Activating Circular Services in the Electric and Electronic Sector

GA NUMBER: 776714

Deliverable 4.4. Demonstration of end-of-life phase for target products

Acronym:	C-SERVEES
Project title:	Activating Circular Services in the Electric and Electronic Sector
Contract Nº:	776714
Start date:	1st May 2018
Duration:	54 months

Deliverable number	D4.4
Deliverable title	Demonstration of end-of-life phase for target products
Submission due date	M50 – June 2022
Actual submission date	M51 – July 2022 (Final version)
Work Package	WP4
WP Lead Beneficiary	GAIKER
Dissemination Level	Public
Version	01
Authors	Arçelik, ADVA, Circularise, Lexmark, Gaiker, Greentronics, Indumetal, Particula, Rina-C, Soltel

DOCUMENT CONTROL PAGE

<table>
<tr><td>Author(s)</td><td>Agnes Vigh, Lexmark
Patrick Carminati, Lexmark
Agnes Bartfai, Lexmark
Maxime Furkel, Lexmark
Aybüke Kaba, Arçelik
Sevgican Koç, Arçelik
Tuğçe Pınar, Arçelik
Özlem Ünlüer, Arçelik
Klaus Grobe, ADVA
Ana Isabel Díaz, Gaiker
Sara Fozza, Rina-C
Teresa Oberhauser, Circularise
Juan Carlos Liébana, Soltel
Luka Dobrovic, Particula
Maider Arieta-araunabeña, Indumetal
Ainhoa Urkitza, Indumetal
Dan Modoran, Greentronics</td></tr>
<tr><td>Version history</td><td>
<table>
<tr><th>#</th><th>Reviewer</th><th>Comments</th></tr>
<tr><td>00</td><td>Lexmark</td><td>Document creation with the input of the different WP4 partners and GAIKER support.</td></tr>
<tr><td>01</td><td>Gaiker</td><td>Document revised by WP leader and TMC</td></tr>
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1. Executive Summary

The purpose of this deliverable is to describe the work performed to demonstrate C-SERVEES eco-innovative solutions and describe the activities carried out to improve circularity in the end-of-life phase of the four large demonstrators selected to represent different EEE categories: washing machine (large household appliances), printers and laser toner cartridges (IT equipment), ALM products (telecommunications equipment) and TV sets and displays (consumer electronics equipment).

The main objectives of the end-of-life phase are to progress the state of the art in WEEE management addressing CE barriers and opportunities to prioritize preparation for reuse, remanufacturing and refurbishing over disposal of used EEE, enabling the recovery of valuable spare parts and materials and avoiding the disposal of recyclable materials. ICT tools to support these activities have been developed and integrated into an ICT platform solution for secure information exchange throughout the value chains.

The present report describes the last stage in the implementation of the four product-specific CEBMs according to the CE actions selected for each demonstration. These CE actions are focused on completing the circularity at the end-of-life phase for those circular offerings (Product Service Systems) explored by each of the demonstrators.

The washing machine and TV set demonstrators, led by Arçelik, focused on developing circular practices related to preparation for repair and refurbishment in order to extend the lifetime of used demo products from Arçelik brands outside Europe. Through the work done in the project with Emaús, a social organisation, a new business line is proposed to collect and repair end-of-use washing machines and TVs and re-sell them to low-income customers in Spain, with potential for replication in other countries. This would complement the B2B leasing/renting model examined by Arçelik during the project, where the products would be collected after the contract period and given a second life after revision and repair, with all required warranties. A first draft of the collaboration scheme is provided, to be further developed. Results from the living labs carried out with end-users confirmed the interest in refurbished products and provided insights to the main customers' concerns. To facilitate repair and refurbishment operations, solutions related to the use of 3D printed parts were also examined, although results outline several difficulties to achieve the desired performance in both cases. The possibility of recovering spare parts from recycling facilities receiving end-of-use devices was also explored together with the recyclers. As an outcome, disassembly guidelines were produced to be used at preparation for reuse and recycling centres.

The printer and toner cartridges demonstrator, led by Lexmark, continued the work started to analyse the potential to expand the printers' refurbishment business within the MPS offered by the company. The two main issues identified previously in the demonstration as critical for the new CEBM (cost and customer acceptance) continue to be addressed here. On the one hand, further research in collaboration with recyclers allowed to determine the viability of a new business line to recover spare parts. On the other hand, by carrying out a testing experience with refurbished printers, new insights were gained about needs and expectations from customers. The potential for refurbishment operations to improve circular economy in the printing services has been

discussed with a competitor company (Ricoh) and a resource recover company (Close the Loop). Finally, 3D printing has proven to be interesting for certain non-functional parts.

The ALM demonstrator, led by ADVA, continued with the validation of an LCA-based lifetime optimisation model for ICT products, developed during previous demonstration stages, in order to extend it to other EEE and develop a useful tool for the determination of the most sustainable lifetime period depending on the use model. This will be complemented by a PSS assessment model, since different PSS may alter the outcome of the UPR_{10} indicator as they influence the use phase intensity. The outcome of this model may provide useful guidelines for EEE manufacturers, to shift their efforts on different eco-design approaches, and to policy makers, to consider different recommendations for circular economy depending on the type of EEE and the expected usage time. As a first outcome, reuse guidelines for ICT products have been developed. A generic disassembly guideline for ICT products is also provided based on the work carried out with recyclers to facilitate material recovery and reuse.

The use of ICT tools as support to the EoL activities was demonstrated through the testing of the integrated C-SERVEES ICT platform, where information related to repair, refurbishment, disassembly and recycling can be shared and requested by the involved actors.

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2. Acronyms and abbreviations

ABS	Acrylonitrile butadiene styrene
B2B	Business to business
CE	Circular economy
CPU	Central processing unit
DfX	Design for X (X = disassembly, reuse, maintainability, recycling etc.)
EF	Emission factor [$kgCO_2e/kWh$]
EoL	End of life
FMD	Full material declaration
GWP	Global warming potential [$kgCO_2e$]
ICT	Information and communication technology
LCA	Lifecycle assessment
LCCP	Lexmark Cartridges Collection Program
LECP	Lexmark Equipment Collection Program
PC	Polycarbonate
PCBA	Printed circuit-board assembly (i.e., including ASICs etc.)
PE	Polyethylene
PSS	Product-service system
PSU	Power-supply unit
RE	Renewable energy / electricity
SW	Software
UPR_{10}	10-years use/production ratio (GWP)
WEEE	Waste electrical and electronic equipment

3. Introduction

This document reports the outcomes of the end-of-life phase for the four large demonstrations run in the C-SERVEES project. The demonstrations consist of the implementation and testing of the four new CEBMs developed within the C-SERVEES project, based on a generic reference CEBM for the E&E sector, the REF-CIRCMODE. The aim of the demonstrations is to validate the four CEBMs integrating four basic pillars: eco-design, eco-leasing, improved WEEE management, and ICT services.

The scope of this document comprises all activities developed within subtask 4.1.3, subtask 4.2.3, subtask 4.3.3 and subtask 4.4.3 of WP4: all four subtasks belonging to the end-of-life phase for each demonstration.

This is the fourth deliverable produced in Work Package 4 of the C-SERVEES project. The first deliverable included an exploration of CEBMs currently applied to the E&E sector, in particular to the four types of EEE products selected in the project: washing machines, TV sets, printers and telecommunication equipment (ALM). It also described the four demonstrators, their materials flow charts and the range of key performance indicators that could be included to evaluate the progress of each demonstration. The deliverable ended with an overview of the C-SERVEES demonstrations and a development plan for the demonstrative activities to be carried out.

The second deliverable reported the results obtained for the first set of eco-innovation actions, related to the first stage in the life cycle of the demonstrators: the design and production phase. The specific activities to be carried out for each product were selected during the validation process of the product specific CIRCMODEs in accordance with the manufacturer's priorities and needs. For each of the target products, eco-design measures were examined and/or introduced to improve the circularity of the product or service offered: (1) high-end model of washing machine containing increased amounts of recycled plastics and connectivity features, (2) set of eco-design measures with potential to be implemented in future models of high-end printers oriented to improve refurbishment and dismantling operations, (3) new eco-designed fire and door sensors (passive units) for the ALM system, based on optical fibre technology and aimed to provide long-lasting and efficient substitution for the electric sensors currently used and (4) high-end model of TV set with increased amounts of recycled plastic. Additionally, the work done includes an in-depth examination of the environmental impact of ICT products (focused on the ALM, but applicable to the whole EEE category) with conclusions relative to the potential for circular economy considering the characteristics and limiting aspects of these products.

The third deliverable reported the results obtained for the second set of eco-innovation actions, related to the distribution and use phase of the demonstrators. The main goal for this phase was to progress the state of the art in EEE eco-leasing by developing and testing new Product Service Systems (PSS) for the demonstration products that include not only the transition of product ownership structures but also focus on aspects like preparation for reuse, remanufactured products and recovery of parts or components, following circular economy principles. In the case of WM and TV set, Arçelik explored the feasibility of moving from a conventional sales model towards an eco-leasing model

oriented to corporate customers (B2B). In the case of the ALM product line, ADVA carried out an in-depth study on different PSS applicable to the ALM, complemented by the development of an LCA-based model to determine the optimum lifetime of ICT products which with to complement the PSS analysis. Finally, Lexmark, already running a PSS for the printers, continued their research on the potential to increase the circularity of their business model by enhancing the refurbishment operations and analysing customer expectancies.

Continuing from the activities carried out during the use phase, the present report describes the last step in the implementation of product specific CEBMs according to the CE actions selected for each demonstration. The end-of-life phase is focused on improving circularity by promoting preparation for reuse, repair, remanufacture or refurbishment of end-of-life EEE, and optimising WEEE management schemes to avoid the disposal of valuable materials, recyclable materials, and spare parts. The use of ICTs will provide support by facilitating reverse logistics and communication among the various actors in the value chain, as well as ensuring secure information exchange.

The actions selected for implementation in the end-of-life phase of each target product are summarized below, including some actions supported by the ICT tools developed in the project. The complete description is found in each of the demonstration sections in this deliverable.

Demo product (OEM)	Circular economy action	Action description
Washing machines (Arçelik) 	• Collect end of life products from B2B customers and provide refurbished products as a new business line • Develop dismantling and repair training programmes • Initiate a take back collection system in Europe with a partner	Initiate new business line to recover, refurbish and give a second life to used WMs with Emaus in Spain
	• Obtain feedback of B2B customers via questionnaires	Customer experience at living labs
	• Use 3D printing for WM components	Select WM parts to be 3D printed and analyse the prototypes
	• Develop circular end-of-life recovery strategies for end of use WMs outside Turkey	Dismantling of WMs and analysis of eco-design potential, recovery of WM parts
Printers and toner cartridges (LEXMARK) 	• Expand LCCP and/merge with LECP program (collecting and refurbishing whole printers and key components)	LCCP platform extension to printers
	• Salvage working and repairable parts from collected/returned printers and use on E2N (Equal to New) printers	Validation of business case on recovered printer parts, extended demo with recyclers
	• Use ICT to improve information sharing across the supply chain	Testing of Smart Questioning functionality and information exchange functionality
Telecom equipment (ADVA) 	• Implement eco-design strategies across the life cycle of ALM products and the subsequent reduction of energy use	Analyses with generic model parameters to test C-SERVEES target products' behaviour
	• Improve on PSS currently offered	Extended analysis of best potential PSS for ALM with special EoL consideration
	• Assessment of component reuse	Assess reuse, based on LCA, AND considering UPR10
TV sets (Arçelik) 	• Collecting and remanufacturing end of use TV sets • Improve reverse logistics • Develop dismantling and repair training programmes	Initiate new business line to recover, refurbish and give a second life to used TVs with Emaus in Spain
	• Use 3D printing for TV components	Select TV parts to be 3D printed and analyse the prototypes
	• Capture customer feedback on the use of circular economy business models	Customer experience at living labs
	• Develop circular end-of-life recovery strategies for end of use TVs outside Turkey	Dismantling of TVs and analysis of eco-design potential, recovery of TV parts

In the washing machines and TV sets demos, Arçelik has continued working with Emaús in the development of new repair and refurbishment protocols and the training of Emaús workers (persons in risk of exclusion) to perform preparation for reuse operations and give a second life to Arçelik products once the renting/eco-leasing period with B2B customers is over. The final goal is to develop a business line to recover and refurbish used WMs and TV sets in Spain that can be replicated anywhere in Europe. In order to gather real customer feedback and promote circular economy and refurbished devices, living labs have been carried out with the Arçelik demonstration products. Moreover, 3D printing technology has been examined for the potential to provide spare parts for refurbishment and repair operations.

For the printer and toner cartridges, Lexmark continued the work already started to validate a potential business line for the recovery of printer spare parts with recyclers, with the aim to expand the refurbishment options of their current MPS (Managed Printing Services) with more circular options. They also investigated acceptance of refurbished products at selected customers' locations by sending printers showing cosmetic defects and gathering users' feedback. Testing of the C-SERVEES ICT platform was conducted to assess its potential to support new CE business lines and management of end-of-life products.

In the ALM demonstration, ADVA continued working on the development and testing of URP_{10} (**U**se-phase-over-**P**roduction-phase **R**atio) by extending the analysis to EEE other than ICT equipment, investigating also the influence of the electricity emission factor. The aim is to demonstrate the benefits of using this indicator to support circular economy options for lifetime optimisation of EEE products and to support the most suitable product-service system (PSS) in each case. In addition, reuse guidelines for ICT B2B products were compiled, not restricted to the ALM. A disassembly guideline for ICT products was also developed with the ALM as example.

The results shown in this report were achieved in the period from October 2021 up to June 2022. The objectives, in all cases, were to examine, test and validate circular strategies for the end-of-life phase of the selected EEE that can be extended and adopted throughout the corresponding product categories.

4. Washing machine demonstrator

The activities conducted in the end-of-life phase were derived from the WASH-CIRCMODE short-term actions validated in WP2. The final list of short-term CE actions to be implementated in WP4 were selected based on SMART objectives at the end of the CEBM validation process and included in D2.2. The table below presents the WASH-CIRCMODE canvas sub-components and their validated short-term CE actions corresponding to the end-of-life phase, as presented in Table 24 in D2.2.

Table 1. Validated short-term WASH-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the end-of-life phase.

