The aim is to contribute to circular economy in the E&E sector, providing replicable guidelines to simplify, encourage and lead incisive solutions to be applied in several E&E products.

Ecodesign of EEE is a relevant issue for a broad group of stakeholders. These Guidelines are mainly addressed to:

- Product managers, marketing directors and other decision makers

These functions are given a brief description of the key elements and the approach that need to be established to set the basis for a meaningful implementation of ecodesign. Furthermore, they are supported in developing a specific ecodesign strategy for their E&E product in the framework of the relevant environmental impact areas. The Guidelines illustrate the available ecodesign strategies addressing the relevant environmental issues and the benefits associated with them. In addition, the Guidelines provide examples of success and best practices from the E&E sector. These examples demonstrate how ecodesign strategies are relevant for product development not only in terms of functionality, but also from an environmental and economic perspective, contributing also to marketing actions by increasing the company's brand reputation.

- Manufacturers and Designers

Manufacturers and designers are provided with the necessary background information as well as practical examples for understanding and implementing the details of the selected ecodesign strategy elements, including detailed information on the specific optimisation strategies to improve the environmental performance of E&E product as well as practical examples from E&E sector and C-SERVEES project that illustrate potential challenges and appropriate solutions, providing concrete strategies already applied in specific case studies.

The Guidelines are structured in the following sections:

- Chapter 1 introduces the background context related to the ecodesign of EEE and gives an overview of C-SERVEES project and main objectives and aim of the Guidelines.
- Chapter 2 describes the methodological approach for the integration of ecodesign into EEE production.
- Chapter 3 describes the identified ecodesign strategies for EEE.
- Chapter 4 reports successful examples and best practices from E&E industry.
- Chapter 5 focuses on the application of ecodesign strategies to C-SERVEES case studies.
- Chapter 6 summarises final conclusions and considerations.

2 Ecodesign approach for EEE industry

The ecodesign approach for EEE aims to create sustainable products, through a life cycle approach based on the evaluation of environmental performances of devices. The final objective is to assess the environmental impacts and to propose solutions for their reduction in all the phases, from 'cradle to grave' (or 'cradle to cradle' in case of recycling): raw material acquisition, manufacturing, distribution, use and final disposal of the product [4].

Figure 2.1 shows the life cycle phases of EEE product and the main environmental issues associated with each phase. These aspects must be deeply investigated in order to identify the major effects that the E&E product has on the environment and to establish a possible improvement strategy.

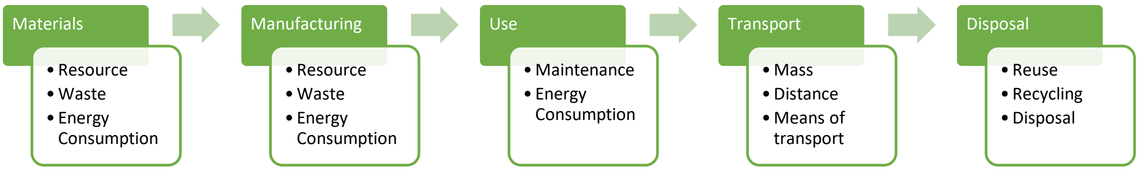

Figure 2.1 – Life cycle phases of EEE product and related environmental issues

2.1 Ecodesign methods and tools

There are different tools, both quantitative and semi-quantitative, to implement ecodesign principles and approaches, including:

- <u>Guidelines and checklists</u>

Guidelines and checklists are also useful tools, especially in the preliminary stages of design, for a quick evaluation of the product's environmental performance. They provide suggestions on how to improve environmental behavior and how to implement ecodesign procedures. Evaluations and procedures are documented step-by-step so that they can be easily transferred and replicated for other EEE application [5].

- <u>Life Cycle Assessment</u>

Life Cycle Assessment (LCA) is one of the most widely used tool to help in design and redesign in a sustainable way. LCA is a structured, comprehensive, and internationally standardized methodology, quantifying the environmental impacts associated to the life cycle of a product or a service.

LCA assists in:

- Identifying opportunities to improve the environmental aspects of products at various points in their life cycle;

- Decision making in industry, governmental or non-governmental organisations (e.g., strategic planning, priority setting, product and process design or redesign);
- Selection of relevant indicators of environmental performance;
- Marketing (e.g., an environmental claim, eco-labelling scheme or environmental product declarations).

Figure 2.2 – Life Cycle Assessment process

The LCA methodology is regulated by the following standards and guidelines:

- ISO 14040: 2006 - Environmental management − Life Cycle Assessment − Principles and framework [6];
- ISO 14044: 2006 - Environmental management − Life Cycle Assessment − Requirements and guidelines [7];
- ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance [8].

According to the ISO 14040 and ISO 14044, LCA consists of four steps: Goal and Scope Definition, Life Cycle Inventory, Impact Assessment, and Interpretation (Figure 2.3).

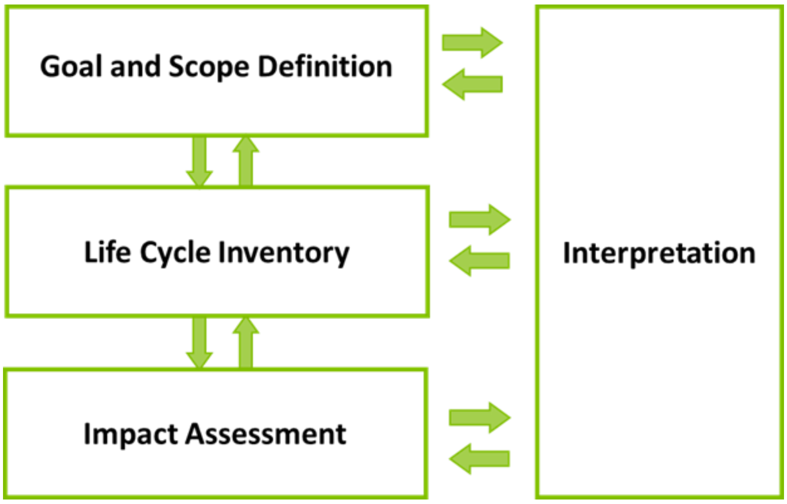

Figure 2.3 – Life Cycle Assessment framework

The objective of each phase is summarized as follows:

1 Goal and Scope: where the reasons for carrying out the study and its intended use are described and where details are given on the approach taken to conduct the study. Notably, it is in this phase of the study that the functional unit is defined, and that modelling approaches are specified.

2 Life Cycle Inventory: where the product system and its constituent unit processes are described, including the inputs and outputs (data) to conduct the analysis. Their amounts are in reference to one functional unit and to system boundary, as defined in the Goal and Scope phase.

3 Life Cycle Impact Assessment: where the magnitude and significance of impacts associated with the inputs and outputs compiled during the previous phase are evaluated. This is done by associating the life cycle inventory results with impact categories and category indicators.

4 Interpretation: where the findings of the previous two phases are combined with the defined goal and scope in order to reach conclusions or recommendations.

Based on the LCA results, the main hotspots in the total life cycle, i.e., critical points (stages, processes, and flows) that entail the highest impacts, can be identified. This evaluation can be the basis for the ecodesign, as it highlights the key aspects on which further development are required as well as allows to prioritise the actions and environmental targets.

2.2 Integration of ecodesign into the production process

Given the growing importance of ecodesign for the E&E sector, the development and integration of an ecodesign strategy become an integral part of the management process and decision making.

The process of integration of ecodesign into the production of electrical and electronics products involves the following steps, as reported in Figure 2.4.

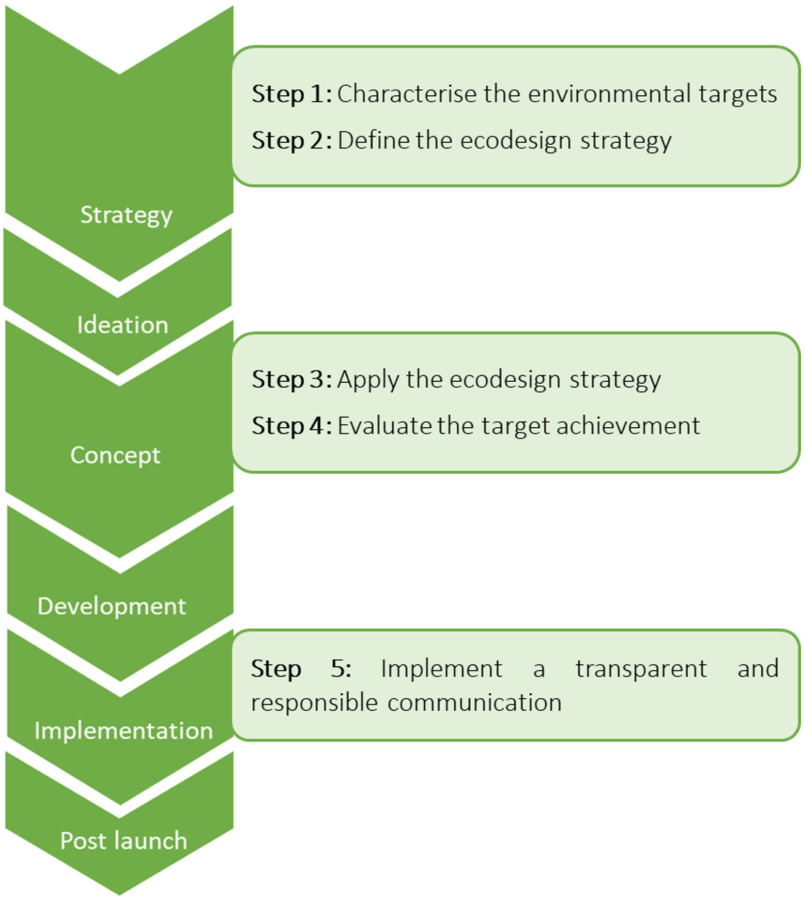

Figure 2.4 – Process of integration of ecodesign

- **Step 1: Characterise the environmental targets**

The first step is to define the environmental targets for the product, starting from a life cycle assessment analysis to evaluate the highest environmental impacts and highlight the main areas of interventions for impact reduction.

Then, the priorities of the environmental objectives should be set based on current environmental regulation, policy and company goals or any possible relevant environmental brand messages.

- Step 2: Define the ecodesign strategy

Once the environmental hotspots are identified and the environmental targets are set up, the next step is to select the most appropriate ecodesign strategies. This process usually is carried out through several activities involving brainstorming and other innovation techniques.

- Step 3: Apply the ecodesign strategy

In this step, the selected ecodesign strategies are integrated in the design of the targeted product. Each proposed solution should be verified.

- Step 4: Evaluate the target achievement

Also in the concept stage, a validation process should be carried out to assess the effectiveness of the applied strategies, in terms of environmental benefits and other technical and sustainability aspects. This phase is an iterative process. If the solutions don't meet the defined targets, it is necessary to go back on step 2 to redefine the eco-design strategy.

- Step 5: Implement a transparent and responsible communication

After the development of the solution, it is important to implement a transparent and responsible communication, oriented to show the achieved environmental benefits.

In addition, there are many eco-labels for EEE products that guarantee the excellent environmental and energy performance of the products [9].

3 Ecodesign strategies

This section focuses on ecodesign strategies for the environmentally compatible design of EEE to prevent, reduce and/or minimize environmental impacts of product throughout the life cycle phases.

Several ecodesign strategies have been identified based on literature review [4] [10] [11]. Furthermore, an online survey was addressed to C-SERVEES partners to collect feedback on the identified strategies.

Table 3.1 shows a comprehensive list of available ecodesign strategies for electric and electronic products. Each strategy is detailed in the following subchapters, including the resulting environmental benefits.

It is important to consider the fact that the E&E sector includes a huge variety of products, which differ in their production processes and intended use. Therefore, each EEE product has different requirements. It is necessary to evaluate the nature of the product in order to select the best ecodesign strategy to apply.

Table 3.1 – List of identified ecodesign strategies for E&E

Ecodesign strategies	
New concept development	S1 Dematerialisation
	S2 Product sharing
	S3 Eco-leasing
	S4 Multifunctionality
	S5 Product-as-service
	S6 Pay per use
	S7 Digital twin
Physical optimisation	S8 Improving product durability and reliability
	S9 Optimisation and integration of functions
	S10 Easy maintenance and repair
Material selection	S11 Recycled materials
	S12 Recyclable materials
	S13 Renewable materials
	S14 Reduction in material use
	S15 Low energy content materials
	S16 Selection of low impact materials
Production optimisation	S17 Alternative production processes
	S18 Process optimisation
	S19 Less energy consumption
	S20 Less waste production
	S21 Use of renewable energy
Distribution optimisation	S22 Packaging optimisation
	S23 Transportation optimisation
	S24 Implementing reverse logistic

Ecodesign strategies	
Product use optimisation	S25 Cleaner energy sources
	S26 Lower energy consumption
	S27 Reduction of consumables
	S28 Cleaner consumables
Optimisation of End of life	S29 Reuse of product
	S30 Remanufacturing
	S31 Re-purposing
	S32 Design for disassembly
	S33 Design for recycling
	S34 Design for safe disposal
Enhancing of circularity	S35 ICT tool for enhancing circularity

3.1 New concept Development

The first stage of the life cycle of EEE is the concept. In this phase, different environmental issues can be investigated to improve environmental performance and product circularity at each life cycle stage.

This common strategy foresees the implementation of innovative strategies such as dematerialisation, multifunctionality and the development of new services into product design (e.g., product sharing, eco-leasing), ensuring that the device fulfils all consumer's needs.

The analysis of consumer needs should be the starting point for the new concept development strategy. For this reason, the involvement of different stakeholders (i.e., consumers and suppliers) plays a fundamental role.

– Dematerialisation (S1)

Description of the strategy	Environmental benefit
Dematerialisation consists of using less or no material to provide the same product or service. Some options to dematerialise a product are: • Optimise - maximise resource efficiency by reducing the mass or types of material in the product. • Digitalize - sell the product electronically or virtually eliminating the need for warehouse and retail stores, and for the materials, energy, and space they consume (ex. electronic grocery shopping). • Servitize - sell the utility of the product as a service, referring to options of shared product use and longer product life.	Reduction of resource consumptions. Opportunities to reduce disposal costs and improve raw material utilisation, finding ways to extend product lifecycles.

– Product sharing (S2)

Description of the strategy	Environmental benefit
This new concept strategy consists of sharing the use of product, which is not used frequently. The product does not belong to a single user but is supplied to different users. This strategy allows to increase the effective use efficiency of the product and reduce demand for new products and their embedded raw materials. To increase the revenues generated by the service, manufactures should extend the service life of the product, ensuring easy maintenance and repair. Typical examples of application of this ecodesign strategy in the E&E sector are photocopiers and laundries.	Increased use of the product entails significant environmental benefits, including less e-waste generation, as well as reduced fixed costs.

– Eco-leasing (S3)

Description of the strategy	Environmental benefit
Eco-leasing is a strategy in which durable goods (e.g., computers, copiers, appliance) are rented to a client for a certain period, after which they are returned to the manufacturer. The manufacturer takes responsibility of the product after its use and ensures the best end-of-life alternative. Therefore, producers must design products to be durable, easy to repair and easily recyclable at the end of their life.	Transition of product ownership structures towards an increased producer responsibility model. Optimisation of product use.

– Multifunctionality (S4)

Description of the strategy	Environmental benefit
Function enhancement in a single product during its use stage, e.g. smartphone or printer. New manufacturing technologies, such as additive manufacturing and developments in functional materials or multi-material design offer new opportunities in the design of multifunctional components.	Reduction of resources per function. The impact of the multifunctional products on the environment is lower than in case of using single function products to fulfil the same functions: fewer resources, less waste and emissions during the production and packaging, transport and distribution stages and less waste to be processed at the product end-of life.

– Product-as-service (S5)

Description of the strategy	Environmental benefit
Product-as-service strategy consists of providing additional services beside the product. Customers subscribe to the product and pay recurring fees. Therefore, producers must take care of the product and take it back to have a new life. To increase profitability, manufacturers should design products for easy maintenance and repair, select high-performance materials that are easy to separate and to put back on the market at the end-of-life phase.	Strengthening the circular economy. Product as a Service will often keep products in use longer as the company will take responsibility for a high level of care for the products. This provides greater utility for the consumer without needing additional natural resources.

– Pay per Use (S6)

Description of the strategy	Environmental benefit
This strategy consists of providing a product for which the customer pays a fee based on the actual use of the equipment, instead of paying the renting of the product. Manufacturers retain ownership of the product and are therefore responsible for delivery, maintenance and take back at end of life. Design for durability, maintenance, and repair as well as recycling should be implemented.	Lower environmental footprint due to optimised product use and improved collection and end-of-life management. Consumers would become more conscious about consumption patterns, as they only pay in the use phase, and do not own the product. Companies would take responsibility for product life cycle issues.

– Digital twin (S7)

Description of the strategy	Environmental benefit
Digital Twin is a virtual representation of a product or process that aims to predict the performance of its physical counterpart. It is used throughout the product lifecycle to simulate, predict, and optimise the product and production system.	Improved process performance and energy efficiency. Extended product life.

3.2 Physical optimisation

Physical optimisation aims to increase the reliability and functionality of the product, improving its environmental performance. The main strategies are the following:

– Improving product durability and reliability (S8)

Description of the strategy	Environmental benefit
Improving durability and reliability of the product to extend its lifespan. Lifespan can be extended through predictive maintenance, minimizing or avoiding the use of problematic components and selecting the most reliable materials and components possible, with high resistance to wear and environmental degradation. In addition, durability can be significantly improved through a modular product design, allowing for product upgrades during the life cycle. Products with interchangeable parts are suitable for modular design.	Saving resources and reducing waste due to the extension of the product lifespan. Prolonging the life of a product type is also a substantial improvement in its environmental efficiency.

– Optimisation and integration of functions (S9)

Description of the strategy	Environmental benefit
Optimisation of function and integration of different functions into a single product, avoiding extra machining process. Some actions may require the reduction of the number of production processes, the use of alternative production techniques and methods, which are cleaner, cheaper, with lower waste production, etc.	Reduction of resource consumption. Looking for opportunities to reduce disposal costs and improve raw material utilisation, finding ways to extend product lifecycles, or designing with the ultimate intention of reusing, refurbishing, or remanufacturing.

– Easy maintenance and repair (S10)

Description of the strategy	Environmental benefit
This strategy consists of designing the product for easy maintenance and repair in order to increase its lifespan. Therefore, maintenance processes must be simplified and all information for a proper maintenance must be stated, such as: frequency, disassembly instructions, troubleshooting, tools required, expected component lifetime, etc.	Reduction of environmental impacts thanks to the prolongation of product lifespan. In this way, the demand for the extraction of new raw material is reduced.