WASH-CIRCMODE Canvas Sub-Component	WASH-CIRCMODE validated short-term Circular Economy Actions
WASH_C1.1 Diversify circular activities	WASH_A1.1.5 Collect end of life products from B2B customers, refurbish them and provide refurbished products to B2B customers as a new business line
WASH-C1.4: Develop circular logistics and distribution	WASH_A1.4.1: Enable collection of products back from customers with a partner in Europe
WASH-C1.5: Provide repair and maintenance services	WASH_A1.5.1 Use 3D printing for WM components
WASH-C1.7: Enhance practices and tools to track materials and components	WASH A.1.7.1 Use a QR code on the refurbished parts to track their service call rate
WASH-C2.2: Develop circular economy enhancement skills and training programmes	WASH_A2.2.1 Develop dismantling and repair training programmes
WASH-C2.3: Introduce and/or expand the use of ICT to foster circular economy	WASH_A2.3.2 Use QR codes to provide information about materials and company's circularity to all the value chain
WASH_C3.3 Address partnerships' cultural issues that would encourage circular economy business models to be widely adopted	WASH_A.3.3.1: Create awareness among B2B consumers via the help of QR codes inserted in products, which include examples of Arçelik's best practices in terms of circularity
	WASH_A3.3.2: Obtain feedback of B2B customers via questionnaires
WASH_C4.1 Adopt circular economy activities to suit B2B and/or B2C ensuring customer segments are wide and varied to capture additional market	WASH_A4.1.1 Expand partnerships with Arçelik dealers and retailers to sell remanufactured B2C WMs
WASH-C4.3: Target B2C social classes and various demographic segments with offerings tailored to different price brackets	WASH_A4.3.1 Target low-income customers for the sale or rent of refurbished WMs (students, pensioners, house shares, etc.)
WASH-C5.3: Change traditional relationships with customers building on the take-back schemes operated for B2C customers	WASH_A.5.3.1: Initiate a take back collection system in Europe with a partner
WASH_C7.2 Introduce and/or enhance offerings of leased, rented or shared product options	WASH_A7.4.2 Develop circular end-of-life recovery strategies for end of use WMs outside Turkey

CE actions WASH_A1.1.5, WASH_A1.4.1, WASH_A2.2.1, WASH_A4.1.1, WASH_A4.3.1 and WASH_A5.3.1_are all related to the development of a new business line to recover, refurbish and give a second life to used WMs with Emaús in Spain and are covered in Section 4.1.

CE action WASH_A1.5.1 is related to the testing of the 3D printing technology to facilitate refurbishment operations and is described in Section 4.2.

CE actions WASH_A3.3.1 and WASH_A3.3.2 are related to the customer feedback collection at the living labs and covered in section 4.3.

CE action WASH_A7.4.2 is related to the dismantling operations to improve the recycling process and obtain eco-design proposals and is described in sections 4.4 and 4.5.

CE action WASH_A2.3.2 is related to the testing of ICT tools to support EoL operations and is described in section 4.6.

4.1. Improve and expand repair and refurbishment operations

4.1.1. Preparation for Refurbishment experience

The preparation for reuse, consists of the recovery operation consisting of testing, cleaning or repair, by which products or components of products that have become waste are prepared so that they can be reused without further processing.

Washing machine refurbishment training

Regarding the recovery processes of washing machines, Emaús has developed refurbishment processes and trainings for Emaús workers through a collaboration with Sareteknika, a company dedicated to providing technical services for electrical appliances.

Those refurbishment processes have been established in order to standardize the most common operations and the most profitable ones. Below an example of the protocols developed (the rest of the procedures can be found in Annex 1):

PROTOCOL	Refurbishment procedure
Type of refurbishment:	BELT REPLACEMENT
Protocol code:	7150341600 DNM C-SERVEES
Introduction:	Some machines refurbishment procedures are edited after a used period.
Description:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products.

	1. Rear wall (rear panel)'s screws (x5) are removed.	
	2. Rear wall is removed.	
	3. Poly-V belt is removed.	
	4. First, the belt is placed in the groove of the motor pulley (lower yellow arrow). Then the belt is placed on the half surface of the pulley to the right of the main pulley (upper yellow arrow). The belt is kept tight so that it does not slip off the main pulley surface.	

	5. The belt is assembled by turning the main pulley counterclockwise half a turn.	
	6. Picture of new belt.	
	7. The belt is replaced with new one. There is no cleaning procedure for belt.	

Training has been imparted to Emaús workers to use these procedures in their WEEE reuse preparation center, organized by Sareteknika. The first training session was focused on generic refurbishment processes applicable to all types of washing machines of any brand or maker. The second training session was more focused on specific refurbishment processes based in Arçelik's eco-designed washing machines.

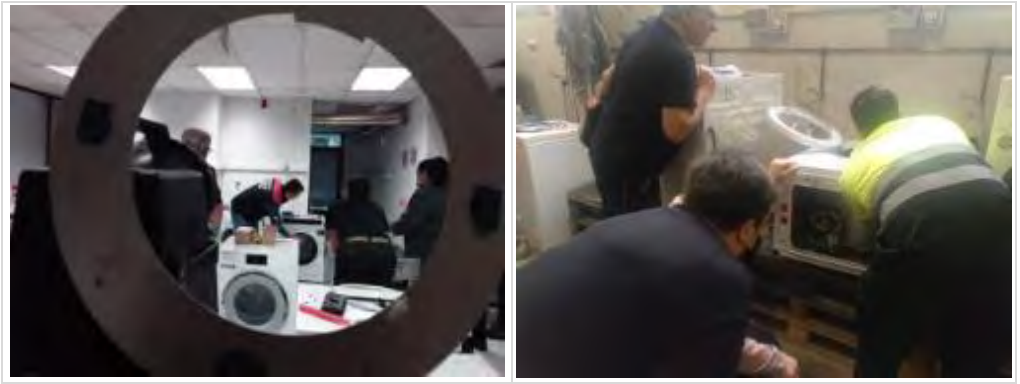


Figure 1. Training courses on WM refurbishment with Emaús workers

The trainings provided to Emaús employees and the development and implementation of new refurbishment procedures helped expand the knowledge of the technicians and the trainings were useful and applicable to the WEEE process in general. The trainings contributed to improving skills of the workers at risk of exclusion that are part of Emaús social programs, facilitating their integration into the labour market.

There has been an improvement in the quality of the protocols, increasing the WEEE refurbishment or recovery rate from 3% to 3,5%, which is above average.

Among the refurbishment operations, the gasket replacement is one of the most labour intensive and difficult to perform as it requires considerable manual dexterity. The belt replacement, on the other hand, was the easiest operation.

In terms of profitability, the review and the comprehensive cleaning operations which verify the proper functioning of the machine as well as the belt replacement were the most cost-effective.

Arçelik products have been rated by Emaús technicians as being very easy to be repaired. As a conclusion, the washing machine repair procedures have proven to work better for Emaús technicians compared to TV process. Therefore, the potential deployment of a washing machine repair and second-hand sale process seems to work better compared to TV process.

Emaús does not currently recover components from refurbished products and in the future, there is also potential to test the use of recovered components in other refurbishment procedures instead of buying new components. As it will be explained in detail in the dismantling section, it is more feasible for repair companies like Emaus to try and recover the components which can be recoverable instead of the recyclers trying to recover the components. Due to the complexity of the recycling business and the current manual technologies at hand, the recovery of the components would prove to be more efficient if they can be recovered by the repair companies rather than recyclers.

Due to the regulations, the manufacturers are not allowed to use second-hand components in new units produced. Instead, such components can be used as spare parts with the condition that the consumer is informed about the second-hand status of the spare parts. The recovered components can best be used in refurbished products by the repairers.

Potential to implement eco-design for repair

To determine potential eco-design measures to be implemented in the washing machine in terms of ease of use and repair, Sareteknika (official repair provider for home appliances in the Basque Country, Spain) has carried out a technical study reviewing all of its components from the point of view of the technician in charge of repair or refurbishment operations. Main components studied are shown below (the rest of them can be found in annexes):

1. Power card

The electronics are made up of:

- Integrated card (power circuit and engine circuit)
- Display card
- Wireless connection system
- Board holder and wiring extension

The power board is included in the charges and in the engine control, in other words, the inverter system part is included in the power part.

The display card allows the user to select different programs and helper functions and sends information of the power circuit to the microprocessor.

The software is equipped with different washing and spin programs, type of engine (brushless), protection and activation of different components sending orders to open or close output triacs (resistor, valves, door block, ntc, temperature sensor, pressure switch.)

On the display panel are the keys for selecting functions.

2. Touch Button system

- The presence or absence of a finger determines the activation of the touch Key
- The keys are capacitive, so the measurement depends on the electrical
- For this reason, to activate the key, a minimum conductivity is required (for example, with a plastic it will never be able to activate)
- When activating the key with your finger or with another conductive material, there shouldn't be gap between them

Figure 2. Washing machine panel

When the finger is brought close to the surface sensor, a conductive material is present and a parasitic capacitor is generated in the surface sensor, the value is measured by the plates (Z) and must touch the surface of the holder. The metal plates (Z) must not be deformed and the contact with the panel must be good. If there is a small gap between them, it may not be detected.

Figure 3. Functioning principle of the WM panel and electronic board (spring)

3. Water inlet valve

This valve allows water to pass through when required by the washing machine.

- The double valve is used on models with single water inlet
- The double valve and an additional single valve are used on models with double water inlet

They are controlled by the triacs in the power circuit.

When one of them is activated, it allows the passage to the prewash zone (normally on the left side of the tank), when the second one is activated, it allows the passage to the wash zone and when both of them are activated at the same time, it allows the passage to the softener zone (in the middle of the tank).

4.1.2. Conclusions on the eco-leasing experience and potential new business line for the CEBM

For the demonstrations purposes, as described in deliverable D4.3 "Demonstration of end-of-life phase for target products", 18 ecodesigned washing machines and 44 ecodesigned televisions where installed in Matia Fundation's sites for a year, with the aim of testing the devices in a real environment where a significant use was made in order to obtain feedback about their design and use conditions and, after that period, testing and optimising the refurbishment processes using the same devices.

Thanks to this three-way collaboration between Emaús, Matia Fundation and Arçelik, a new business opportunity has been created. That opportunity is related to a household appliances eco-leasing model, which is explained in the next paragraphs:

The collaboration proposal between the company Arçelik and Emaús Fundación Social aims at generating an alliance that contributes to developing the sustainability and circular economy strategy of both organizations.

The opportunity arises from the obligation contained in the Spanish Royal Decree (R.D)-Law 110/2015 on waste electrical and electronic equipment. In its article 43, it indicates that producers, through Extended producer responsibility (EPR) schemes, must finance the treatment of domestic WEEE deposited in the facilities of local entities and distributors; as well as the waste management organizations with whom they have reached agreements.

As it is stated in the Royal Decree-Law (article 43.2), the individual or collective Systems will finance the actions of Preparation for the Reuse of waste electrical and electronic equipment (WEEE), as well as other types of actions such as those related to waste collection. This is due to the ERPs, who must deal with the end of the life cycle of its product.

The ERP schemes have determined a certain volume of refurbished products that should be reached (fractions 4 and 6 defined in annex VIII of the R.D), and for the calculation of this volume only products that have been refurbished in recognized Preparation for Reuse Centres (PRC) can be taken into account. This ensures the traceability of the product in all its phases.

The following collaboration proposal specifies areas in which it is possible to work together and that can be applied to the development of all the PRCs that Arçelik wants to support internationally.

In short, the collaboration in Spain between Arçelik and Emaús Fundación Social can facilitate the replication of these experiences in other countries.

The potential areas of collaboration between Arçelik and Emaús Fundación Social are described below.

Contribution of Arçelik

- Ongoing training process for employees: Producers, either directly or through their Integrated Management Systems, can contribute to the training on refurbishment processes to achieve the objective of developing skills that ensure the adequate WEEE treatment. Through this training activities the workers can learn on an on-going basis how to repair and refurbish the e-waste.
- Product manufacturers incorporate new technologies, so that each year, the collected devices tend to have new technologies that are more difficult to refurbish. Therefore, the employees have to keep up to date with new technologies.
- The proposal is therefore to develop a training program whose contents can be used in other countries. The agreement between Arçelik and Emaús would imply to transfer knowledge about the repair, refurbishing and remanufacturing processes of its products.
- In addition, the training of the sales teams is equally important. Some technical knowledge is necessary to be able to answer the queries that customers may ask (i.e. energy efficiency).

- Ecodesign for the circular economy and product repairability: Although there are cases where it has been possible to reach an agreement with manufactures to design the products based on the circular economy so that the products can be refurbished more easily, in reality still there are obstacles to, for example, reusing components in new products. For this reason, the modular design can be taken into account, that is, the most suitable designs for the product to be repaired, refurbished or remanufactured. Products that are made up of components grouped into modules are easier to remanufacture. Emaús could work with Arçelik on the development of new circular products.

- Facilitate agreements with distributors. Facilitate agreements with large distributors to effectively recover Beko and Grundig branded products. The distributors can be selected according to the volume they manage.

- Facilitate agreements with logistics operators that remove and collect equipment from the stores.

- Develop joint circular economy marketing campaigns communicating the above actions to institutional and private clients. Likewise, Arçelik can work with Emaús

to develop commercial campaigns at physical points of sale and online platforms for the sale of refurbished products.

- Opportunity for a pilot experience of an eco-leasing model with the collaboration of Emaús, Arçelik and the Matia Foundation, which would consist of carrying out a demo of a home appliance leasing model, which at the end of their life will be sent to Emaús for their recovery and subsequent resale.

- Possibility of studying a new business model linked to WEEE in relation to the extraction and sale of components. Service linked to after-sales services.

By carrying out these activities Arçelik contributes to generating a positive social and environmental impact, generating employment and offering training for people at risk of social exclusion. It can be considered as part of its CSR activities to promote the circular economy.

Contribution of Emaús Social Foundation:

Emaús Fundación Social, hereinafter Emaús, would work in the following areas:

- Waste recapture: Consists of collecting WEEE following the obligations set forth in the Royal Decree mentioned above.

- Ecodesign for repairability of products: In general, products and especially low-cost products are not usually designed to be refurbished, that is, they are difficult to repair or remanufacture. Emaús will make recommendations to Arçelik on the level of repairability of its products (washing machines and TVs). The demo products have been rated as very easy to repair by Emaús technicians.

- Preparation process for reuse and recycling: For the product refurbishment process, it is necessary to work on the clear definition of the necessary operations. Easy-to-understand manuals are required to be created so that the technicians can repair appliances efficiently. Emaús can work together with Arçelik to develop reference manuals that can be used by other waste management organizations around the world. For this, ICT platforms such as that of SOLTEL platform can be used to share existing procedures where information can be exchanged between different repairers and manufacturers in a secure manner.

- Collaboration with logistics operators and platforms that are part of the Beko network and with its commercial network: In the case of logistics operators or temporary storage centres, the service would consist of reviewing all the WEEE existing in the collection facilities, identifying and classifying WEEE that can be Prepared for Reuse and, therefore, referred to a PRC.

- Article 18 of the RD indicates that the collection facilities will sign agreements that include preparation for reuse procedures, that is, they will establish agreements directly with the PRCs. In these agreements they must establish the conditions of

access of these centres to the collection facilities so that those responsible for the preparation for reuse can select the waste for that purpose. The waste that, after its sorting process cannot be refurbished will be sent to the authorized treatment facilities.

- Consumers' education and awareness: These new business models and initiatives can serve to deepen the consumers' education and awareness on circular economy and sustainability. Emaús can develop marketing campaigns in collaboration with Arçelik.

- Collaboration in the creation of a community: Emaús is committed to creating dynamics with consumers to build a community involved with the circular economy and sustainability. Emaús can collaborate and involve Arçelik in the different actions to build this local and global community (i.e. CSERVEES living labs).