Description of the strategy	Environmental benefit
Manufacturers must ensure spare parts availability for repair.	

3.3 Material selection

The selection of suitable materials at the design stage entails significant environmental benefits in terms of saving critical raw materials, reducing limited resources, increasing reuse and recycling of materials.

– Recycled materials (S11)

Description of the strategy	Environmental benefit
Increasing the amount of recycled content in the product. Promoting the use of recycled materials in product design is a fundamental strategy to achieve a circular economy. For this reason, it is interesting a design approach to determine the convenience of using recycled material (i.e., feasibility and suitability) and thus simplify the process of material selection.	Reduction of the consumption of virgin material. Reduction of environmental impacts linked to material production. Improved circularity

– Recyclable materials (S12)

Description of the strategy	Environmental benefit
Selecting recyclable materials that can be easily managed at the end of life. The recyclability of materials is a performance indicator for the recycling chain that focuses on the efficiency of recycling.	Reduction of the environmental impacts related to end-of-life phase. Enhanced circularity.

– Renewable materials (S13)

Description of the strategy	Environmental benefit
Use of renewable resources. Renewable material is a material made of natural resources that can be replenished, generation after generation (ex. wood).	Decoupling of non-renewable resources. During growth, renewable resources absorb carbon dioxide. Whilst these resources are kept in the technical system, they act as carbon storage. For many renewable materials, it is more sustainable to re-use or recycle them.

– Reduction in material use (S14)

Description of the strategy	Environmental benefit
Reduction of material use: ▪ avoiding the oversizing of the product, decreasing the thickness of the component, using lighter materials, ▪ decreasing the surface treatments of the product.	Reduction of environmental impacts of the product, lower production impacts and costs, and less waste generation at the end-of-life phase.

– Low energy content materials (S15)

Description of the strategy	Environmental benefit
Use of materials with lower embodied energy. A material that is locally sourced and is relatively un-processed will have a low level of embodied energy. Materials that have high levels of embodied energy are generally not sustainable and should be avoided whenever possible. For example, the proportion of embodied energy that is linked to transport is much lower for lightweight materials.	Energy saving and reduction of GHG emissions embodied in the material. A 'sustainable material' in one place may have a high energy load in another due to local availability and the type of transport involved. Thus, it is necessary a LCA study to assess and choose the appropriate material.

– Selection of low impact materials (S16)

Description of the strategy	Environmental benefit
Replacement of hazardous materials or those responsible for the major impacts of the life cycle with low-impact materials.	Reduction of environmental impacts of the product during its life cycle. Nonuse of toxic materials entails significant benefits for human health and better waste management.

3.4 Production optimisation

The production process should be optimised to improve the environmental performance of the product. Environmental impacts can be reduced by improving process efficiency, reducing resources use and waste generation, adopting alternative processes that are more environmentally friendly and efficient, increasing internal recycling, and favouring the use of renewable energy systems.

– Alternative production processes (S17)

Description of the strategy	Environmental benefit
Processes that entail significant environmental impacts should be replaced with alternative processes. These latter should be evaluated	Reduction of production impacts. See [S9] environmental benefit for further information.

Description of the strategy	Environmental benefit
within the lifecycle to guarantee an effective reduction of environmental impacts.	

– Process optimisation (S18)

Description of the strategy	Environmental benefit
Process optimisation involves reducing the number of production steps and improving process layout thanks to the implementation of more efficient technologies.	Reduction of production impacts. See [S9] environmental benefit for further information.

– Less energy consumption (S19)

Description of the strategy	Environmental benefit
Minimizing energy consumption. This can be achieved through the optimisation and recovery of energy streams and the use of high-efficiency technologies.	Reduce impacts related to high energy consumption.

– Less waste production (S20)

Description of the strategy	Environmental benefit
Minimizing the waste production through process optimisation. Corporate managers often need to choose the optimal configurations of production processes to reduce waste.	Reduction in the production of waste and reduction in the related consumption of resources.

– Use of renewable energy (S21)

Description of the strategy	Environmental benefit
Incorporation of renewable energy sources in production processes. Renewable energy is one of the most important and accessible ways that companies can progress to meet their business and sustainability goals.	Reduction of impacts related to energy consumption. Decrease the use of destructive fossil fuels.

3.5 Distribution optimisation

The distribution phase can be optimised by acting on packaging and enhancing transport and logistics. Regarding packaging, ecodesign strategies mainly focus on reducing the amount of packaging and resources and the associated impacts. While transportation can be improved by optimizing each shipment, selecting the best transportation mode, reducing packaging sizes and improving the logistics network.

– Packaging optimisation (S22)

Description of the strategy	Environmental benefit
Avoiding unnecessary packaging use for certain products that can be distributed unpacked	Reduction of resources consumption
Reducing the amount of material	Reduction of resources consumption
Use of reusable packaging	Enlargement of lifespan, decrease packaging waste
Use of recycled material	Reduction the need for extracting, refining, and processing new raw materials, energy saving and reduction of CO_2 emissions
Use of low-impact materials	Reduction of product impacts related to packaging
Use of recyclable materials	Increased recycling leading to less waste impact
Reducing the volume of packaging	Environmental benefits linked to the optimisation of distribution phase

– Transportation optimisation (S23)

Description of the strategy	Environmental benefit
Increasing the efficiency of transportation	Reduction of environmental impacts related to transportation phase.
Enhancing the logistics efficiency	
Reducing size and weight of product	
Relocation of major sites (logistic hubs, production) back to Europe	

– Implementing reverse logistic solutions (S24)

Description of the strategy	Environmental benefit
Implementing an effective reverse logistic strategy, i.e., supply chain management that moves goods from customers back to the sellers or manufacturers.	Reduction of waste; less materials and energy consumption; reduction of environmental impacts.

Description of the strategy	Environmental benefit
The reverse logistics aims to recover value from product and to manage its end-of life, enhancing the circular economy. An effective reverse logistic strategy may minimize return-related losses.	

3.6 Product use optimisation

Regarding use phase, the ecodesign strategies focus on optimisation of product use to reduce waste generation and high consumption of energy and consumables during the product's life cycle.

– Cleaner energy sources (S25)

Description of the strategy	Environmental benefit
Use of renewable energy sources during the using phase of the product, e.g., solar electric chargers, providing clean power to the EEE products.	Reduction of impacts related to the energy consumption during the use phase.

– Lower energy consumption (S26)

Description of the strategy	Environmental benefit
Improving the energy efficiency of product, especially for energy-intensive products. An energy efficient product is any type of consumer product (lightbulbs, power strips, etc.) that performs the same function as its non-energy efficient alternative, while saving money and energy through smart energy technology and decisions.	Reduction of impacts linked to the high energy consumptions. Reduction of the amount of energy needed to be generated through the burning of fossil fuels like coal and natural gas. Less energy generation from fossil fuels leads to lower greenhouse gas emissions, which contribute to global climate change and have been proven detrimental to our natural environment.

– Reduction of consumables (S27)

Description of the strategy	Environmental benefit
Reducing the use of consumables. This can be achieved by designing product in way to reduce the consumable materials required. Another solution is to extend the durability of consumables in order to decrease their use along the product lifetime.	Reduction of resources consumption. See [S9] environmental benefit for further information.

Description of the strategy	Environmental benefit
Furthermore, it is important to provide the instruction on correct maintenance and consumable replacement.	

– Cleaner consumables (S28)

Description of the strategy	Environmental benefit
Use of consumables that can be recycled, reused or remanufactured, thus reducing the amount of waste to be landfilled. All the information on the correct disposal of the consumables must be provided to user.	Reduction of impacts related to the consumable's final disposal. This strategy leads to the availability of more materials that can be recycled and thus it can reduce the extraction of raw materials for production purposes.

3.7 Optimisation of End of life

Different ecodesign strategies can be adopted to reduce the high environmental impacts related to the End-of-Life phase of EEE. These aims at facilitating the end-of-life management, encouraging the recycling, re-using and remanufacturing options.

Furthermore, communication-to-user strategies can enhance best practices regarding end-of-life treatments.

– Reuse of product (S29)

Description of the strategy	Environmental benefit
This strategy implies the refurbishment of product to be used by a second customer. Design for reuse must ensure easy disassembly and repair in order to simplify the partial reuse of components.	Minimisation of environmental impacts due to the enlargement of product's lifetime.

– Remanufacturing (S30)

Description of the strategy	Environmental benefit
This strategy focuses on product restoration and reconditioning of its parts to rebuild a new product. This strategy is an efficient way to maintain the product in a closed loop.	Reduction of the use of raw materials and energy necessary to manufacture new product. The extension of product's lifetime significantly reduces the environmental impacts and costs of the manufacturing process.

– Re-purposing (S31)

Description of the strategy	Environmental benefit
Re-purposing consists of transforming the product to a new one product with alternative purpose. Therefore, design for re-purposing must include features and details that facilitate re-purposing.	Saving of environmental impacts due to final disposal. Saving of material resources consumption.

– Design for disassembly (S32)

Description of the strategy	Environmental benefit
Design for disassembly aims at ensuring that the product and its components are recycled, re-used, or remanufactured at the end of life. The product must be designed to be easily disassembled. The use of connectors and fasters can facilitate the disassembly.	Boosting the recycling and reuse options to reduce the impacts related to the product's end-of-life.