Conclusions

- The demonstration of an eco-leasing model for WMs including the take back, refurbishment and second hand sale of products has proven that there is a potential for Arçelik to try this model in B2B consumers in Spain as well as in other parts of the world. Arçelik also sees potential to expand their cooperation with Emaús but the parties need to invest in financing and labour resources to deploy the project to not just demo products but to other product groups.
- Based on Fundacion Matia survey results, residents were satisfied with the rent model.
- In terms of both WM and TV process, there is an interesting point to make. The results of the living labs, as explained in more detail showed that consumers were more willing to try the rent and second-hand refurbished TV case compared to the washing machine case mainly because of hygiene reasons. On the other hand, repair technicians were better equipped and more ready to repair washing machines instead of TV's. This shows that despite the demand from customers, the rate of repair and refurbishment for TV's might not be as high as that of washing machines without adequate investment to equip technicians with the technical know-how and tools needed to refurbish TV's. This also shows that it is important to be able to prove the consumers that the refurbished washing machines are also compliant with hygiene measures as if it were a new one to be purchased from the market.
- Washing machines have the potential to be tried and tested as the first product group by Arçelik and Emaús potential cooperation outside of the C-SERVEES project.

4.2. Collect customer's feedback (living labs)

To test the acceptance of final user in front of the eco-designed and refurbished products, pedagogic/testing events were carried out with potential customers in Emaús ecocentre in Arrasate (Basque Country). The objective was to obtain relevant feedback for the project that is being developed in the WEEE recovery line, and this experience is known as a "living lab". This process has been designed and carried out by the strategic design company H-Enea.

The process consisted of an analysis to understand the context of the products proposed as a purchase option. This analysis includes the perspective of manufacturers and reconditioners of C-SERVEES products, in this case televisions and washing machines. A demonstration space is then designed in the Emaús sales area. User profiles that can match with the offered products are created and defined. Once defined, they are recruited. 17 tests are carried out to measure the interest in the reconditioned washing machine product and 17 tests to measure interest in the reconditioned television product. Subsequently, the data are collected and the test results are analysed.

Different infographic prototypes are designed for the living lab test. The main objective of the infographics is to describe the C-SERVEES pedagogically to explain the results of the project related with the business models for televisions and washing machines.

Infographic prototypes are made analysing different deliverables of the project and then contrasted with the different agents of the project identified as key agents of the descriptions: EMAÚS, GAIKER, Arçelik, INDUMETAL, GREENTRONICS, SOLTEL and CIRCULARISE.

The infographic prototypes are contrasted by these agents. As a result, the demonstration is composed by a large general C-SERVEES description in 6 steps with examples of the result of each of the steps.

Figure 4. Infographics at the C-SERVEES living labs

The info used for the infographics was obtained from the following deliverables and was tested with different agents involved in the project: Arçelik, CIRCULARISE, GAIKER, GREENTRONICS, EMAÚS, INDUMETAL and SOLTEL.

- Deliverable 4.1. Framework for setting up and running the demonstrations
- Deliverable 4.2. Demonstration of design & production phase for target products
- Deliverable 4.3. Demonstration of distribution & use phase for target products
- Deliverable 5.1. Results of environmental, economic and social preliminary analyses

Some examples of the different infographic prototypes (the rest of the prototypes can be found in the annexes) are shown below.

Figure 5. Infographics on washing machine eco-design (left) and TV ecodesign (right)

The usage profiles varied between young profiles and environmentally conscious profiles. The questionaries for Washing Machine and Televisions are similar, to see the predilections of the users.

Figure 6. Development of the living labs

Complete results from the survey of the washing machine living lab experience can be found in Annex 1.

Qualitative inputs based on the feedback received in the customer experience

- The design of new household appliances based on eco-design principles and the offer of the 3-year renting model looked attractive to participants. The purchase of reconditioned appliances is also interesting, but they express doubts about the durability of that product due to the higher frequency of use as compared to a standard household product.
- It is perceived that a lot of information has been provided about how eco-design has been improved, but less about durability. It might be interesting for the project to think about how to convey this information in an accessible way, especially in the case of washing machines. For example, by introducing information about the average lifetime of this appliance and the level of wear and tear of the parts during the 3 years it is rented and to what extent the "overwearing" that occurs in the supervised flats is solved in the reconditioning.
- The participants expect the washing machine to last longer than the television, so they may be more reluctant to see the product they purchase last less time because it comes from a leasing where the frequency of use of the appliance is higher, as these are supervised flats with several people living together equivalent to a large family or more. The wear and tear related to the frequency of use affects washing machines more than televisions.
- As for the proposed prices, they are seen as competitive with respect to the initial prices, but there is a representative percentage of people in all the sessions who, although they do not reject the decision to buy, would have to think about it.
- Participants are more willing to buy a refurbished TV than a refurbished washing machine. It is likely to be related to the fact that washing machines are associated with cleanliness and at certain prices consumers prefer to buy something new because they do not know the cleaning habits of previous users.
- Qualitative inputs from participants in the rental housing without appliances profile: from the qualitative analysis carried out after the surveys were conducted, it can be deduced that the use of televisions may be more homogeneous in all households, but the frequency of use of washing machines may be much higher in the case of supervised flats, where the washing machines from the "renting" contract come

from. It is even likely that users of rented flats do their laundry separately, which increases the frequency of use.

- Qualitative Inputs Participants' environmental profile: In terms of qualitative inputs, they are more interested in the materials of household appliances and their impact and in eco-design aspects. They are more interested in aspects related to the use that the household appliances have had before being sold on the second-hand market. On the other hand, the number of hours that appliances work in supervised flats is higher than the number of hours that appliances would work in a normal household, so they believe that there is a lack of data on whether appliances are designed to last longer or not. This is the question they address to the manufacturer.

4.3. Use 3D printing for refurbishment or customisation

4.3.1. Selection of suitable parts/components for 3D printing tests

During the washing machine demonstration period, Particula worked in cooperation with Arçelik and Gaiker to develop a methodology to obtain and validate 3D printed washing machine spare plastic parts. After setting up the demonstration for washing machine parts according to Arçelik's protocol and guidelines preliminary tests with different filaments were conducted while analysing their performances on different models to ensure proper performance.

In November 2019 Arçelik prepared and sent the first set of three-dimensional objects (3D objects) in digital format (.stp CAD file) introducing several washing machines parts for testing and 3D scanning to determine the most suitable 3D printing technology for the washing machine parts.

Furthermore, different raw materials and formulations provided by Arçelik were evaluated for potential use and compounding processes with the goal of producing 3D filaments and 3D printed parts in a vertically integrated system which will be in accordance with CEBM developed model. Configurations and several tests were conducted in order to prepare appropriate file formats (.stl) and to determine the most suitable technology for trials and 3D printing washing machine models.

In February 2020 Particula visited Arçelik's headquarters in Turkey to arrange and elaborate R&D tasks within WP4 and ways to produce optimal 3D printing parts and to select and receive the most suitable models to create the final prototypes using suitable 3D printing technology taking into consideration model's characteristics, the object to print, the quality and the cost required. On-site visit to Arçelik's premises in Istanbul showed to be very important for understanding of possibilities for including 3D printed parts into washing machines prototypes.

Figure 7. Arçelik washing machine parts received after the meeting in Turkey, February 2020

After the first trials with PLA and ABS filaments for 3D printing available on the market it was concluded that the delivered pieces/models primarily selected for testing were not optimized due to their shape and size and therefore it was very demanding to perform cost effective duplicates via FDM 3D printing method. As it was particularly difficult to derive the mechanically usable listed parts, SLS 3D technology was also applied, but the functionality of the surfaces was not satisfying (twisting of large thin surfaces) especially considering the high printing costs when using SLS technology.

After another set of testing trials, scanning the functionality of other pieces/models, and surface, optimization, and selection of the proper 3D printing technology, Particula conducted tests on several 3D printers (Prusa i3 MK3, Zortrax M200 and custom made FDM 3D printer for larger models). Finally, the Fused Deposition Modelling (FDM)1 technology was selected as the most suitable one for the selected pieces, considering the quality and cost required. The simple concept behind FDM printers is to melt a plastic filament while positioning it in a structured way, layer by layer. FDM is the type of additive manufacturing technology that enables the construction of three-dimensional objects, prototypes, and products through a computer-aided or driven manufacturing process.

The different washing machine parts finally selected showed good initial performance during the 3D printing scanning. Particula selected the following parts:

- Model 1. Sivi Deterjan Kabi Yeni C2L
- Model 2. SIFON Yeni C2L
- Model 3. Deterjan SIFONU Yeni C2L
- Model 4. Large washing machine part/1
- Model 5. Large washing machine part/2

[1] https://www.techopedia.com/definition/29376/fused-deposition-modeling-fdm

Figure 8. Selected washing machine's suitable parts /components for 3D printing tests

4.3.2. Results from 3D printing tests

Off-the-shelf filaments 3D printing tests

Once the final models were selected and defined, prepared as a -stl file format, Particula started to conduct 3D printing tests, optimizing printing properties in the slicer and the 3D printing procedure.

The main point of the test trials was to establish the right protocol and to optimize the slicer options and functions in order to properly adjust the standard and advanced settings to deliver very complex and challenging 3D printed models using FDM 3D printing technology – printing layer by layer. During the trials Particula experimented with the slicer software settings adjusting the right layer thickness, the better quality of a 3D print, fine-tuning to get to know printer and filament choices, changing and adjusting one setting option at a time before conducting a new print, tracking the changes and progress of how the new print differs from previous one, testing different temperature of the nozzle, Z offset and bed adhesion properties (conducting tests on different surfaces using adhesive products such as spray, glue and other adhesives). Particula tested and adjusted slicer properties to convert a 3D model into the instructions G-code.

Particula also conducted optimization tests using a 3D print slicer programme to add proper support materials, to customize support material and save the filament, adjusting too long bridge or the too high angle of an overhang to avoid sagging due to the very demanding 3D models.

After the first trials and printed models with PLA (polylactic acid), ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene Terephthalate Glycol), rPETG (recycled Polyethylene Terephthalate Glycol), Facilan C8 and PLA Strongman (polylactic acid), Particula coordinated with EEE manufacturers and WEEE managers in Arçelik and focused on their feedback on the production of the product, their quality and functionality. After the feedback and first testing period in Arçelik, first results of the tests showed that the selection of rPET and PETG filament are the most suitable for washing machine spare plastic parts production.

Particula continued to conduct more tests to adjust the slicer programme settings options and print models with the different infill density and different perimeters. In 3D printing, infill plays an important role in a part's strength, structure, and weight. Also Infill density can significantly affect material consumption and time required to print. Trimming and sanding treatment along with coloration of washing machine model DETERJAN SIFONU YENI CL2 was conducted to fine finish the model as requested by Arçelik. Finally, after numerous attempts and intense test trials Particula delivered to Arçelik factory five types of 3D printed models: 1. Deterjan Sifonu Yeni CL2 (fine polished, sanded and coloured) , 2. Sivi Deterjan Kabi Yeni C2L, 3. SIFON KABI Yeni C2L, 4. Large washing machine part/1, and 5. Large washing machine part/2. In total 20 prototypes were sent to the testing facility in Turkey – Arçelik.

The results from the 3D printed tests are shown in Annex 1.

Particula delivered the final prototypes (TRL6) to Arçelik. A total of 47 testing models were obtained for trials using PLA, PLA Strongman, PETG, rPETG, ABS and Facilan C8 including failed printing models and the ones that were sent to the testing facility in Arçelik for further analysis and testing (mechanical balance and safety tests result, General Configuration/Marking Control, Needle Flame Flammability Test). Particula selected recycled PETG filament for the final testing and 3D printing the final prototypes due to its properties.

PETG filament (Polyethylene Terephthalate Glycol-modified) is a modified PET, PETG is a clear amorphous thermoplastic with a lower melting point than PET. The material is easy to print and has the glossy and smooth surface finish, due to great thermal characteristics the print will cool efficiently resulting in minimal wrappage and strong layer bonding. The mechanical properties feature high impact resistance and excellent flexibility. PETG is an environmentally friendly material that you can easily recycle after use. It is used for 3D printing of mechanical products most often in the manufacture of electronic enclosures and robotics. The technical data sheet of PETG is shown in Annex 1.

Raw material extruded filaments

In June 2020 standard raw materials for the production of washing machines plastic parts were delivered from Arçelik. Particula then conducted compounding in a single-screw extruder to produce filaments for potential 3D printed parts. In cooperation with Gaiker and Arçelik 3D filaments were obtained to be used for production of washing machine parts.

Six samples of polymer granules called PP Static, Bexaz, Wax Natural, 0, 10 and 15 were delivered. The pellets were extruded on a single-screw extruder Noztek Pro.

Figure 9. Filaments from extruded polymer pellets to use in WM 3D printing tests

1. PP Static material was extruded at a temperature of 184 ° C and the diameter of the obtained filament was 1.75 + 0.13 mm. Due to the very nature of the polymer, there was little stretching of the filament during extrusion, and the cross section is slightly ellipsoidal in shape. A variation in the diameter of the filament at a distance of every 20 cm was observed, and this change was due to the appearance of fibers on the nozzle and probably the inhomogeneity of the material. Collecting occurred during extrusion every 3 to 5 min fibrous formations around the nozzle that needed to be removed. During the extrusion, there was no change in the color of the filament in relation to the granules and no brittleness increased. A square measuring 10 mm x 5 mm x S mm is printed under the following conditions: nozzle temperature 240 ° C and substrate temperature 30 ° C.

2. Beyaz material was extruded at a temperature of 172 ° C and a filament with a diameter of 1.70 + 0.10 mm was obtained. Extrusion of this material was very slow and the resulting filament very soft. Due to the softness of the material, the cross section is ellipsoidal. The surface of the filament is not uniform in color, which indicates the inhomogeneity of the material. The filament was successfully installed on the 3D printer, but no model was successfully 3D-printed. This is due to the softness of the material, which prevents the 3D printer extruder gear from pulling the filament.

3. Wax Natural was extruded at ISS ° C and the resulting filament diameter was between 1.42 mm and 1.83 mm. The reason for such a wide distribution of diameters is the very slow flow of the filament from the nozzle, which resulted in local stretching of the filament or local compression, due to which the filament reached a thickness of 1.83 mm. The cross section is ellipsoidal in shape and with a difference in ellipse diameter up to a maximum of 0.18 mm. The material is very smooth, and a very unpleasant odour occurs during extrusion. The square was printed at an extruder temperature of 240 ° C and a substrate temperature 30 ° C. Due to the smoothness of the filament, the filament had to be removed several times in order for the gear to pull the material correctly.

4. Material 0 was extruded at 195 ° C. The diameter of the obtained filament is 1.83 + 0.19 mm. The oscillation of the diameter occurred due to the accumulation of fibers on the nozzle. although the fibers were continuously removed by hand, they affected

the diameter of the filament, but the cross-section is not so much because the cross-section is slightly ellipsoidal. The filament produced is brittle and has retained its black color. The square is 3D-printed at extruder temperature conditions of 243 ° C and substrate temperature of 30 ° C.