– Design for recycling (S33)

Description of the strategy	Environmental benefit
Design for recycling aims at promoting the recovery of the materials for additional use by: ▪ Use smaller more compact board design; ▪ Minimize the number of components; ▪ Minimize the number of fasteners or connectors; ▪ Minimize different types of plastics and metals; ▪ Minimize use of plated or contaminated metals ▪ Do not use nuts and bolts; ▪ Minimize adhesives for plastic parts; ▪ Follow regulations and standards, such as RoHS.	Reduction of resources consumption, reduction of GHG emissions. See [S9] environmental benefit for further information.

– Design for safe disposal (S34)

Description of the strategy	Environmental benefit
Design for a safe disposal means avoiding the use of toxic and hazardous substances, providing detailed instruction on proper disposal, using biodegradable materials whenever possible.	Reduction of impacts related to the product's end-of-life phase. See [S9] environmental benefit for further information.

3.8 Enhancing of circularity

– Use of ICT tool to enhance circularity (S35)

Description of the strategy	Environmental benefit
Use of ICT tool for communication and information exchange throughout the EEE value chain to significantly enhance circular economy in the E&E sector. Different functionalities can be implemented based on the product needs, such as: tracking, end-user feedback, iterative user and repair manual, consumables management, WEEE management protocols for re-use or recycling, impact assessment tool, stakeholders' interaction toolbox, etc.	Strengthening the circular economy. See [S9] environmental benefit for further information.

4 Successful examples and best practices

This Chapter provides an overview of successful examples of ecodesign strategies, actions, and best practices from the E&E industry. Several cases studies were analysed, taking into account environmental and economic implications associated with them, in order to validate the identified strategies, demonstrate real-world strategies and best practices and prove the environmental and economic benefits that can be achieved by applying ecodesign strategies in EEE.

The different case studies are described below. For each of them, the applied ecodesign strategies, as defined in Chapter 3, are outlined.

Case study 1: Philips Senseo® Viva Café Eco

Applied ecodesign strategies:

- ✓ **Material selection**: Recycled materials (S11), Recyclable materials (S12), Low energy content materials (S15), Selection of low impact materials (S16).
- ✓ **Product use optimisation:** Low energy consumption (S26).

The Senseo® Viva Café Eco reflects the Philips's growing commitment to developing innovative sustainable products through ecodesign and enhancing the circular economy.

The new model Philips Senseo® Viva Café Eco HD6562 (Figure 4.1) was developed within European research project PolyCE [12]. The product has been designed applying different ecodesign strategies such as use of more recycled and recyclable materials, product energy efficiency optimisation and sustainable packaging, thus reducing the machine's carbon footprint.

Figure 4.1 – SENSEO® Viva Café Eco HD6562 [13]

The plastic in contact with water and coffee is free of bisphenol A. The cardboard packaging material contains a minimum of 90% recycled content.

Eco mode shut-off for 28% less energy consumption, and thus potential energy cost savings. Philips Green Products can reduce costs, energy consumption and CO_2 emissions, offering a significant environmental improvement in one or more of the Philips Green Focal Areas – Energy efficiency, Packaging, Hazardous substances, Weight, Recycling and disposal and Lifetime reliability [13].

Case study 2: Signify lighting services

Applied ecodesign strategies:

- ✓ **New concept development**: Dematerialisation (S1), Product-as-service (S5).
- ✓ **Product use optimisation:** Low energy consumption (S26).

Signify provides lighting as service, guaranteeing high efficiency and taking care of installation, maintenance, and management of the lighting throughout its lifecycle.

Thanks to the use of smart lighting and IoT sensors, real-time data on operations, activities and consumption are provided. This allows to optimize energy efficiency, as well as reducing CO2 emissions. Other benefits of lighting as service are energy cost saving, reduction of maintenance costs, more sustainable lighting as well as dematerialisation. Figure 4.2 shows an example of annual energy cost saving due to the implementation of lighting as service provided by Signify [14].

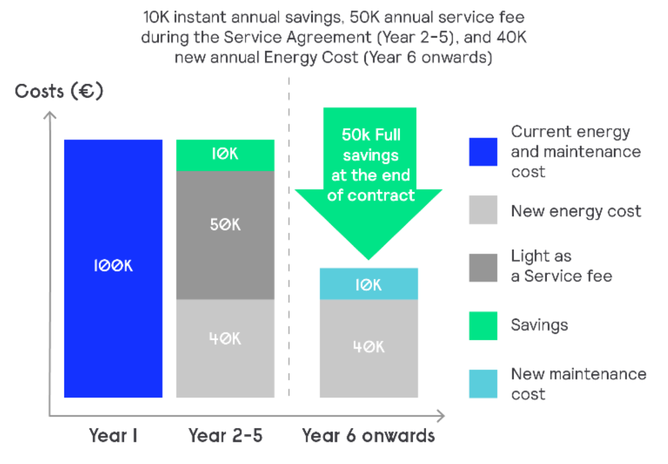

Figure 4.2 – Example of annual energy cost saving related to lighting as service [14]

Case study 3: CISCO sustainable packaging

Applied ecodesign strategies:

- ✓ **Material selection**: Recycled materials (S11), Reduction in material use (S14).
- ✓ **Distribution optimisation:** Packaging optimisation (S22).
- ✓ **Optimisation of End of life:** Design for recycling (S33).

Cisco has implemented several eco-design strategies to optimize packaging of its products and reduce the related environmental burden, such as optimizing packaging efficiency, minimizing single-use plastic and foam, reducing unwanted or redundant items in shipments, and using easily recyclable materials.

Cisco reduced the amount of packaging needed to protect products through design optimisation. This has led to reduction in in corrugate carboard, paper and foam. Furthermore, packaging is made of single material or multiple materials that are easy to separate to facilitate recycling.

Cisco uses thermoformed medium- density polyethylene cushions made from recycled material wherever is possible, and corrugated carboard with a minimum of 25% recycled content.

For selected high-volume products or spare, such as cables, optics pluggables, memory, central processing units, hard drives, fans, and rack gear kits, multi-packs are used [15].

The reduction of the dimensional weight of the spare pack can lead to economic benefits in terms of reduction of the cost of such material and its transportation since the amount used is diminished.

Case study 4: Fairphone smarthphone

Applied ecodesign strategies:

- ✓ **Physical optimisation**: Improving product durability and reliability (S8), Easy maintenance and repair (S10).
- ✓ **Material selection:** Recycled materials (S11), Reduction in material use (S14).
- ✓ **Optimisation of End of life:** Reuse of product (S29), Design for disassembly (S32), Design for recycling (33).

Fairphone is one of the most sustainability-focused companies in the mobile technology sector. Fairphone has developed a series of more sustainable smartphones.

Fairphone smartphone is designed to be durable, modular, easy repair and easy to recycle. Hardware is designed to last as long as possible, and software upgrades are constantly provided by Fairphone in order to increase the phone's lifetime.
Fairphone sells spare parts and offers detailed repairs instruction and tutorials. Moreover, the modular design has significantly decreased the complexity of disassembly and repairs by users (Figure 4.3).
Fairphone gathers old phones by tack-back programme to give them a new life. Phones that are no longer functional go to recycling, where they are processed to recover the valuable resources, avoiding e-waste generation.
Furthermore, Fairphone use increasingly fair trade, recycled, and responsibly extracted materials. For example, in the new Fairphone 4 model, the phone's body is made from aluminium from certified vendors, with a 100% recycled plastic back cover.
The characteristics of durability and repairability confer to the product cost saving in terms of repair and maintenance costs of the product. [16].

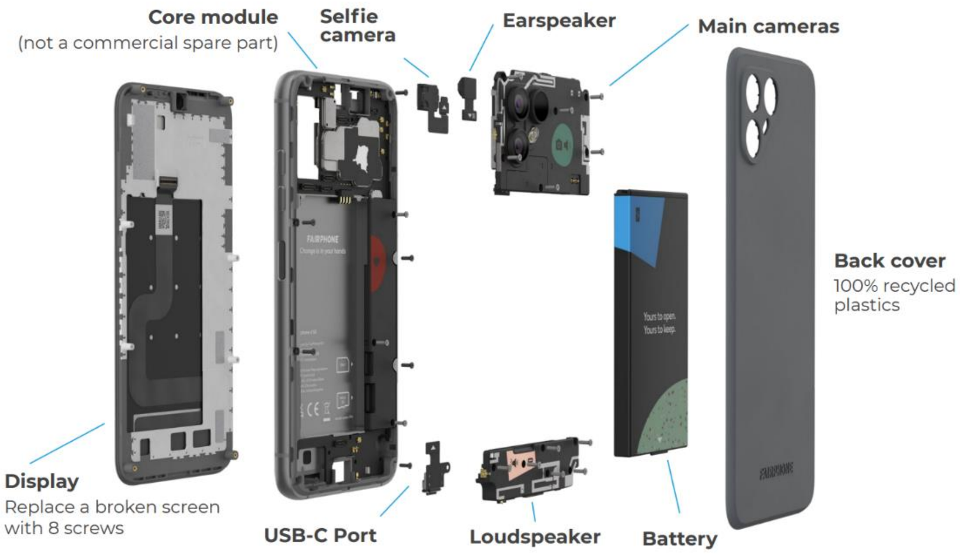

Figure 4.3 – Modular design of Fairphone 4 [17]

Case study 5: Philips healthcare

Applied ecodesign strategies:

- ✓ New concept development: Eco-leasing (S3).
- ✓ Physical optimisation: Improving product durability and reliability (S8).
- ✓ Optimisation of End of life: Reuse of product (S29), Design for recycling (33).

The continuous technological development of healthcare systems involves the replacement of equipment with high residual value at a high disposal cost. In this framework, Philips has introduced ecoleasing strategy for healthcare equipment to ensure high quality and low costs for customers.

Philips provides upgradeable equipment and takes care of refurbishing systems as well as reusing materials, reducing the life cycle costs of the equipment and extending their life.

Philips has achieved 50-90% material reuse (depending on the product) through its refurbishment activities [18] [19].

Case study 6: Production optimisation in Samsung facilities

> Applied ecodesign strategies:
>
> ✓ **Production optimisation**: Alternative production processes (S17), Process optimisation (S18), Less energy consumption (S19), Less waste production (S20), Use of renewable energy (S21).

Samsung has dedicated many efforts to reduce the GHG at its worksites, increasing the use of renewable energy, treating process gases, improving the efficiency of equipment and production processes. Such efforts have led to a reduction in GHG emissions equal to 7,091 thousand tonnes compared to the expected emission amount in 2020.

Samsung achieved its goal of 100% renewable energy usage for its worksites in the U.S, China and Europe by 2020. Moreover, the company is expanding the renewable energy to other regions.

For example, solar and geothermal systems have been installed in Korea (Figure 4.4).

Figure 4.4 – Solar panels at parking lots in Samsung campuses in Korea [20]

To minimize energy consumption in manufacturing processes, many actions have been taken, such as:

- Optimizing the capacity utilisation rate of equipment such as HVAC systems, freezers, air compressors, and pumps.
- Blocking airflow in-between clean room doors, and adjusting the supply of air from outside to maintain the positive pressure
- Installing self-cleaning condensers to improve the efficiency of freezers
- Adjusting the expanded polystyrene (EPS) shape molding machine's steam pressure.

Regarding semiconductor manufacturing, different strategies have been implemented to reduce the environmental impacts related to processes gas:

- reducing the use of process gases through process optimisation;
- improving the efficiency of the process gas treatment facilities;
- development of alternative gases to replace PFCs, which are used in the major semiconductor processing steps. 23% of PFCs have been replaced in processing steps of some products.

Furthermore, the company are continuously improving the product design and manufacturing process to minimize the waste generation, developing waste process technologies, and increasing waste separation.

In terms of economic benefits, investments in renewable energy power plant can lead to future savings considering that the solar costs expect to fall below those of coal. Moreover, enhancing energy efficiency in production processes entails decreasing energy usage and thus a reduction in the total cost of energy [21].

Case study 7: WeWash shared washing machine and dryers

<u>Applied ecodesign strategies:</u>

✓ **New concept development**: Product sharing (S2).

WeWash [22], an innovative spin-off of BOSH Group, is the market leader in digital booking and billing systems in communal laundries. The goal of the company is to make washing and drying more sustainable and user-friendly, combining digitalisation, sharing economy and sustainability.

The company offers WeWash Care (Figure 4.5), a full-service solution that equip laundry with high quality and energy-efficient BOSH machines, including WeWash Box a maintenance-free device for digital booking and billing. WeWash takes care of the installation, service and maintenance of the machines. In addition, the laundry is continuously monitored by the Network Operation Center (NOC). Therefore, any faults are identified immediately, allowing fast and efficient maintenance.

Figure 4.5 – WeWash solution for laundry [22]

WeWash laundry brings significant environmental benefits in terms of CO_2 emissions. For example, in a 50-unit residential building, a WeWash laundry room with 3 shared machines with a life cycle of 3 years each equals a total of 10 machines over 10 years of standard usage entail saving 49% of CO_2 emissions compared to the standard use of private machines.

Manual processes concerning everything to do with a communal laundry room are inefficient and cost intensive. The automatization of the laundry room operated by WeWash gives many cost-saving opportunities. For example, the initial setup costs (depending on the option chosen) are cheaper than any of the coin-operated machines commonly used in the industry. Payment from the users is entirely cashless with the possibility to choose between different digital payment methods. This means retaining full control over costs and removing pay high deposit fees to the bank for the coins added.

Case study 8: Olivetti multifunction printer

Applied ecodesign strategies:

- ✓ **New concept development**: Multifunctionality (S4).
- ✓ **Physical optimisation**: Optimisation and integration of functions (S9).
- ✓ **Product use optimisation**: Lower energy consumption (S26), Reduction of consumables (S27), Cleaner consumables (S28).

The Olivetti d-Color MF459, d-Color MF559 and d-Color MF659 A3 colour multi-functional printers have been designed to provide high efficiency and productivity, providing fast print, copy and scan speeds, a vast array of finishing options and several mobile and direct print functionalities (Figure 4.6). With all these functions and the ability to customize the operator panel control, these systems offer great versatility, which allows to satisfy a wide range of customers.

Furthermore, Olivetti has significantly improved the products performance, considering environmental issues. The energy efficiency has been increased, reducing the energy consumption (close to 0 W when the machine is not in use and only 0.5 W while in sleep mode). Moreover, the capacity and durability of consumables have been considerably extended, entailing the reduction of waste produced, greater productivity and less downtime for maintenance [23].

Olivetti provides high quality, environmentally friendly and completely non-toxic consumables for its printers to ensure high safety for users [24]. These systems are designed specifically to boost productivity by cutting costs. Providing fast print, copy and scan speeds, a vast array of finishing options and unsurpassed mobile and direct print functionalities reduces management and running costs. Cost energy saving features result from the Auto Power off function that automatically switches the unit off after a predetermined operation time and the Auto Sleep function that enables the duplicator to enter “sleep mood”.

Figure 4.6 – Olivetti multifunction printer [23]

Case study 9: Digital twin in healthcare

Applied ecodesign strategies:

- ✓ **New concept development**: Digital twin (S7).

Philips has applied digital twin for their medical equipment for hospitals or personal health devices to assist their design progress. Designers have conducted simulations in the development of a portable oxygen generator and used the digital prototypes to perform tests, reducing the product testing time.

Digital twin (DT) is a dynamic virtual representation of a device, which is continuously fed with data from embedded sensors and software (Figure 4.7). This gives an accurate real-time status of the physical device. Data from DT can significantly help the product and software development (e.g., understanding user behaviour and need) to develop a more user-friendly design and achieve efficient, flexible, customised, cost-effective and high-quality production and reduced maintenance interventions and costs. Conducting scenario tests by digital twin technology for any changes or expected changes with respect to operational strategy, staffing and care delivery models leads to low operation costs. Indeed, the virtual simulation reduces product development time and cost while maintaining a high level of quality [25] [26].

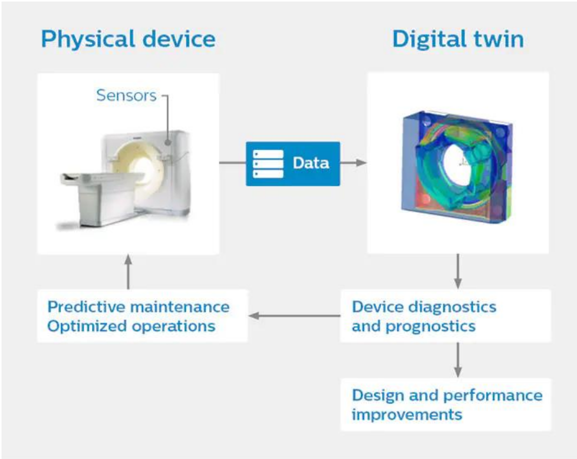

Figure 4.7 – Schematisation of digital twin in product design [25]

Case study 10: ONA lamp

<u>Applied ecodesign strategies:</u>

- ✓ **Material selection**: Recycled materials (S11), Recyclable materials (S12), Renewable materials (S13).
- ✓ **Optimisation of End of life**: Remanufacturing (S30), Design for disassembly (S32), Design for recycling (S33).

ONA [27] has developed circular lamps made from industrial scrap materials (i.e., wood, metal, plastic) within EU CIRC4Life project [28].

The Medusa wood model is made with renewable and recyclable materials and is available in 3 dimensions (Figure 4.8). This modular lamp consists of few materials to ensure an easy and practical disassembly and facilitate recycling.

ONA lamp shows a lower environmental impact compared with other similar products in the domestic lighting sector.

Moreover, as part of the CIRC4Life research project, ONA is demonstrating a new circular economy approach based on the use of eco-cost and eco-credit in order to reward consumer's eco-friendly behaviour. ONA's lamps displays the eco-costs, which show consumer information on its environmental impact.

Eco-credits are points that are awarded when consumers return the lamp to have it recycled. ONA offers discounts on new products, depending on the status of the product and its evaluation. Returned products are sorted at the nearest recycling centre. The components that are still in working condition returns to ONA, which are used for remanufacturing new circular lamps. The Eco-costs and Eco-credits systems were designed to encourage end-users to reuse and recycle their small electronic products. Such system can produce economic benefits by reducing the management costs of the disposal incentivizing the consumers to return the products at the nearest recycling centre. Moreover, the modularity creates saving opportunity in the sorting phase by reducing the cost of disassembly the product.