5. Material 10 was extruded at 197 ° C and the filament diameter varied between 1.58 and 1.86-mm. Smoke occurred several times during extrusion. The resulting filament is very brittle and flowed very well and practically retained the shape of the cross section of the circle along its entire length. Occasionally, manually removed fibers appeared. The conditions for 3D printing of a square are: extruder temperature 243 ° C and substrate temperature 30 ° C. Minor problems occurred during 3D printing, so the filament had to be unloaded and loaded again several times

6. Material 15 was extruded at 200 ° C and the produced filament had a brittleness greater than material 10. As with some previous materials, fibers appeared on the nozzle and filament wrapping and clumping occurred. The reason for this is very likely the inhomogeneity of the material. This created major problems during extrusion, but the diameter of the lS material is between 1.63 and 1.77 mm. The filament is very brittle as mentioned earlier and should be handled very carefully to avoid breakage. During 3D printing, it showed less problems than material 10, so great care had to be taken with the required filament thickness. The square is 3D-printed at extruder temperature conditions of 243 ° C and substrate temperature of 30 ° C.

Table 1 shows 3D-printed squares of five extruded materials, all except Bexaz, which could not even begin 3D printing due to inadequate mechanical properties.

During the testing period with extruded materials from polymer pellets delivered from Arçelik all the new filaments were tested and trials were conducted on 3D printers. These trials were conducted during the attempts to 3D print the prototypes using the raw material extruded filaments, and potential incorporation into washing machines demos.

Developed filaments were compared with off-the-shelf available filaments, and the results showed good potential for Arçelik raw materials for the development of refurbished and customized 3D parts in the near future. Particula was then focused on finding appropriate smaller washing machine parts together with Arçelik for easier and more cost-effective 3D print refurbishment. The smaller and more simple models were not detected so Particula conduced trials with the already tested complexed models using off the shelf filaments.

There were several difficulties in trying to print with all the above-mentioned novel filaments: their often-non-adhesive properties to the printer bed sheet, large deviations in diameter, brittleness of the filaments, clogging with fibers and potential danger of breaking the nozzle of the 3D printer. Finally, after numerous attempts Particula managed to print several square shape testing print models of five extruded materials, all except Bexaz, which could not even begin 3D printing due to inadequate mechanical properties, and one cube model 20 * 20 * 20 mm using Material 15. Cube angles raised from the work surface, adhesion to larger pieces was questionable, subsequent attempt to print a larger model in a closed printer due to better adhesion to the surface, extrusion difficulties, clogged extruder, risk of damaging the extruder. Particula concluded that it is

very demanding to 3Dprint any of the washing machine 3D models spare parts due to their structure and model properties with the risk to potentially damage the extruder.

Figure 10. 3D-printed squares of five extruded materials

Table 2. Parameters used during the extrusion and 3D printing processes.

	T(ekstruzije)/°C	T(dize)/°C	T(pod1oge)/°C
PP Static	184	240	30
Bexaz	172		
Wax Natural	155	240	30
0	195	243	30
10	197	243	30
lS	200	243	30

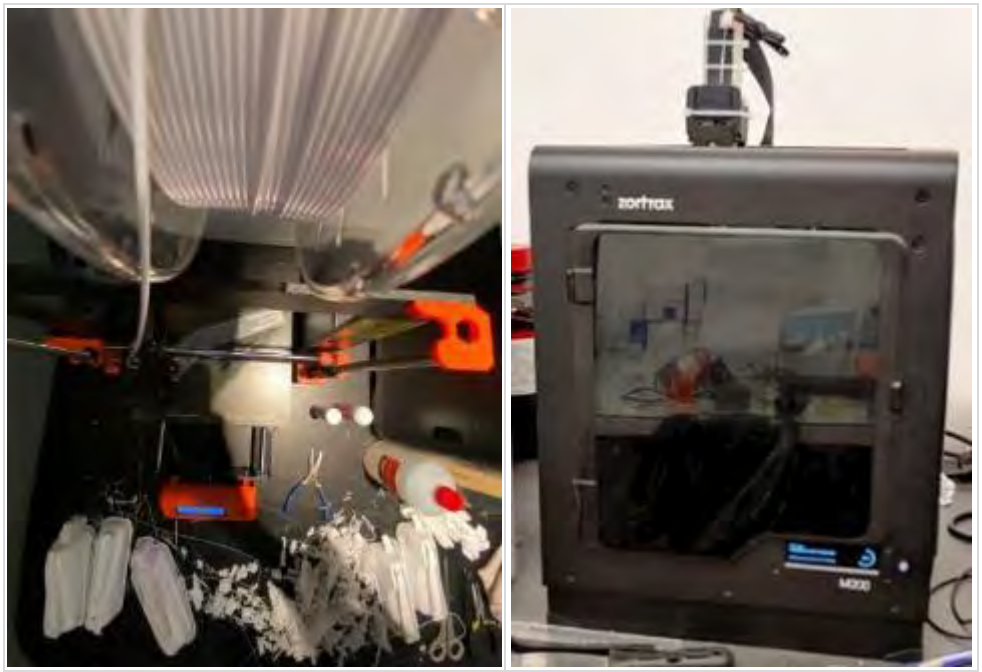


Figure 11. Testing trials Prusa i3 MK3 (left) and ZortraxM200 (right)

4.3.3. Validation of 3D printed parts/components

The washing machine works under dynamic loads and water with some chemicals (bleach, detergent, softener etc). and raw material selection for each part/component is really important. Raw materials must be approved first, then parts prepared with this raw material are tested on the product. The expected spectra and test methods of each raw material are different from each other according to the working conditions. For example, for the washing machine tub, which is part of the dynamic group, first of all, raw material approval tests are carried out in the central R&D. These tests include physical properties control (density, melt flow index, ash content, etc.) and mechanical properties control (yield strength, yield elongation, Young's modulus, izod impact test, bending strength, bending modulus, etc.), performed according to a standard. After the raw material approval process, product approval phase is started. If all product approval tests are successful, the raw material begins to be used in mass production.

The washing machine runs at high speed. For this reason, it is expected that the dynamic group's parts and the parts associated with this dynamic group will have the maximum strength for high speed (demo product speed is 1200 rpm). For this reason, 3D printing was not considered appropriate for these parts. Also, the part sizes are too big for a 3D printer. Excluding the dynamic group and the parts related to the dynamic group, the number of parts that can be selected for 3D printing is significantly reduced.

Initially, detergent box group was selected for 3D printer trials. This is a visible part, and also a part that the customer values for hygiene. Depending on the customer use, bacteria or molds may grow in the box. Again, staining may occur due to customer use. In this case, the customer may wish to change the detergent box group, especially the drawer part.

Detergent box group parts and raw materials for detergent group parts were sent to Particula to be tested with a 3D printer, but the trials did not result in success due to the part dimensions. It was decided to test smaller sized parts.

Since the demo product includes a liquid detergent container group, Arçelik & Particula decided to select this part due to the small dimension. Particula sent 3D printed parts for Arçelik validation tests.

Figure 12. Liquid detergent container group, front face (left) and rear face (right). Upper side: liquid detergent container cover. Lower side, left to right: original liquid detergent siphon, 3D printed liquid detergent siphon, 3D printed liquid detergent siphon after the test, 3D printed and polished liquid detergent siphon

3D printed and unpolished siphon part surface was not smooth, showing lots of discontinuity. Since it is a visual piece, it is not suitable for perceptual quality and it was not acceptable. However, this part has also been tested.

A second sample which is better for perceptual quality was prepared by Particula. The surface of this part was cleaned and then polished. 3D printed and polished siphon part surface was better than unpolished one. Surface is smooth and does not show discontinuity.

Arçelik tested both parts in the laboratory. For the unpolished part, in early cycles siphon surface clogged with detergent, which is undesirable. If the surface is clogged with detergent, there will be a problem during the washing process. Figure 13 shows the clogged surface. Moreover, deformation was observed in the shape of the part during the tests. This deformation prevents the machine from siphoning properly.

Figure 13. 3D printed and unpolished siphon part surface after testing

For the polished part, in early cycles it was found to be deformed and this caused swelling and cracking. Therefore, this specimen did not pass approval tests.

Figure 14. 3D printed and unpolished siphon part surface (swelled and cracked) after testing

Conclusions:

- Washing machines include different composites, metals, plastics and rubbers. For example, this demo product has ~25 kg concrete (upper and lower counterweight), different steel parts in the cabinet, front wall and drum, Al alloys as the spring arm, different rubbers in the gasket and hose groups. Due to this complexity, the selection of potentially 3D printable parts was very reduced considering the 3D printers available at a Particula. Only plastic parts are selectable for 3D printing.
- An important consideration is that washing machines work under dynamic loads and dynamic group parts' raw material (like tub) need to have mechanical strength.
- Another critical issue is the parts' dimensions. For Particula 3D printers small and not grift parts had to be selected for 3D printing.
- On the other hand, there is a perceptual quality expectation for visible parts of the washing machine like front panel, front door, so this raises the quality requirements.
- Last but not least, washing machines work with hot water and different chemicals. Parts in contact with water are expected to be resistant to chemicals and high temperatures.
- Considering all of the above, it is very challenging to produce washing machine parts with a 3D printer. Particula and Arçelik developed different washing machine parts by 3D printing, but they all failed the validation tests. Results show that the plastic parts of the washing machine were not found suitable for 3D printing. Trials were made on different parts, but no successful result was achieved.
- Derived from these learnings, Arçelik and Particula have discussed trials for another WM part, the front door hinge. This part needs mechanical strength and it is visible, but it does not work with water and chemicals. If 3D printed hinge parts passed the mechanical approval tests (like 500N zwick, transportation tests, etc), surface can be polished for perceptual quality. But the critical point is mechanical strength of 3D printed parts and approval tests are compelling. Raw material should be chosen correctly or should be improved is 3D testing is to be successful.

4.4. Improve dismantling and recycling operations

4.4.1. Technical analysis of the recycling and dismantling operations

Three washing machines from the dorms in Turkey were sent to Greentronics in Romania for an in-depth analysis of the dismantling operations. 16 different parts/components of the WM were considered relevant for potential use as spare parts:

1	**Cabinet & back wall**
2	Top plate
3	Detergent box group
4	Panel (with electric card group)
5	Front door
6	Front wall
7	Gasket
8	Upper& lower counterweight
9	Valve & drain pump
10	Belt
11	Pulley
12	Motor
13	Spring
14	Welded tub group (tub & drum)
15	Heater
16	Cable group

Greentronics analysed the viability of recovering the list of spare parts and prepared a dismantling procedure for the demo product, included in Annex 1. The aim is to facilitate the extraction operations of non-damaged spare parts from EoL washing machines and to provide expert advice on design-for-recycling or design-for-dismantling measures to Arçelik.

Greentronics also recorded dismantling times for all selected parts:

Code	Part/component	Time (sec)
1	Cabinet & back wall	31
2	Top plate	37
3	Detergent box group	5
4	Panel (with electric card group)	75
5	Front door	23
6	Front wall	137
7	Gasket	31
8	Upper& lower counterweight	154
9	Valve & drain pump	86
10	Belt	3
11	Pulley	75
12	Motor	126
13	Spring	35
14	Welded tub group (tub&drum)	246
15	Heater	32
16	Cable group	195
		1291

A washing machine was disassembled before the exercise to establish the logical disassembly order of the indicated components and identify them in conjunction with the disassembly manuals. The total time for this first trial was one hour. For the following two WMs the total time decreased to 36 and 33 minutes respectively, for full disassembly.

Greentronics shared their observations regarding potential improvements for the disassembly process:

1. Difficulties with the rubber/plastic brushing when disassembling the engine, making it harder to remove.

2. Use of screws with 2 types of torx heads and PS2 cross requires a change in the dismantling tools, which leads to extra time. If possible, change to screws with the same kind of ends to decrease operation times.

4.4.2. Cost and price analysis of the recycling and dismantling operations

A dismantling template was used to analyse the cost of recovering pre-selected WM parts/components based on time/human labour/shipment costs.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	2833790100 2827610100	2464600100	2412700600	2472907016	2467200700	2835951193	2827086900	2816990700 2831720900	2906870200 2878103000	2907260500	2824490200	2843120300	2820360300	2500703900	2882601700	2856670400	Code
	Cabinet & back wall	Top plate	Detergent box group	Panel(with electronic card group)	Front door	Front wall	Gasket	Upper & Lower counterweight	Valve & drain pump	Belt	Pulley	Motor	Spring	Welded tub group (tub&drum)	Heater	Cable group	Part 15
Washing machine 1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Washing machine 2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Washing machine 3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

	Recycler
Time to dismantle/check parts (mins)*	22
Time to pack parts ready for shipment (mins)*	14
Cost to pack the parts (€)*	50
Cost to ship the parts (€)*	180/730
Hourly rate (€)	3,8

**Average time per WM part*

The template was completed by Greentronics concluding in the following information:

- an average time of 22 minutes per WM part
- a packing time of 14 minutes for the components
- an average cost of the materials to protect the parts
- cost options to ship the parts, considering two destinations: Arctic Plant in Romania or Arçelik facilities in Istanbul

After this analysis, the following conclusions can be derived:

- Even though Arçelik has a WM factory in Romania (Arctic Plant) there is no Reassessment Centre like in Turkey, so at the current time spare parts could not be used there.
- Finding a company in Romania to purchase these parts and use them for washing machine refurbishment processes would make this business case possible, but the current costs of the dismantling, packaging, labour and shipping provided by dismantlers is considerably high compared to the cost of obtaining new components. This makes it unlikely for repair companies/manufacturers to opt to use these recovered components instead of new ones. They do not seem to be compatible at current costs.
- Although these parts could be used in the Arçelik Reassessment Centre in Turkey, transportation costs in this estimation render this solution too costly.
- As discussed in the first section of the report, the recovery of the components by a refurbishment company rather than a recycler can add more value considering the complexity of the recycling process and the low chances of recover at the site of the recyclers coupled with high costs. Additionally, due to the logistics costs, it makes more business sense for the sake of circularity overall to invest in

infrastructure to increase number of sites that can recover components in close proximity to manufacturers/repairers.

- Arçelik has its own washing machine refurbishment centre in Turkey and the current dismantling costs and labour costs provided by the recyclers are not competitive with the current costs incurred by Arçelik in Turkey.

4.5. Improve material circularity of the washing machines

Within the washing machine demo Arçelik has performed a case study on the potential to use recycled plastics from EoL devices outside Turkey. The main objective of the study was to analyze the technical feasibility of reusing polypropylene (PP) from end-of-life products belonging to Arçelik brands and incorporate the recycled plastic material into new WM parts. With this case study, Arçelik intends to explore the potential to increase circularity in its business model.

Therefore, the aim of this exercise is to evaluate the technical feasibility of using recycled PP from end-of-life washing machines collected by a European partner (in this case Emaus) as secondary raw material to be incorporated in new Arçelik product parts.

At the beginning of the study, two plastic material streams from end-of-life washing machines were identified as potential candidates for recovery and reuse: ABS and PP. Although ABS is used in larger quantities in the WM, the requirements for this material included specific colour and gloss which is difficult to obtain from secondary (recycled) materials. Due to this fact, only PP was selected for this study.