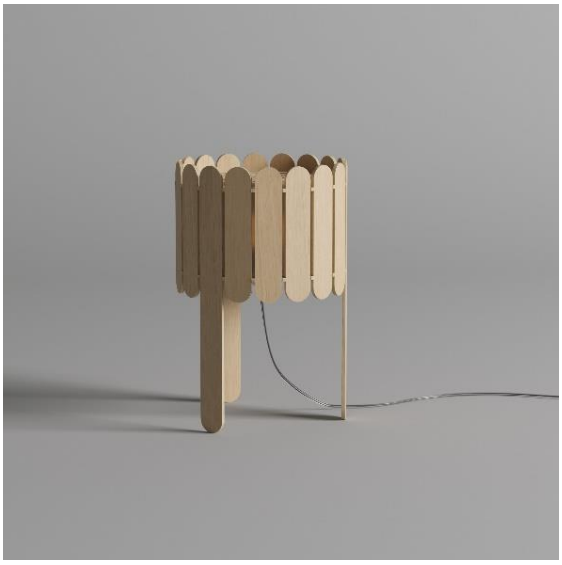

Figure 4.8 – ONA lamp Medusa wood [29]

Case study 11: Repurposing end of life notebook computers from consumer WEEE as thin client computers

Applied ecodesign strategies:

- ✓ Optimisation of End of life: Re-purposing (S31).

Coughlan et al. (2018) [30] have reported that 9% of laptops from consumer WEEE, sourced from Civic Amenity sites (CA), were suitable for repurposing as thin client computers. A thin client is a lightweight computer that is designed to operate in a server-based environment and does not require a hard disk drive.

This strategy allows the reuse of the motherboard, central processing unit (CPU) and memory (RAM) modules to produce thin client computers, and the recycling of components that contain the most concentrated quantities of critical raw materials such as batteries, hard drives, LCD and the larger fractions for recycling (Figure 4.9).

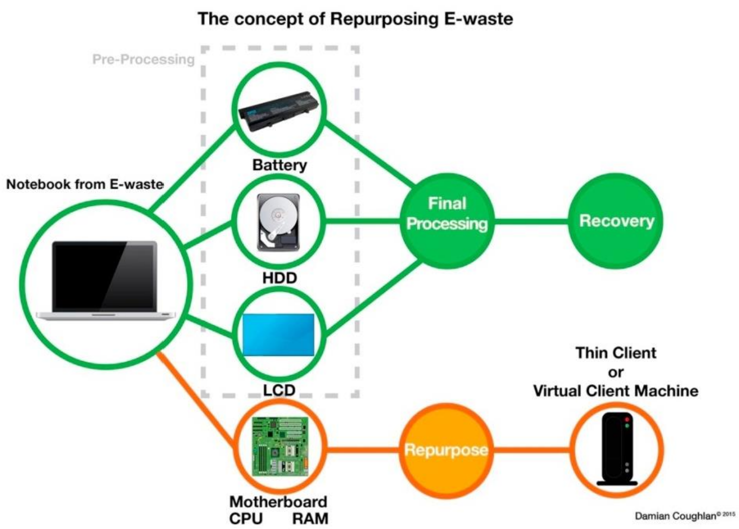

Figure 4.9 – Concept of repurposing notebook computers from E-waste [30]

To increase the feasibility and efficiency of this end-of life strategy, the following design criteria for repurposing EoL notebooks as thin clients have been identified:

- PCB mounted Fan and Heatsink assembly,
- Eliminate daughter and I/O boards,
- A separate Power Button assembly,
- Reduction in size of the motherboards surface area or physical size.

An LCA analysis has demonstrated that the repurposed notebook can lead to a significant emission saving compared to a new thin client computer due to the extension lifetime and offsetting the production of new product.

Therefore, repurposing may be a very promising end-of-life strategy, suitable for notebooks that cannot be reused directly for economic or technical reasons.

Concerning the economic factor, avoidance of high hazardous waste disposal costs by repurposing can also be an economic incentive. The use of recycled materials may lead to a lower material costs or higher profit margin due to the higher market appreciation of more sustainable materials.

Case study 12: KFI Pay per Use service

Applied ecodesign strategies:

- ✓ **New concept development**: Pay per use (S6).

KFI [31] provides the Pay per Use service, an all-inclusive solution in which, through the payment of quarterly fee, KFI provides:

- operational rental of the printer, including print head;
- supply of consumables, according to a program agreed based on specific customer's need;
- maintenance and technical assistance service.

KFI service offers customers benefits such as no investment costs, continuous technology renewal, no unexpected costs and less downtime risk. At the same time, this strategy allows to optimize the equipment usage, entailing economic benefits to the company as well as positive environmental effects.

Case study 13: Green transportation and logistics in DELL

Applied ecodesign strategies:

- ✓ **Distribution optimisation**: Packaging optimisation (S22), Transportation optimisation (S23), Implementing reverse logistic (S24).

DELL is committed to minimizing the environmental footprint of every shipment, selecting the best transportation mode, right-sizing of packaging as well as refining continuously their global transportation and logistics network to achieve a smaller footprint.

DELL is looking for more efficient modes of transportation (e.g., shifting from air to sea) and is optimizing route selection for transportation of products and materials within the supply chain. This allows to reduce waste and carbon emissions.

The expansion of the network of fulfilment centres for retail orders has led to a reduction in shipments and travel distance, entailing reduced fuel consumption, truck loading volumes and carbon emissions.

Packaging has been optimized reducing the size through the 3Cs strategy, which focuses on the cube (size and shape), the content (material choice) and the curb (recyclability), in order to ship more units per pallet or per container.

The processes for pallet manufacturing and trailer loading have been refined to take advantage of changed dimensions and to decrease load times, helping reduce fuel consumption and carbon emissions.

The company has implemented efficient reverse logistics to manage product returns. DELL quickly returns them to the utility by refurbishing (if necessary) and reselling about 90% of the returns (about 800,000 units per years) via the Global Dell Outlet [32]. All products (i.e., certified refurbished, Dell outlet new, or scratch and den) carry the Same-as-New warranty. The remaining 10 percent that cannot be refurbished/resold are responsibly recycled [33]. The implementation of reverse logistics plan costs about 7-10% of the cost of goods in a company. However, an optimised reverse logistics significantly reduce the losses associated with returns as well as produces other benefits for the company such as, better visibility, greater customer satisfaction and customer retention [34].

Case study 14: Circ4life ICT tool for circular economy business models

Applied ecodesign strategies:

- ✓ **Enhancing of circularity**: ICT tool for enhancing circularity (S35).

In the framework of the EU H2020 CIRC4Life project [28], an ICT platform was developed to support new circular economy business models (CEBM) and the Eco-account system, which were developed within the project. The CEBM were demonstrated in different industrial sectors, including electrical and electronic sector (lighting products and computer tables).

The developed ICT platform collects necessary information and offers the following end user applications:

- End user toolbox, which enables the customer to follow the eco-information related to his purchasing and recycling activities (eco-points and sustainable production information).
- Retailer tool for eco accounting, which allows the consumer to buy the product at the store and obtain the related eco-point information.

- Impact assessment tool, which reports the impact of different materials and provides information about their reuse or recycling.
- Stakeholders' interaction tool, which allows the interactions along the value chain, offering the possibility of matchmaking and exchange of services and materials.

The ICT platform is designed to serve new business models that have not yet been verified in the market, and so it minimizes the risk of changing user requirements and the related costs. Indeed, by collecting necessary information and offering tools which facilitates sustainable actions it reduces the cost of information, of networks and of intermediation.

Case study 15: Philips eco monitors

Applied ecodesign strategies:

- ✓ **Physical optimisation**: Improving product durability and reliability (S8).
- ✓ **Material selection:** Recycled materials (S11), Low energy content materials (S15), Selection of low impact materials (S16).
- ✓ **Product use optimisation:** Lower energy consumption (S26).
- ✓ **Optimisation of End of life:** Design for safe disposal.

Philips monitors (Figure 4.10) are designed for sustainable productivity. Super energy-efficient design ensures maximum power savings. PowerSensor transmits and receives harmless infrared signals to determine if the user is present and automatically reduces monitor brightness. This reduces energy costs by up to 70% and prolongs the lifetime of the monitor. Furthermore, LightSensor uses a smart sensor to adjust the picture brightness with minimal power use, while ensuring high image quality [35].

Philips is committed to using sustainable and eco-friendly materials in its monitors (Figure 3.10), using up to 85% post-consumer recycled plastic in some models. 100% recyclable materials are used for packaging.

Strict adherence to RoHS standards ensures a substantial reduction or elimination of toxic substances. The monitors are designed halogen-free and mercury-free to ensure a sustainable product use and safe waste disposal, reducing the environmental impacts.

Figure 4.10 – Philips eco monitor [35]

Case study 16: Solar battery chargers

Applied ecodesign strategies:

- ✓ **Product use optimisation**: Cleaner energy sources (S25).

BigBlue [36], founded in China in 2015, is committed to developing environmentally friendly portable power stations with better performance, newer design, and higher safety factor.

After extensive research, BigBlue has created a series of practical consumer electronics products that use green energy such as solar chargers, desktop docking stations, energy storage systems, car chargers, microUSB cables, etc.

BigBlue 28 W SunPower Solar Charger (Figure 4.11) allows to charge multiple devices at once and is compatible for most all devices. This is equipped with smart charge technology, which recognized the user device smartly and then providing optimal charging speed vary with different devices. BigBlue ensure 100% safe charging with overcharging, overheating and short circuit protection. Through its ultra-thin lightweight design, it can be carried easily in a bag. In addition, SunPower solar panel is highly efficient, converting up to 23.5% of solar and is highly durable and resistant to external agents and wear.
The solar charger which are more energy efficient can be expensive compared with the willingness to pay of the consumer. While customers may be able to save some money on their electric bills by using solar-powered cell phone chargers, some customers may not want to absorb the initial expense.