Detergent drawers from end-of-life Beko and Grundig washing machines were collected by Emaus at their facilities. Both brands are sold by Arçelik in Spain, so in order to ensure that the composition of the WM parts was within Arçelik standards only those were selected for this study. The WM part recovered was the detergent drawer as this is entirely composed of PP.

Figure 15. Detergent drawers from EoL washing machines (Beko/Grundig)

To ensure only PP was collected and processed, the pieces were analysed in Gaiker by NIR spectroscopy to detect the presence of non-PP plastic pieces or inserts. Once these non-desirable parts were removed (the front panel of the detergent drawer, for example, is made in ABS), the rest of the material was processed to obtain recycled PP flakes.

The material was then processed by Aimplas to obtain testing samples for characterisation. Received shredded sample from Gaiker was washed and dried to remove detergents, soaps, dust and humidity. Grinded material was then shaped into injected test specimens, used for characterization.

Figure 16. Recycled PP flakes from detergent drawers (left) and injected specimens (right)

AIMPLAS carried out the following tests with the corresponding results over these samples.

Table 3. Characterisation of recycled PP from EoL washing machine detergent drawers.

	STANDARD	ACCEPTANCE LIMITS PP %43 CaCO3 filled	RESULTS OF RECYCLED PP
PHYSICAL PROPERTIES			
Density, g/cm^3	ISO 1183	1,3	1,268 ± 0,001
Melt Flow Rate, g/10’	ISO 1133	10	16,2 ± 0,5
MECHANICAL PROPERTIES			
Flexural Modulus, MPa	ISO 178	2100	2370 ± 60
Flexural Strength, MPa	ISO 178	33	33,4 ± 0,4
Izod Impact Strength, kJ/m2 (notched)	ISO 180	3.1	3,04 ± 0,44
Tensile Strength at yield, MPa	ISO 527	22	17,8 ± 0,1
Elongation at yield, %	ISO 527	3,8	3,8 ± 0,1

The tests proved to provide positive results and are compliant with Arçelik specs except for physical properties such as MFI and mechanical properties such as Izod and tensile strength. These properties can be improved to meet Arçelik standards by including virgin materials and reformulating. According to the usage area of this raw material, the expected material properties can be accepted or improved.

Arçelik WM plants are located in Turkey, Russia and Romania and Turkey restricts the import of recycled raw materials. Therefore, although using the recycled raw materials recovered by Emaus/Greentronic/Indumetal would prove to be a very viable option if Arçelik would be able to import recycled raw materials, in practice, this is not possible due to the regulation in Turkey. It would be good option for Romania factory. On the other hand, Arçelik has its own WEEE recycling plants in Turkey and the products collected from the market regardless of their brand are manually dismantled in these facilities. Arçelik can try to be collect these materials from own WEEE plants. Turkey can be recycled and recovered to be used in WM components like detergent drawer.

4.6. Use ICT to enhance washing machines' circularity during the end-of-life phase

4.6.1. Smart questioning demo

Circularise is a blockchain-based supply chain transparency platform that allows the safe but trustworthy communication of material data along the supply chain.

Recent legislation like the Digital Product Passport preparations of the EU as well as societal developments towards more sustainability assessments of products and production processes have started to transform the way we think about supply chains. There is an increased need for reliable and trustworthy information on material compositions in order to ensure sustainability, mitigate supply risks and provide reliable information on the product composition which is required for better repairing, refurbishing or recycling. Blockchain is an excellent technology that builds on public records in order to avoid the provision of wrong information. Furthermore, it enables the possibility to accumulate lots of decentrally stored data into one chain of information. Circularise has combined these properties of blockchain with the highest standards of encryption. The patented blockchain technology and its zero knowledge proof mechanisms make it possible to keep all sensitive material data stored decentrally and only reveal specific insights into the data as per request. This technology thereby makes it possible to fine-tune how much information is shared e.g.,

which material composition data, down to the chemical elements, can be shared by indicating a range of material quantity in the product. The technology also allows companies to specify which type of actors are allowed to access the information.

The demonstration of Smart Questioning technology with Arcelik evolves around several planning steps. The preparatory phase entailed the onboarding of suppliers or different

colleagues within the team, whenever suppliers are not able to participate in the demonstration. Afterwards the data is logged on the Circularise Smart Pledges system and accumulated by transferring material data tokens. Finally, the querying mechanism allows the assessment of the data.

Preparation

At the start of the demonstration Circularise and Arcelik jointly analysed which suppliers could be brought into the demonstration directly and which had to be replaced by an employee of the Arcelik team. Generally speaking, the decentralised system aims to onboard all stakeholders along the whole supply chain. This is necessary, as the system is based on linking decentrally stored up-to-date data and thereby establishing a communication channel. This enables the OEMs to decentralise the responsibility of data provision and fulfils the principle that each supplier only has to report about the base chemicals added and production process conducted at its stage of supply chain. The onboarding process entailed the registration of accounts on the two Circularise platforms. The smart pledge platform and the digital asset transaction platform (both platforms are used in an updated version that additionally already entails technical development of a follow-up project of C-SERVEES) https://demo.sq.circularise.com/ and https://demo.circularise.com/. Furthermore, all stakeholders involved were required to connect their suppliers and customers via a relations request on the platform sending invitation emails to each other automatically.

As a next step, Arcelik identified the materials and chemical composition of the products in cooperation with its suppliers.

The total weight of the washing machine is 75 kilos.

Table 4. Information about materials and and chemicals in the washing machine

Weight situation	Part	Raw material	CAS Number
0.75kg	Gasket	EPDM	25034-71-3
6.5kg	Tub	Compound- PP with glass fiber filler and Recycled PET filler	GF: 65997-17-3 PET: 25038-59-9 homoPP: 9003-07-0 coPP: 9010-79-1
4.1kg	Drum	430 – stainless steel	65997-19-5
0.6kg	Detergent box gr	Compound- PP with calcite filler	homoPP: 9003-07-0 coPP: 9010-79-1 calcite: 471-34-1
2.6kg	Soda lime glass		2446523-50-6
0.7kg	ABS panel		9003-56-9

Implementation

In the implementation phase, all stakeholders created digital assets on the Circularise system by using base chemicals and components submitted to them by their suppliers. These base chemicals were then merged through production processes into new components. The components are submitted to the next step of the supply chain (direct customer) and merged with further components until the final product assembly is reached.

By assessing the material overview provided above, we created smart pledges containing chemical element information of each component, more precisely one for gasket, drum, detergent box, tub, soda lime glass and ABS panel. In an ideal scenario, each subcomponent is down to the mining of the base chemicals (e.g., mining of iron ore) is tracked on the system. However, involving all stakeholders until the mining stage of the supply chain is out of scope for this project. In this scenario we reflected the supplied materials from tier 3 upwards by adding the chemical elements information to the components with the specificity of the tier 3 or 2 suppliers. The tiers of supply chain reflected are to be seen in the table below. All sections in grey are not included.

Table 5. Supply chain tiers in the Circularise smart pledge system

OEM	Tier 1	Tier 2	Tier 3	Tier …
Washing machine	Gasket	rubber material		
		Glue/Fastening…	materials of glue…	
	Tub	Steel		
		Screws …	material of screws…	
	Drum	Polymer		
		recycled polymer	recyclate from recycler	
		Glass fibre filler	composition material	
	Detergent box	PP with calcite filler		
	Soda lime glass	Glass		
		Glue/Fastening…	material of glue…	
	ABS panel	ABS		

In the demonstration sessions, the team created a smart pledge template on the Smart Questioning Platform of Circularise for each of the components. The template entailed the material name, manufacturer information and information about the chemical composition via CAS numbers. LCA data beyond the recycled nature of materials was not added as per the scope of the project.

Afterwards, the smart pledge fingerprint was downloaded. This smart pledge fingerprint is a PDF document that contains the secret fingerprint of the material data. It can be uploaded to the Blockchain system without any risk of sharing sensitive data. The fingerprint can only be used for smart questioning queries, however it is impossible to decrypt it in order to have access to the sensitive data used to create the smart pledge.

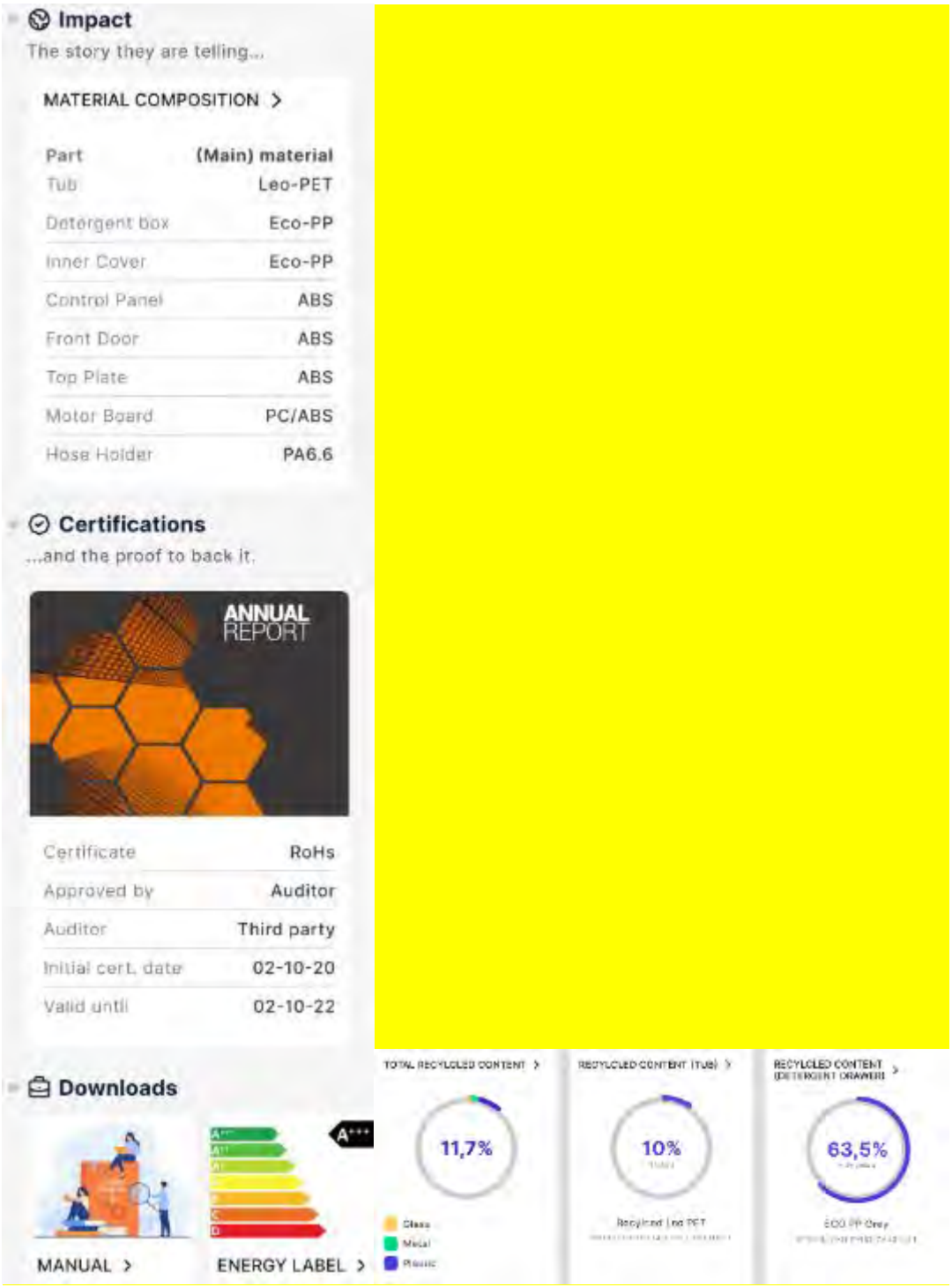
The digital asset

The smart pledge itself is simply a fingerprint of the data, however it is a locally downloaded document without any link to the blockchain. In order to use blockchain for the transaction of digital twins of the actual material shipped along the supply chain, the team then went to the Circularise system that interacts with blockchain (public dashboard). On this public dashboard, the suppliers each created digital assets for the materials and components to be submitted to Arcelik. Following the mass balance system, the material was created in the exact amount of weight as the original material. The smart pledges on material composition were then uploaded in order to provide an

encrypted fingerprint that can be questioned through smart questioning. The digital assets for each of the supplied components were transmitted via blockchain transactions from the suppliers to Arcelik. Arcelik functions as final assembly partner in the supply chain of washing machines. As per its role, Arcelik assembled the received components to the finished good.

Results

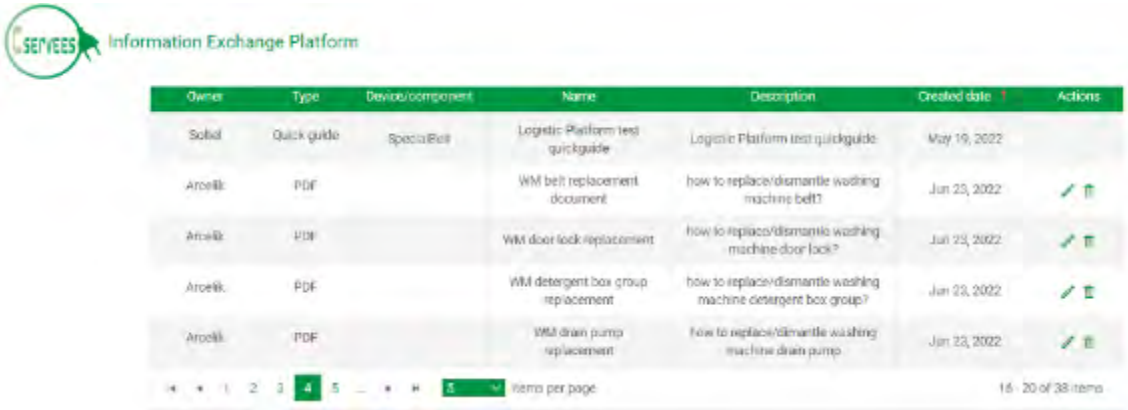
The digital asset of the finished washing machine could then be transferred further to customers or recyclers in order for them to have access to the question functionality of Circularise Smart Questioning. This allows anyone along the value chain, including retailers, recyclers or refurbishers to access data about the product in order to improve decision making and circularity opportunities. Smart questioning can now be performed to understand the material content of the product. Furthermore, it is possible to share the material prevalence with customers via a website developed by Circularise for customers: The Circu-page is a customer facing dashboard displaying public data for customers. This dashboard can be displayed as a website or as a mobile format of the website. Circularise developed an example of this dashboard displaying the public part of the information on the Circularise System as a marketing and customer communication opportunity. The visuals entail example data.

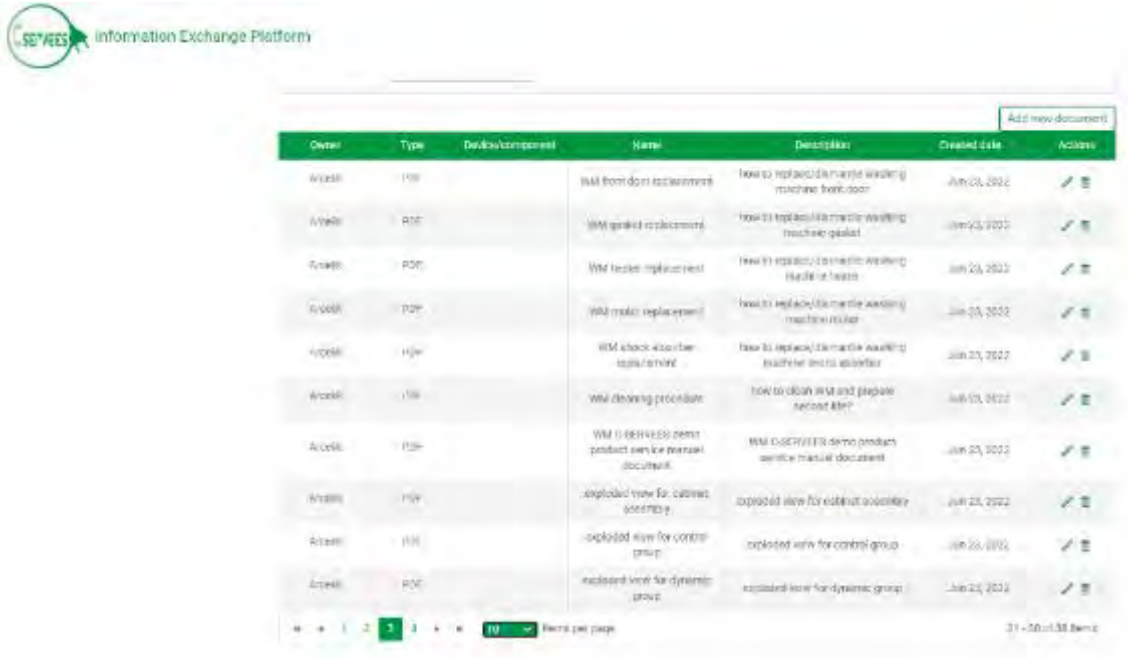

Impact
The story they are telling...
MATERIAL COMPOSITION >
Part
(Main) material
Tub
Leo-PET
Detergent box
Eco-PP
Inner Cover
Eco-PP
Control Panel
ABS
Front Door
ABS
Top Plate
ABS
Motor Board
PC/ABS
Hose Holder
PA6.6
Certifications
...and the proof to back it.
ANNUAL
REPORT
Certificate
RoHs
Approved by
Auditor
Auditor
Third party
Initial cert. date
02-10-20
Valid until
02-10-22
Downloads
MANUAL >
ENERGY LABEL >
11,7%
10%
63,5%

4.6.2. Information exchange platform

For the testing of the Soltel platform, Arçelik uploaded a total of 22 different documents to share with the different actors in the CEBM value chain:

- User manuals for EN; ES and TR
- WM cleaning procedure
- Exploded views for cabinet, control group, dynamic group, fascia group, front door group, front panel, kick plate group, water circulating system
- Circuit diagram
- Replacement/dismantling documents for belt, door lock, detergent box group, drain pump, front door, gasket, heater, motor, shock absorber





The information is accessible to all approved accounts connected to Arçelik's account and it makes possible to share information related to dismantling and repair operations with organisations such as Emáus, or recyclers such as Greentronics. This facilitates communication in a secure environment and can also connect to the Rina-C tool for logistics operations when shipping of materials or parts is required, and to the Circularise

tool to request information on the bill of materials, recycled content of the washing machine parts, etc.

Due to the Ecodesign regulations in Europe, Arçelik uploads similar documents on their website. For countries outside of Europe, using the Soltel platform can be a quick and practical solution.

In order for this application to be successful, companies like recyclers, reuse and repair technicians etc. should use the documents uploaded by Arçelik and ask questions. Arçelik can answer their incoming queries, which in turn can guide Arçelik's new design studies. In this way, modularity can be the focus for new designs. Useful and guiding comments can be given to designers as a target while designing.

5. Printers and laser toner cartridges demonstrator

The activities conducted in the end-of-life phase and described in this deliverable were derived from the PRINT-CIRCMODE short-term actions validated in WP2 and for the most part continue with the work started in the previous phases to enhance the circularity of the current PSS for printers by promoting and increasing refurbishment operations.

The table below presents the PRINT-CIRCMODE canvas sub-components and their validated short-term CE actions corresponding to the end-of-life phase, as presented in Table 24 in D2.3.

Table 6. Validated short-term PRINT-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the end-of-life phase.

PRINT-CIRCMODE Canvas Sub-Component	PRINT-CIRCMODE validated short-term Circular Economy Actions
PRINT_C1.1 Diversify circular activities	PRINT_A1.1.1 Expand LCCP and/merge with LECP program (collecting and refurbishing whole printers and key components)
PRINT_C1.4 Develop circular logistics and distribution (reverse logistics)	PRINT_A1.4.2 Reduce the number of unnecessary and incorrect shipments
PRINT_C1.5 Provide repair and maintenance services, including new technologies such as 3D printing	PRINT_A1.5.2 Salvage working and repairable parts from collected/return printers and use on E2N (Equal to New) printers
	PRINT_A1.5.3 Explore competitiveness of 3D printing for smaller plastic parts for repair
PRINT_C1.6 Optimise end-of-life circularity	PRINT_A1.6.1 increase the flow of returned end-of-life printers by reducing the associated time and cost
PRINT_C2.1 Devise competitive financing models and cost saving by using and/or purchasing fewer components and obtaining materials reused or recycled from other sources	PRINT_A2.1.1 Assess options to reuse material from EOL/WEEE printers
	PRINT_A2.1.2 Learn from recyclers what materials can be recycled better or more profitably to use more of them instead of low-recycle value or efficiency materials
PRINT_C2.3 Introduce and/or expand the use of ICT to foster circular economy	PRINT_A2.3.1 Use ICT to support information sharing across the supply chain related to recycled content
PRINT_C3.2 Participate in partnerships that ensure both private and public sector procurement practices are addressed in order to ensure organisation appeals to a broader customer base	PRINT_A3.2.1 Engage with key customer to understand their needs and requirements as it relates to refurbished products
PRINT_C3.3 Address partnerships' cultural issues that would encourage economy business models to be widely adopted	PRINT_A3.3.1 Active Promotion at EU and national level for wider acceptance of circular business models
	PRINT_A3.3.2 Active media/PR campaign on refurbished printers

PRINT-CIRCMODE Canvas Sub-Component	PRINT-CIRCMODE validated short-term Circular Economy Actions
PRINT_C4.1Adopt economy activities to suit B2B and/or B2C ensuring customer segments are wide and varied to capture additional market	PRINT_A4.1.2 Promote refurbished printers

CE actions PRINT_A1.1.1, PRINT_A1.5.2, PRINT_A1.5.3 and PRINT A1.6.1 are all related to the assessment of opportunities to enhance circularity of the current PSS run by Lexmark, looking at the recovery of printer parts and components, use of 3D printed parts and analysis of the economic viability of the options studied. All of them are covered in section 5.1.

CE actions PRINT_A2.1.1, PRINT_A2.1.2 and PRINT_A2.3.1 are related to the assessment of potential to increase material circularity in Lexmark products and the use of ICT functionalities to support these measures, and are covered in section 5.2

CE actions PRINT_A1.4.2 and PRINT_A1.6.1 are related to the improvement of the reverse logistics to support the circularity of the PSS and covered in sections 5.3.

Finally, CE actions PRINT_A3.2.1, PRINT_A3.3.1, PRINT_A3.3.2 and PRINT_A4.1.2 are related to the promotion of the refurbishment business and customer engagement and covered in section 5.4.

Therefore, activities were carried out focusing on one hand on the reverse logistic as well as the spare parts costs and on another hand, customer acceptance.

- ➔ To address the cost issues, a follow up of previously performed dismantling activity was carried out to scale up the activity completed in deliverable 4.3 and analyze the pertinency of recovering parts at recyclers locations, resulting in mix result. Another focus has been on the reverse logistic platform go live to facilitate and maximize the collection of used products, successfully implemented and driving promising results. The activity related to WEEE product resin reuse was also finalized showing significant limitations. A follow up of the 3D printing activity was also conducted, finally showing opportunities.
- ➔ To address the customer acceptance issue, several printers were also refurbished with visible parts showing cosmetic defects deemed as not acceptable as per Lexmark/industry standards and then shipped to customers to gather their feedback, highlighting positive and encouraging changes in customer acceptance of refurbished products.

C-SERVEES project was also presented to

- ➔ The competition, gathering valuable comments and feedback, especially as it relates to the reverse logistic issues and the customer demand generation.
- ➔ Not only to competition but also a major “resource recovery” actor in the industry, driving interesting inputs for our C-SERVEES project to enhance Circular Economy in the EEE industry

And of course, activities were conducted on the ICT tools developed by the C-SERVEES partners to analyze how such tools can help to enhance and boost the Circular Economy of the EEE industry, therefore,

- ➔ an activity was run with Rina C to test the transportation simulation platform
- ➔ another one with Soltel to test a platform aiming at streamlining communication amongst the SC actors
- ➔ and finally, a test of the smart questioning tool from Circularise

5.1. Assessment of opportunities to enhance circularity during the end-of-life phase

In deliverable D4.3 "Demonstration of distribution and use phase for target products", a dismantling demo aiming at identifying potential benefits to have recyclers dismantling printer products instead of recycling them with custom procedures (shredding) was conducted with the conclusion that recovering printer parts from WEEE products at a recycler location using a dismantling manual can be cost efficient but would require recyclers to adapt to such new activity. It does also require the recycler to get access to a dismantling manual as well as information from the OEM related to the required quality level and the cost the OEM is ready to pay for the given parts, all of which can be achieved through an ICT tool. Also, WEEE products would need to be handled differently and not anymore as waste till they reach the recycler's location to maximize parts recovery. As a next step, it was identified the need to confirm the above findings by getting recyclers to process a larger batch of units and get actuals as it relates to sorting and cleaning at Syncreon, which was done in the last stage of the demonstration and is reported in this deliverable.

The challenge was to have recyclers receiving enough printers of the same type during the timeframe of the demonstration period to run the activity. The team therefore collected and put aside printers from the same model at Syncreon (Lexmark collection center) and when enough were collected, put aside 60 of them with a plan to process 20 units at each location (Indumetal in Spain, Greentronics in Romania and Syncreon in Poland).

It must be said that there is obviously no plan to ship collected printers to recyclers for parts dismantling moving forward as capabilities exist at the collection center and this is where the cost would be the lowest. The reason for shipping printers to recyclers was to simulate a situation where recyclers would receive such products from their usual end of life products flow

In parallel, recyclers were asked for the 6 months of the activity to put aside any Lexmark printers they received from their usual waste flow. A short list of useful printers (268 models) was shared with recyclers to identify printers which can be used for dismantling or even better to be shipped as is to Lexmark for refurbishing.

Capitalizing on the previous deliverables, a dismantling manual was developed and circulated to the recyclers who brought useful comments to get it fully practical.

The major challenge at this stage was to determine which parts would be worth dismantling at recyclers location, indeed, some parts need to be tested (what is called further in this report "pretest") and therefore printers need to be plugged on the main before determining if some of the parts can be harvested (motors, fans for example); some other parts can be recovered assuming page count is below a certain number, over this number, the parts is considered as at end of its life and must be recycled; some parts are deemed not valuable to be recovered (labour cost to access the parts is much higher than the cost of a new part); some finally needs to be refurbished after dismantling. Deep dive was done with Lexmark engineers to determine what parts to be harvested for this activity, taking also into account that a recycler is a recycler, meaning that engineering skills are based on recycling activity which also drives limitations. Engineers ended up with a short list of 20 parts, including parts which would ideally require pretesting (these being the most expensive parts), despite decision (see below in the report) to ask recyclers to not proceed with pretest, it was decided to ask recyclers to harvest them and then test them at Syncreon.

Quality specifications have been provided to the recyclers and included in the dismantling manual. A challenge was faced when instructing recyclers regarding the cosmetic defect acceptance criteria. While Lexmark specification is quite detailed and specific, it remains complex for someone who is not familiar with it and there is also a bit of subjectivity here. Recyclers were therefore trained by video conference. The objective was to avoid as much as possible extra costs driven by packing and shipping parts which would not pass quality criteria at the refurbishing stage.

A template was then developed to provide the same instructions to the 3 companies: recyclers Indumetal and Greentronics as well as Syncreon.

	1	2	3
	40X7678	40X8017	40X7673
	Rear door	Fuser - MS81x Fuser Type 06, 220-240V A4	Top cover
Printer 1			
Printer 2			
Printer 3			
Printer 4			
Printer 5			
Printer 6			
Printer 7			
Printer 8			
Printer 9			

This is an abstract of the said format. For each printer it was requested to note if the part passed the quality inspection with criteria set by Lexmark

It was also requested to collect time per part to then also allow to compute a cumulative time. Indeed, in case only some parts would show specific interest, a cumulative time could be computed considering which one would need to be prior dismantled, see below.

			Time (sec)	Cumulative time (sec)
1	40X7678	Rear door		
2	40X8017	Fuser - MS81x Fuser Type 06, 220-240V A4		
3	40X7673	Top cover		
4	41X0976	550-sheet tray insert		
5	40X7680	Right Cover		
6	40X7679	Left Cover		
7	40X7578	HVPS		

The current process for printers dismantling at Syncreon is as follows:

1. Pretesting: to gather page count and test motors, fan, fuser units as well as mother board
2. Dismantling
3. Storing dismantled parts to stock location
4. When any part is requested, it is pulled out of stock and repaired if required (short list) or cleaned and packed

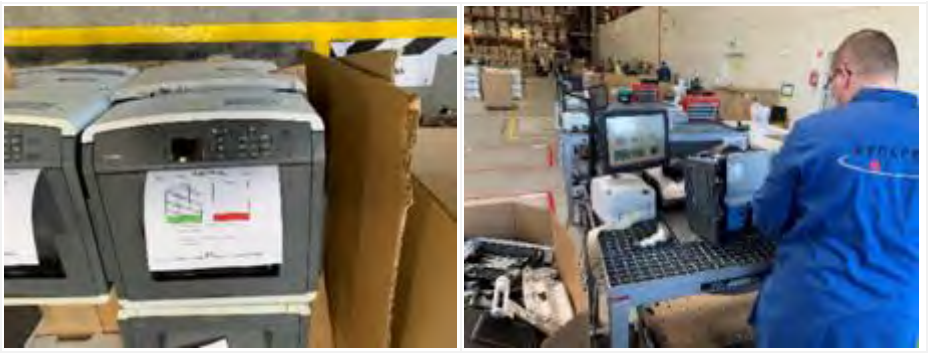


Figure 17. Pretesting of end-of-life printers at Syncreon

For the purpose of processing the activity, parts were dismantled at recyclers' locations without pretesting, same for Syncreon. Indeed, getting pretest at recyclers locations would not be relevant as it is unlikely to happen that this could be done as it would also require some product knowledge which would not make sense to pass to recycler based on the low usage they would have about this knowledge.