Figure 4.11 – BigBlue 28 W Sunpower Solar Charger [37]

Table 4.1 shows an overview of ecodesign strategies implemented in the respective case studies from E&E sector.

Table 4.1 – Overview of ecodesign strategies and related case studies from E&E sector

Ecodesign strategies		Case studies															
		1. Philips Senseo® Viva Café Eco	2. Signify lighting services	3. CISCO sustainable packaging	4. Fairphone smartphone	5. Philips healthcare	6. Optimisation of Samsung facilities	7. WeWash washing machine & dryers	8. Olivetti printer	9. Digital twin in healthcare	10. ONA lamp	11. Repurposing EoL notebook	12. KFI Pay per Use service	13. Green transport in DELL	14. Circ4life ICT tool for CE BM	15. Philips eco monitors	16. Solar battery chargers
New concept development	S1 Dematerialisation		x														
	S2 Product sharing							x									
	S3 Eco-leasing					x											
	S4 Multifunctionality								x								
	S5 Product-as-service		x														
	S6 Pay per use												x				
	S7 Digital twin									x							
Physical optimisation	S8 Improving product durability and reliability				x	x										x	
	S9 Optimisation and integration of functions								x								
	S10 Easy maintenance and repair				x												
Material selection	S11 Recycled materials	x		x	x						x					x	
	S12 Recyclable materials	x									x						
	S13 Renewable materials										x						
	S14 Reduction in material use			x													
	S15 Low energy content materials	x			x											x	
	S16 Selection of low impact materials	x			x											x	

Ecodesign strategies		Case studies															
		1. Philips Senseo® Viva Café Eco	2. Signify lighting services	3. CISCO sustainable packaging	4. Fairphone smartphone	5. Philips healthcare	6. Optimisation of Samsung facilities	7. WeWash washing machine & dryers	8. Olivetti printer	9. Digital twin in healthcare	10. ONA lamp	11. Repurposing EoL notebook	12. KFI Pay per Use service	13. Green transport in DELL	14. Circ4life ICT tool for CE BM	15. Philips eco monitors	16. Solar battery chargers
Production optimisation	S17 Alternative production processes						x										
	S18 Process optimisation						x										
	S19 Less energy consumption						x										
	S20 Less waste production						x										
	S21 Use of renewable energy						x										
Distribution optimisation	S22 Packaging optimisation			x										x			
	S23Transportation optimisation													x			
	S24 Implementing reverse logistic													x			
Product use optimisation	S25 Cleaner energy sources																x
	S26 Lower energy consumption	x	x						x							x	
	S27 Reduction of consumables								x								
	S28 Cleaner consumables								x								
Optimisation of End of life	S29 Reuse of product				x	x											
	S30 Remanufacturing										x						
	S31 Re-purposing											x					
	S32 Design for disassembly				x						x						
	S33 Design for recycling			x	x	x					x						
	S34 Design for safe disposal															x	
Enhancing of circularity	S35 ICT tool for enhancing circularity														x		

5 Application of ecodesign strategies to C-SEERVES case studies

This chapter focuses on the case studies developed within WP4 in the framework of C-SERVEES project as practical examples of how ecodesign strategies can be implemented in the E&E sector. Different ecodesign solutions were applied to the targeted products: washing machine (large household appliances), printers and laser toner cartridges (IT equipment), ALM products (telecommunication equipment) and TV sets and displays (consumer electronics equipment).

Such eco-design measures were derived from the four C-SERVEES target products' circular economy business models (CIRCMODEs) developed in WP2. The new CEBMs focused on the identification of ARÇELIK's, LEXMARK's and ADVA's current business objectives and business models with a view to shift towards circular objectives, identifying a series of eco-design and circular economy actions.

All the activities carried out to demonstrate C-SERVEES eco-innovative solutions are reported in D4.2 "Demonstration of design & production phase for target products" and D4.3 "Demonstration of distribution & use phase for target products".

5.1 Washing machine

The C-SERVEES demo product selected for large household appliance category is a GRUNDIG washing machine from ARÇELIK (Figure 5.1). This washing machine model has 9 kg of capacity, maximum spinning 1200 rpm, energy efficiency class A+++ and connectivity features. The smart home technology allows to control the smart features of the product such as switch on/off, program selection, user instructions, etc., through a dedicated app. The model is being manufactured in Çayırova (Turkey) and planned to be sold in Turkey and in the EU market.

Figure 5.1 – C-SERVEES washing machine demo

Table 5.1 shows the ecodesign actions that were implemented in the C-SERVEES washing machine demo within Task 4.1 and related environmental benefits.

Table 5.1 – Ecodesign actions implemented in the C-SERVEES washing machine demo

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Reduction of PP use by using blowing agent in detergent box group and inner cover	S14 Reduction in material use, S26 Lower energy consumption, S23 Transportation optimization.	• Less plastic usage and lower CO_2 emissions. • 10% weight reduction. • Increased productivity by reducing process cycle times by ~25%, which entails the reduction of energy consumption in the use phase.
Increase recycled plastic content in washing machine parts: - using 10% recycled PET in tub - using 63,5% recycled PP in detergent box group	S11 Recycled material, S15 Low energy content materials.	• Less environmental impacts by using recycled raw materials instead of virgin materials • Reduction of fossil-based resources consumption • Reduction of plastic waste disposal • Recycling of plastic waste to value-added product • High potential cost saving due to the use of recycled plastics
Use of ICT tool for tracing the recycled content. QR codes were integrated in the product so that consumer can access via app about the sustainability and circularity of the demo	S35 ICT tool for enhancing circularity.	• Enhancing product circularity during the production and end-of life phase. Tracking a product or material's path from raw material to finished good can verify certain sustainability claims about commodities and products, helping ensure good practices and respect for people and the environment in supply chains.

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Developing of ecoleasing model for corporate washing machine customers (B2B). The C-SERVEES washing machines were installed in different demo sites (i.e., nursing home in Spain, student dorms in Turkey, partner company in Italy) to evaluate the feasibility of this strategy. To ensure an efficient maintenance and repair service during the leasing period, an analysis of the washing machine's most often replaced spare part was carried out as well as repair protocols developed to standardize the repair operations.	S3 Eco-leasing.	• The company takes care of the end of life of the products. The washing machines will be refurbished to give them a second life, thus reducing waste generation. • From an economic perspective, the feasibility of the leasing model is positive for a 10-year period.
The C-SERVEES demo products will be reused to give them a second life and to be sold at Emaus facilities. From the results of repair and recycling operations, potential ecodesign measures can be drawn, to be further implemented by Arçelik by the end of the project	S29 Reuse of product, S30 Remanufacturing.	• Reduction environmental impacts due to the enlargement of product's lifetime. • Reduction of resources consumption and waste generation. • Saving purchasing and disposal cost.

5.2 Printer and laser cartridges

The C-SERVEES demo products selected for the study of eco-design potential in IT equipment are three different multifunctional laser printer models by LEXMARK. The selected models are the following:

- low-end Multifunction, Color Lexmark OEM A4 printer CX510 (Figure 5.2)
- high-end Multifunction, Monochrome Lexmark OEM A4 printer: MS812
- high-end Multifunction, Color acquisition A3 printer: X950.

Figure 5.2 – Lexmark printer models CX510, MS812, X950de, CX860dte

For the Printer and toner cartridges demonstration, the activities focused on the analysis of selected Lexmark printers and toner cartridges in order to determine potential eco-design measures to be implemented in future models in terms of material circularity and recyclability. All the eco-design actions are reported in Table 5.2.

Table 5.2 – Ecodesign actions implemented in the C-SERVEES printer demo

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Design for recycling: an analysis of potential improvements based on the collaboration with recyclers to implement design for recycling was carried out. The following aspects were analysed: – Ease of disassembly – Recovery of components – Value of recovered materials – Hazardous or toxic materials – Material compatibility for recycling The recycler has provided information on the obstacles to disassembling the printer as well as the time and resources needed to recover critical components. From these results, a new dismantling manual was created, and the potential to recover and reuse some components from EoL printers and toner cartridges was evaluated.	S33 Design for recycling, S32 Design for disassembly	• Reduction of resources consumption, reduction of GHG emissions by the extension of product lifecycles • Dismantling devices provide more value for the printers, as complete parts and components result in higher value to the original manufacturer than the potential selling price of the secondary raw material on the recycled material market.
Use of ICT tool to improve circularity of the printer and toner cartridges (i.e., improve tracking of printers and information sharing across the value chain). Refurbished printers, newly manufactured cartridges and refurbished/remanufactured cartridges will receive a QR code that allows user access the following information via app:	S35 ICT tool for enhancing circularity	• Enhancing product circularity during the production and end-of life phase. Tracking a product or material's path from raw material to finished good can verify certain sustainability claims about commodities and products, helping ensure good practices and respect for people and the environment in supply chains.

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
- The % of the changed parts in the printer - All product and process certifications (like Energy Star, Blue Angel, EPEAT, ISO, etc.) - Hazardous material and chemical of concern information (RoHS, REACH) - The warranty information for the printer - Technical specifications - Life Cycle Assessment data - Other data based upon the feedback obtained from authorities, NGO's, customers, recyclers.		
Design for remanufacture has been explored. The potential for expansion of the printer refurbishment activity was analysed, taking into account cost and customer acceptance. 4 refurbished printers built with various cosmetic defects were sent to consumers to test acceptance of cosmetic defects and acceptance of functionality.	S30 Remanufacturing	• The extension of product's lifetime reduces the CO_2 emissions, reducing the resources consumption and costs of the manufacturing process. • Potentially acceptable damages can drive a significant cost impact and play a major role in the final business case. • Substantial efficiency gains can be obtained with minimum investments to help the refurbishment operations and generate higher customer traction.
Increase the reverse logistics efficiency by the extension of the current LCCP platform to printers to facilitate buy back and take back operations and by the adoption of the new ICT platform developed within C-SERVEES project for the optimisation of logistic operations. This latter allows to	S24 Implementing reverse logistic, S35 ICT tool for enhancing circularity	• Reduction of unnecessary and incorrect shipments, avoiding the CO2 emissions and costs associated with them.

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
calculate air pollutant emissions, determine truck capacity needed, compare the possible transportation routes and display the maps of the sections of the best route solutions.		

5.3 ALM products

The C-SERVEES demo product selected for telecommunications equipment category is ALM (Advanced Link Monitoring) product for optical network from ADVA (Figure 5.3).

ALM product splits into an (electrically) active unit and passive fibre-optic sensors for fibre monitoring tasks like real-time information on fibre integrity, fast and easy localization of user traffic and remote passive fire detection in sites accessed with a fibre.
Two ALM variants were considered for the demonstration, namely 16 ALM (16 access-fibre ports device) and 64 ALM (64 access-fibre ports device).

Figure 5.3 - C-SERVEES 64 ALM demo product

For the ALM demonstration, no new active ALM units are being developed within the project time frame, as this is not feasible due to time constraints, same as for the printer demo. However, a new version of the Design for Environment (DfE) Guide, which is an ADVA-internal ecodesign guide will be released toward the end of the C-SERVEES project, containing potential eco-design strategies to be implemented and new recommendation derived from the demonstration experiences. All the eco-design actions are reported in Table 5.3.

Table 5.3 – Ecodesign actions implemented in the C-SERVEES ALM demo

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Manual disassembly of ALM units and XFR analysis of plastic parts derived from disassembly were carried out to investigate the suitability for easy disassembly and recycling. From the results of dismantling and recycling operations, the potential to introduce new ecodesign measures will be analysed.	S32 Design for disassembly, S33 Design for recycling.	• Disassemble components without destroying the components itself for the purpose of reuse, repair and remanufacturing in line with the vision of a circular economy.
New fibre-optic sensors were developed, specifically designed to substitute the conventional fire alarm system based on electricity signal. This eco-designed solution is more energy efficient and offers longer lifetime, increased reliability, and sustainable design (Ecodesign of ICT).	S8 Improving product durability and reliability, S26 Lower energy consumption.	• Thanks to the high lifetime and energy efficiency of these new sensors, the total environmental impact is significantly lower than the electrical sensors.
Use of more efficient resources (Ecodesign by ICT).	S25-S28 Product use optimization.	• Sustainable use of resources in sectors other than ICT that are enabled by ICT.
Improving packaging by developing new plastic-free packaging and tape.	S22 Packaging optimization.	• Less single plastic usage to reduce plastic pollution and to reduce the environmental footprint of the packaging.
PSS selection combined with lifetime optimisation study for ICT products.	S3 Eco-leasing.	• Less environmental impacts due to the increased producer responsibility in terms of sustainability. • Less environmental impacts derived from the optimisation of the product lifecycle.

5.4 TV sets and displays

The TV set selected for demonstration is GRUNDIG G43C 891 5A (Figure 5.4). It is a 43" smart-TV model with energy efficiency class A+ and connectivity features. This product is manufactured in Tekirdağ (Turkey) and currently on sale in Turkey and the EU.

Figure 5.4 – C-SERVEES TV set demo

All the ecodesign measures that were implemented in the C-SERVEES TV set demo are reported in Table 5.4.

Figure 5.5 shows the solution adopted for the packaging optimisation 100% recycled, i.e., 100% carboard box and multi-use plastic box.

Figure 5.5 – C-SERVEES 100% recycled carboard TV box and multi-use plastic box

Table 5.4 – Ecodesign actions implemented in the C-SERVEES TV set demo

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Increase recycled plastic materials in TV back cover, using 30% PC/ABS (Polycarbonate/Acrylonitrile Butadiene Styrene) halogen free	S11 Recycled materials, S15 Low energy content materials.	• Reduction of virgin raw materials consumption. • Decrease in the environmental footprint by interfering on a non-strategic part of the product. The reason for choosing TV' back cover as a potential part is that its weight is higher than all plastic parts and it is not a visual aesthetic part of the product.
Introducing reusable packaging: multi-use plastic boxes instead of individual carboard packaging in forward and reverse logistics	S22 Packaging optimization.	• Decrease of packaging waste. • The use of this packaging can significantly raise logistics costs because of the need to control the return cycle. However, reusable packaging has cost advantages and uses less cardboard and Styrofoam. • This packaging is more durable and robust and offers better protection of the products. This reduces the transit damage; thus it helps to reduce the resources and costs required to refurbish of the returned products.
Tracing of recycled content via ICT (ICT-based certification). QR codes were added to the demo products, thus consumers can access via app about information on product sustainability, such as: product user manual, parts made from recycled materials and their proportions, hazardous substance information in product raw material content, instruction for recycling.	S35 ICT tool for enhancing circularity.	• Enhancing product circularity during the production and end-of life phase. Tracking a product or material's path from raw material to finished good can verify certain sustainability claims about commodities and products, helping ensure good practices and respect for people and the environment in supply chains. • Arcelik received a personalised dashboard in order to receive tokens from their supplier, certifying the material as recycled

C-SERVEES adopted ecodesign actions	Strategy	Environmental benefit & Additional Info
Developing of eco-leasing model for corporate TV customers (B2B). The C-SERVEES TV set demos were installed in demo sites (Spain and Turkey) to evaluate the feasibility and acceptance of this strategy.	S3 Eco-leasing.	• The company will recover the materials to create another product with it after the product reached the end of its lifespan increasing the circularity of TVs • The strategy leads to a reduction of consumption and waste generation
The C-SERVEES tv demo products will be remanufactured or re-conditioned. From the results of repair and recycling operations, potential ecodesign strategies can be drawn, to be further implemented by Arçelik.	S29 Reuse of product, S30 Remanufacturing.	• Reduction environmental impacts due to the enlargement of product's lifetime • Reduction of resources consumption and waste generation • Saving purchasing and disposal cost

Table 5.5 summarises the ecodesign measures implemented in C-SERVEES case studies.

Table 5.5 – Overview of ecodesign strategies implemented in C-SERVEES case studies

Ecodesign strategies		C-SERVEES case studies			
		WASH	PRINT	ALM	TV
New concept development	S1 Dematerialisation				
	S2 Product sharing				
	S3 Eco-leasing	x		x	x
	S4 Multifunctionality				
	S5 Product-as-service				
	S6 Pay per use				
	S7 Digital twin				
Physical optimisation	S8 Improving product durability and reliability			x	
	S9 Optimisation and integration of functions				
	S10 Easy maintenance and repair				
Material selection	S11 Recycled materials	x			x
	S12 Recyclable materials				
	S13 Renewable materials				
	S14 Reduction in material use	x			
	S15 Low energy content materials	x			x
	S16 Selection of low impact materials				
Production optimisation	S17 Alternative production processes				
	S18 Process optimisation				
	S19 Less energy consumption				
	S20 Less waste production				
	S21 Use of renewable energy				
Distribution optimisation	S22 Packaging optimisation			x	x
	S23Transportation optimisation	x			

	Ecodesign strategies	C-SERVEES case studies			
		WASH	PRINT	ALM	TV
	S24 Implementing reverse logistic		x		
Product use optimisation	S25 Cleaner energy sources			x	
	S26 Lower energy consumption	x		x	
	S27 Reduction of consumables			x	
	S28 Cleaner consumables			x	
Optimisation of End of life	S29 Reuse of product	x			x
	S30 Remanufacturing	x	x		x
	S31 Re-purposing				
	S32 Design for disassembly		x	x	
	S33 Design for recycling		x	x	
	S34 Design for safe disposal				
Enhancing of circularity	S35 ICT tool for enhancing circularity	x	x		x

6 Conclusions

The main objective of this deliverable was to provide ecodesign guidelines for the electrical and electronic sector that include aspects for a proper, sustainable, and efficient management of EEE.

The Guidelines provide key elements for effective implementation of ecodesign, as well as a detailed information on the available ecodesign strategies to improve the sustainability performance and circularity of E&E products.

Several case studies from the E&E sector are reported in these Guidelines in order to validate the identified strategies and demonstrate real-world strategies and best practices, proving the environmental and economic benefits that can be achieved by applying ecodesign strategies in EEE.

Indeed, more wide-spread adoption of such strategies and practices will be key to prevent and mitigate the environmental impacts associated with the rapid growth of EEE products by reducing the resource consumption, intensifying the product usage, increasing the energy efficiency as well as optimising waste management.

Furthermore, the C-SERVEES case studies represent practical examples of how ecodesign strategies can be implemented in the E&E sector. The ecodesign solutions that were applied (or explored) in the four demonstration products are in accordance with the generic strategies for eco-design in the E&E sector and can help to pave the way towards strengthening the circular economy in the E&E sector.

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