In a second step, Syncreon was requested to receive, sort and as appropriate test the parts received from recyclers as well as the one they dismantled themselves.

Bottom line objective being in a first step to compute the following cost

Cost to dismantle the parts @ recycler's location
\+ *Cost to ship the parts to Syncreon*
\+ *Cost of sorting, testing, and refurbishing @ Syncreon*

Cost of getting parts from recyclers

Figure 18. Recovered parts at the recyclers location, checking and packing process

Interesting points to note at this stage:

- While they both had the same products, they recovered a significantly different number of parts. This can be explained by the "quality" of the printer received; indeed, these are used products, another possible explanation is the subjectivity level of the cosmetic defect sorting criteria as many dismantled parts are visible ones, associated with the lack of experience.
- Another interesting finding is that despite differences in hourly rates, in the end the per unit cost to recover parts (while not fully representative, as recovering one parts would not cost such amount due to fix cost at stake), is fairly closed and around 3€.

Below are the details of the cost analysis to get parts from recyclers.

The two main cost parameters are for both recyclers labor as well as shipping.

Indumetal

19 printers processed	
Total recovered parts	**298**
Total theoritical number	380

Total time to dismantle (mins)	549.1	
Total time to pack the part (mins)	515.6	
Cost per hour	€ 30	
Labor + dismantling + packing	**€ 532**	
Material cost (packaging)	€ 77	
Shipping	€ 200	w/o VAT

Total cost	**€ 809**
Number of recovered parts	**298.0**
Avg per unit cost	**€ 2.7**

Greentronics

19 printers processed	
Total recovered parts	**221**
Total theoritical number	380

Total time to dismantle (mins)	399	
tal time to pack the part (mins)	285	
Cost per hour	€ 19.8	
Labor + dismantling + packing	**€ 225.2**	
Material cost (packaging)	€ 120.0	
Shipping cost	€ 355.0	w/o VAT

Total cost	**€ 700**
Number of recovered parts	**221**
Avg per unit cc	**€ 3.2**

In parallel Syncreon ran the dismantling on 20 printers from same model. No packaging, no freight cost at Syncreon, only dismantling cost was incurred. No pre-sorting at Syncreon, full sorting of Syncreon sorted parts being done at final sorting stage with Indumetal and Greentronics parts, which explain the number of recovered parts as well as the average per unit cost.

Syncreon

20 printers processed	
Total recovered parts	**420**
Total theoritical number	420

Total time to dismantle (mins)	306.7	
Total time to pack the part (mins)	NA	
Cost per hour	€ 39	
Labor + dismantling + packing	**€ 199**	
Material cost (packaging)	NA	
Shipping cost	NA	w/o VAT
Benefit from recycling remainings of the printers	NA	included in the hourly rate

Total cost	**€ 199**
Number of recovered parts	**420.0**
Avg per unit cost	**€ 0.5**

In the last phase Syncreon was instructed to proceed with sorting, cleaning, and testing (as appropriate) of all the dismantled parts, from both recyclers as well as Syncreon.

Figure 19. Printer parts cleaning at Syncreon

Data summary associated with above mentioned operations is shown in the table below.

- Higher sorting time and related cost at Syncreon due to no pre-sorting (see above). Then, Greentronics shows higher numbers than Indumetal driven by the product mix and necessary cleaning.
- Despite the dismantling manual, 40% less good parts were recovered at recyclers than at Syncreon: many parts rejected for cosmetic issues as well as broken or damaged parts (apparently not during transportation but during disassembly) which shows some limitations in the activity.
- 30% of the parts shipped from recyclers considered as good parts after sorting (we were anticipating 70% in Deliverable 4.3)

	Total parts sorted	Parts for Repair	OK parts	Parts for scrap	TTL Time (minutes)	TTL recovered parts	Sorting and cleaning cost	Per unit
indumetal	295	38	40	217	716.8	78	€ 466.0	€ 6.0
greentronics	218	19	61	138	1121.17	80	€ 729.0	€ 9.1
syncreon	420	40	91	289	1367.37	131	€ 889.0	€ 6.8

We can observe that on a per unit basis, not distinguishing parts, the most economical option is to get Syncreon (a specialized sorting center) to proceed and harvest parts, which is not surprising. As mentioned before, business as usual, Syncreon would perform pre-testing of the printer prior dismantling (which is not an option for recyclers), this pretesting would avoid unnecessary tasks, driving an even lower cost.

Total per unit cost summary

	Delivered to syncreon	Sorting & cleaning	**Total**		
indumetal	€ 2.5	€ 6.0	**€ 8.48**		
greentronics	€ 2.8	€ 9.1	**€ 11.94**		
syncreon	€ 0.5	€ 6.8	**€ 7.26**	**€ 5.97**	*with pretesting

As per above, the average recycler cost to recover a good part is 10.21€

This confirms the cost computed and reported previously in deliverable 4.3 for which some estimates were used for the fall out rate after sorting as well as Syncreon cost to sort and clean the sorted parts. Indeed, in deliverable 4.3 we ended up with: 119€ and 140€ per printer to recover 12 parts, meaning 9.91€ and 11.67€ per part respectively for Greentronics and Indumetal, not far from to the 11.94€ and 8.48€ in the above table

What about the cost of brand-new parts? Removing all parts which cost less or very close to 10.21€ (average dismantling cost per part), considering that some of the remaining ones would need to go to repair (and therefore incur in cost) in case they are coming from dismantling, we end up with a short list of 4 parts for a total of 112€. In other words, getting those 4 specific parts from recyclers could be beneficial.

Basic computation would drive: 112€ – (10.21€ x 4) = 71€, although there is a bias here as recovering only specific parts would be more costly for the recyclers, due to longer time to access those parts and some fix cost absorption. Working on estimates, we can assume no more than 50% higher cost, therefore in this scenario, the case would still be favourable.

Conclusion

This activity confirmed what was anticipated in the previous deliverable: getting specific parts recovered at recycler's locations can drive positive financial outcome, assuming recyclers get such products in their WEEE stream, which may be a major challenge.

Indeed, in parallel of the above-described activity, recyclers were asked to put aside Lexmark printers they do received in their WEEE flow (see introduction), it appears that none were received. While we do have to be cautious as this statement is based on two recyclers only, amongst hundreds in Europe. Anyway, if this finding was valid for the recycling industry, it could be seen as good news as it would mean that those printers for any reason don't end up in recycling and may be refurbished or see their lifetime extended which is a positive point for the Circular Economy. However, they also might end up in third world countries to retrieve basic raw materials such as copper and then be land filled which is obviously a less good news for the Circular Economy. These are only speculations as nothing in this study can determine the reasons why Lexmark printers would not be appearing at recyclers' facilities.

5.2. Replication of the Lexmark cartridges Collection program for printers

To address one of the end-of-life issues related to the cost challenge (see Deliverable 4.3, section 5.3.1. Extending the current LCCP online platform to printers) of making printer refurbishment a cost-effective activity and therefore boost the Circular Economy, Lexmark elected to initiate a project related to the reverse logistic cost element, indeed, reverse logistic is one of the top 3 cost contributor to refurbish a printer.

The aim of this project is to increase the EMEA refurbish volume by leveraging, enhancing and automating all internal related processes, and optimize costs as much as possible,

mainly labour related cost as the various processes as we'll see below are much labour related. Another objective of the project is to make it easier for customers and partners to get their used units returned, so they don't end to WEEE stream and get damaged.

The project scope includes developing the return flows for printers and enlarge the already existing LCCP (Lexmark Cartridge Collection Program) web platform to printer LECP (Lexmark Equipment Collection Program) - as this will accelerate our circular economy projects in Europe.

The new webtool, also called platform, is made by a third-party service provider who played a key role in the development of the new digital platform for LCCP. They created a new identity with « Collected by Lexmark » and created a customer friendly website, set up new efficient functionalities, and rolled out the program in 32 countries.

This platform is dedicated to be one single customer hub; the goal is to optimize and converge the resources and offer a smart and intuitive process flow for customers and partners, boost the refurbishment printer program and automatize the process. Using this kind of platform will make our collections easier and faster, it could serve the refurbishment supply more effectively. Also an advantage of this webtool could be to link the sales community to promote the TB/BB process.

In 2021 Lexmark has collected back printers from 19 countries. The biggest volumes are collected from Germany and France out of more than 100 partners. It is of course expected to see more printers collected from those 2 countries but also expected to see many more from other countries as the platform should help to reach more customers and partners.

And it leads Lexmark to be an innovative and sustainable partner for other companies.

About the Lexmark return/ collection processes

According to the EU electronic waste legislation, Lexmark as a manufacturer is obliged to take back old electronic equipment. It means that Lexmark has to organise and finance the collection, treatment, recycling and recovery of the products.

Lexmark has to provide a Take Back (TB) service where the customers can return electric and electronic waste, free of charge. In case Take Back is not an option, Lexmark set a Buy Back (BB) process, see below a summary about those 2 processes.

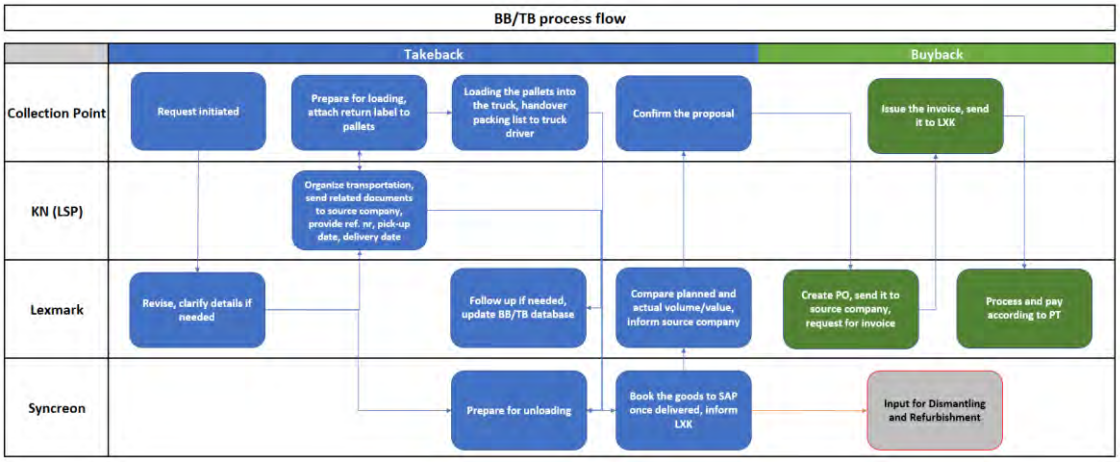
Takeback (TB): the Lexmark owned printers are taken back (FoC – Free of Charge) from customers, former customers, install partners, service partners, brokers, etc... Returned devices can be refurbished or dismantled, spare parts will be re-used. All media containing customer specific data are destroyed or permanently wiped. These printers are still Lexmark property. The Take Back Cost is bear by Lexmark.

Buyback (BB): if the printer is not Lexmark property (Printer sold to a Lexmark sales partner as an example), Lexmark might propose to the customer to buy the printer to enhance the return of products for which there is a demand for refurbished units. Buy Back and associated prices are determined and reviewed by Lexmark once a quarter

based on demand for both refurbished printers as well as spare parts availability. Therefore, a list of eligible devices is published (now published on the newly developed platform), so the printer owner knows in advance what Lexmark is ready to pay to collect the said printer, Lexmark also provide the customer with quality criteria and inform the customer on how to pack the printer to ensure it will be delivered in good shape ready to be refurbished. Payment of the Buy Back price is triggered upon reception and inspection of the printer by Lexmark refurbishment centre to ensure it is part of the eligible list, was well packed and therefore not damaged and conforms to the quality criteria. Option is of course offered to customers to send back any Lexmark printer, meaning that if the printer is not eligible to Buy Back, it will be handled as a Take Back (see above). Syncreon confirms if the printer arrived back in a good condition which trigger Lexmark payment decision to customer.

Lexmark BB/TB team takes care about the transportation itself with a contracted freight forwarder company. It is important to highlight that either a Particular transaction is a buyback or takeback, printers need to be put on pallets and loaded into the trucks by the customer we get the printers from.

How the BB/TB (Buyback/Takeback) process (B2B) (Business to Business) looked like



Major differences between the manual and automated systems

	Original TB/BB process	TB/BB Webtool
Communication regarding a transaction during the process, like status update	via email only	automated email via the tool
Communication on other related topics like price change, eligibility list change	via email only	via email, but always available via the tool
Reporting for KPI	manually built excel database	database generated automatically
Printer volume	16.3k/year 2021	might be increased due to the ease of use

Transaction volume	251 / year 2021	minimal additional work for LXK in case the number of transactions increase

Disadvantages of the old TB/BB process

- Manually built Excel based database
- Labour intensive
- The too much data can make a difficult file management
- Communication via e-mail only
- Require one person full time to handle current volume, would volume increase, it would require additional persons

Advantages of the newly developed TB/BB webtool

- Web based, automatically generated database
- Easily accessible to customers
- Communication via automated e-mails via the tool
- Easy maintenance
- No labour related volume constraint as one person can handle much more volume than with the manual process (see table below)
- Lower labour content per transaction linked to faster turnaround per transaction

Comparing processing time

	Old Model		Estimations with the Webtool	
Description	Time (minutes)	Number of emails	Time (minutes)	Number of emails
Initial communication, alignment	10	2	5	0
Check if all details provided by the requestor, ask back if something is missing	10	2	5	0
Send the completed form to KN	2	1	1	0
Send pre-notification to Syncreon	2	1	0	0
Align with KN if needed	20	2	20	2
Align w/ Syncreon if needed	10	2	10	2
Add the transaction to the excel database and update it with the available data	20	0	15	0
Monthly KPI update	10	0	8	0
Final confirmation with the initiator	15	2	2	0
Sum:	**75**	**12**	**42**	4

Total hours / transaction	1.3		0.70	
number of emails / transactions		12		4

With the manual system it took ~1,3 hours to complete a transaction end to end and it needed about 12 emails. With the webtool it is expected to reduce the time by half (50%), less than an hour and to require only 4 emails. Significant productivity gains. End to end Lead Time (LT) from an average of ~25 days can be decreased to ~15-20 days with the automation. Another substantial productivity gain, which will help to get the printer available for refurbishment faster and therefore to customers.

One of the limitations of the manual system as mentioned above is resource related and one person couldn't handle much more than 60 requestors locations (mainly sales partners), the automated system should now allow for at least two times this number, which will drive higher volumes.

These are the first numbers after the go live since early May.

	Webtool Actual for 1 month	
Description	Time (minutes)	number of emails
initial communication, alignment	5	0
check if all details provided by the requestor, ask back if something is missing	0	0
Send the completed form to freight forwarder	1	0
Send pre-notification to Syncreon	0	0
Align with freight forwarder if needed	20	2
Align w/ Syncreon if needed	10	2
Add the transaction to the excel database and update it with the available data	20	0
Monthly KPI update	10	0
Final confirmation with the initiator	15	0
Webtool trouble shooting with the developer company and the partners	90	6
Sum:	**57**	4
Total hours / transaction	**0.95**	
number of emails / transactions		**4**

The numbers show that the total working time decreased with 26% in the first month with the new tool. Sending pre-notification to the refurbishing centre is every time done by our contracted freight forwarder company. And the communication needs also less time from Lexmark side, as the process is more automatic. Some issues have been identified during these first production weeks and they are being fixed. The team is confident that the original target of 50% processing time reduction can be reached.

We can conclude that investment in IT systems will be almost essential in the development of TB BB processes in the future, for printing industry but not only and it will likely benefit most of the EEE industry.

The new LECP platform can be reached at https://www.collectedbylexmark.com/

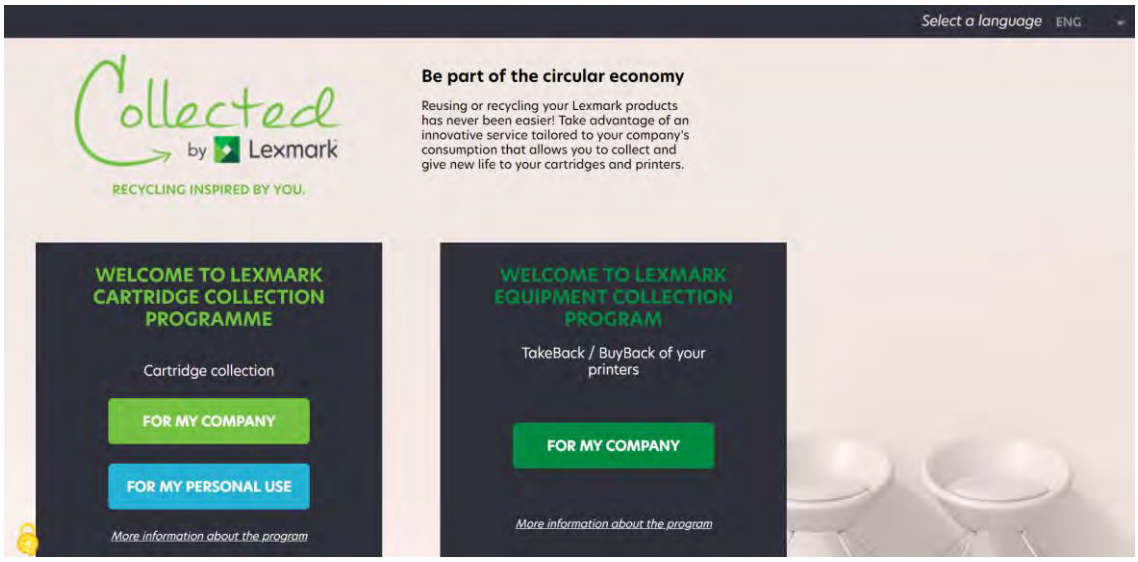
How does the platform work in few words ?

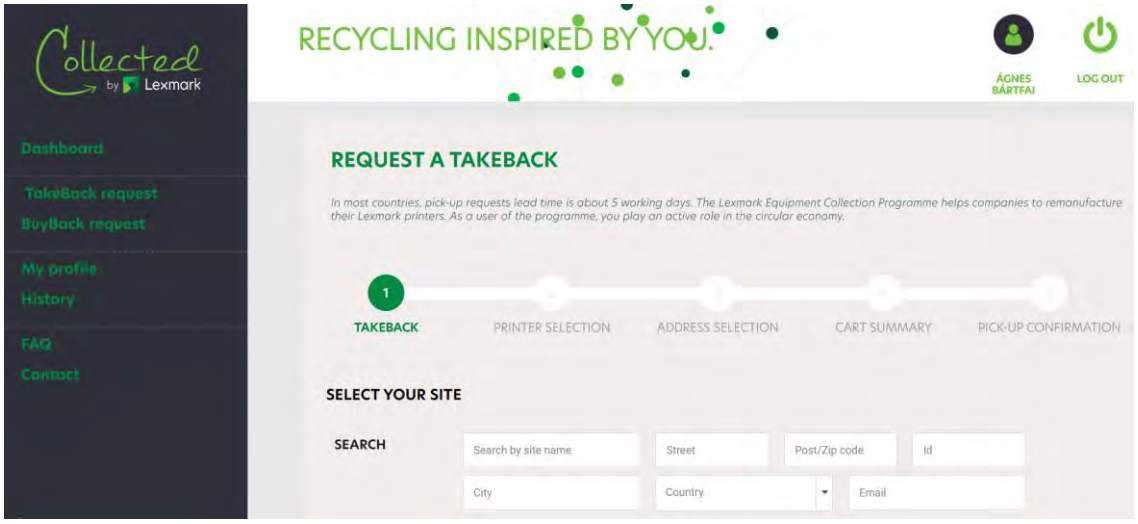
- Separated flows for TB / BB requests
- Customers have to go through 5 steps to submit a request and it takes no more than 10 minutes
- Any changes remain possible before the request is submitted, and it can even be cancelled 4 hours after it is submitted
- Various documents are available on the platform such as a printer model list, price list to help customer to place the request
- When a request is completed on customer end, Lexmark's team receive a notification via email to review and as appropriate approve the request
- In a next step, it is Lexmark's freight forwarder who then automatically receives pick up instructions
- Upon arrival at Lexmark sorting and refurbishing centre, for BB requests, printers are checked to ensure they comply with Lexmark specifications to then trigger payment to customer

After the various development milestone and testing, it went live on May 9th, at the time this report is written it is a bit too early to get a view of the objective achievements.

The team has planned to proceed with customer survey 3 months after the go live to (i) determine if we achieve the objectives and (ii) what can be further improved.

Results are very encouraging and based on the expected outcome, the team is very excited about this project.





5.3. Reclaimed ABS plastic resin completion

5.3.1. Reclaimed ABS from non-Lexmark products

As part of the recycled resin demonstration, Lexmark carried out a study to examine the feasibility of ABS plastic recovery from non-Lexmark printers, see deliverable 4.3, section 5.2. 'Assessment of the potential to increase material circularity' and more specifically 5.2.1. 'Result of recycled materials from EoL printers and toner cartridges' point 3. The aim was to inspect the properties of recycled materials obtained from non-Lexmark end-of-life printers which have been collected by Greentronics in Romania and determine if the recycled material is suitable to incorporate into new cartridges and track the recycled content by the ICT tool.

Within the project there were previous attempts to use ABS plastics obtained from Lexmark used products. The activities showed that recovered plastic from cartridge parts was successfully incorporated into new cartridge housing and passed all quality criterion and the recycled material content have been tracked by the ICT tool. One of the reasons of the success is that there is good control over Lexmark feed stream, limiting the risk of pollution with other kind of material. In case of Lexmark printer parts which has been dismantled and sorted by a recycler partner the test showed different contaminants (like Polycarbonate) as well as metal particles in the grinded material and therefore could not be used for further processes. The team nevertheless decided to conduct a demo with recovered printer ABS plastic material which derives from non-Lexmark products, paying special attention to avoid contaminant (non-ABS parts as well as metal particles and therefore use appropriate metal separator this time).

Greentronics collected printer devices from any other brands but Lexmark, then manually sorted the plastic parts at their facilities to only keep ABS parts to then shred them. Gaiker received around 25 kg of shredded plastic material from Greentronics with particle size between 5-10 cm.

Figure 20. Sample of shredded printer parts (ABS only) from Greentronics

Gaiker grinded the samples into 8mm particles then washed and dried them to remove the dust and dirt. Metal parts, stickers and non-ABS inserts were manually removed. They used eddy current separator to make sure all metallic contaminants are eliminated. Based on Lexmark instructions, Gaiker characterised the samples and completed the following analysis/tests

- DSC (Differential Scanning Calorimeter)
- FTIR (Fourier Transform Infrared Spectroscopy)
- TGA (Thermogravimetric analysis)
- MFI (Melt Flow Index)

The analysis at Gaiker confirmed that this was ABS material. The results and the samples were then sent to Lexmark engineers for further examination.

For the flake analysis, Lexmark engineers took a small 5-gram sample of flakes. The sample showed white, black and some off-colour flakes and most of them were found to be ABS which was positive. In the flakes they also observed small metals particles such as Aluminium and brass and several clear particles turned out to be small glass pieces (Figure 21). One black particle observed in this sample was Polypropylene with 30% mineral filler. Nothing redhibitory at this stage as these articles can be removed by filtering.

Additional tests were performed, molding ASTM standard Flex Bars to perform Izod impact and Flexural Strength testing. The bars had obvious and consistent swirl patterns in the molded parts, driven by rubber particles which is an issue as it would significantly alter the property of a molded part.

Molded flex bars were also used to complete Pendulum Notched Izod impact testing. The result of property testing showed promise in the quality of the recycled material.

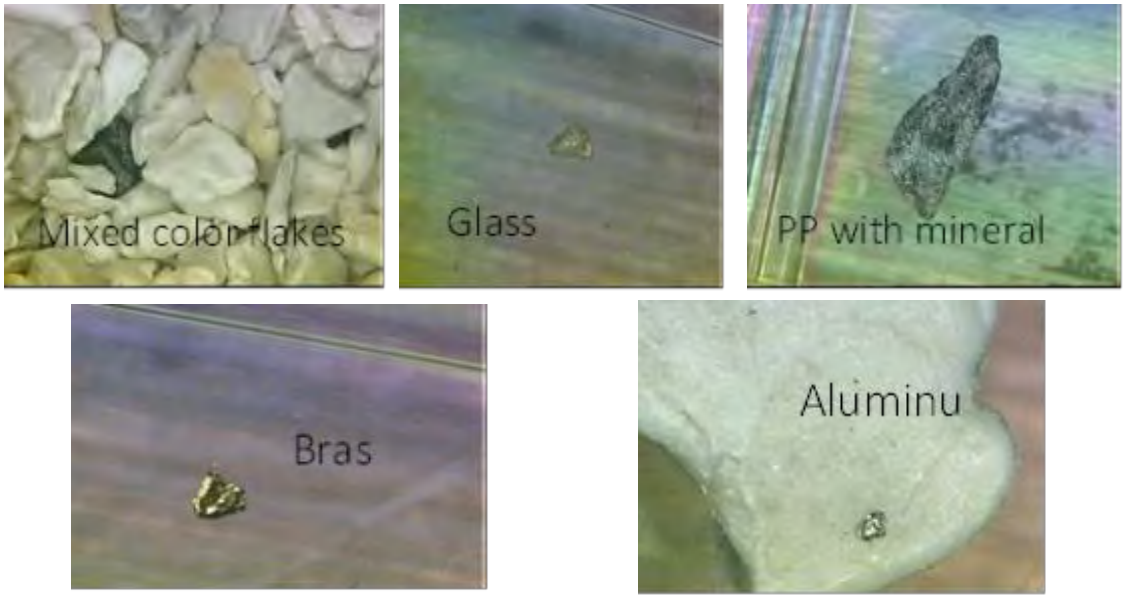


Figure 21. Samples of particles found in the ABS sample analysed at Lexmark

Finally, analytical testing was performed, IR, DSC and TGA of the samples did not show any significant contamination. The DSC displayed a small amount of Polypropylene, but it would not be considered intolerable, however the XRF analysis of the sample indicated that the level of Bromine in the sample was high higher than Lexmark and electronic industry standards. Other heavy metals seemed relatively absent in the parts which is good news.

Based on above analysis, following recommendations from Lexmark Engineers were done to improve the removal process and avoid contamination.

- Have a system which separates rubbers up front, before grinding which seems the best way to avoid rubber contamination.
- Separate Solid metal as much as possible up front, but magnets and eddy current remove most that is left.
- The ceramic is best to separate up front, but filters will catch any left in the flakes
- Mineral filled plastics should fall out in the float separation step because it should be heavier than other plastics.
- Finally, for bromine the most effective way for minimizing is to control the feedstream of material, purchasing a known feedstream of plastic parts. There are other techniques, but the best is to avoid it initially.

The conclusion is that the ABS material samples obtained from external printers looked good and had good properties, however definite contamination (specifically rubber and bromine) was found which drove the decision to not pursue the activity.

Special focus needed to improve the separation and removal processes. For example, the removal of metals, ceramics, and rubber. Challenge is brominated plastic as there is no way to sort brominated ABS from non-brominated ones and this is a major challenge to envision using WEEE ABS. Material contamination such as metal and glass, while found in small size particles could also cause problem during molding process, potentially

damaging equipment and molds but also significantly alter the molded parts quality except if flakes are re-pelletized and proper filtering applied.

Conclusion

This activity reinforces the conclusion made in Deliverable 4.3 which highlights the importance of getting material properly sorted and processed, which require the rights means and may need to be processed by company specialized in resin processing to ensure proper purity.

5.3.2. Resin recycling economic analysis

Following the recycled resin activity performed (see deliverable 4.3, 5.2.1. 'Result of recycled materials from EoL printers and toner cartridges'), it's been identified that reusing ABS from Lexmark collected laser cartridge drove a positive outcome. Considering the challenge highlighted in deliverable 4.3 to identify grinding and compounding capacity/suppliers in the market, the team analysed the opportunity of setting up sorting/dismantling and grinding at its sorting centre location. It was decided in a first stage to not include compounding in the analysis and only look at grinding. Assuming grinding would be economically a viable option, then compounding would be investigated. Benefit of compounding being to re-use the material as is and no need to get it mixed with virgin material at the molder.

The first step has been to look at the 2022 projected volume to determine the volume at stake. Therefore, 2021 actual were used, looking at all products collected and sorted and selecting the one made of ABS which ended up to scrap and could have been good candidate for resin recycling. Looking at the BOM to find out the weight of considered parts, time the associated volume, we ended up to 14 000kg (13 856) of ABS which could have been recovered.

What would be the associated savings?

- Resin: at the time we put the business case together, virgin ABS was valued at 1.6€/kg. This fluctuating significantly with oil price and no doubt that it is currently increasing. A total of 22k€
- Recycling cost incurred by the recycler: considered neutral as recycler is also getting benefit out of those parts
- Freight cost to ship empty units to recycler: considered as not significant
- Toner: residual toner can be recovered from dismantled units. Indeed, when printing, some of the ink is not transferred to the paper and recovered in the cleaning unit of the cartridge. 9 700kgs of residual toner valued at 10€ per kg, a total of 97k€.

Total of about 120k€ savings, interestingly mainly driven by residual toner recovery and not much by resin. Which toner recovery may vary significantly depending on product mix.

The second step has been to estimate the cost associated with such sorting/dismantling activity. Lexmark worked with Syncreon to get this estimation.

- Vacuuming, installation: 60k€
- Specific equipment, such as grinder, conveyor with metal detection, second metal detection station…: 148k€
- Labour: at minimum, 2 headcounts: 40k€
- Total of about 240k€ associated cost, mainly driven by fix cost to procure equipment and get them installed

With the above working assumptions, there is a payback of 2 years (internal requirement is a year or less for such project). Various parameters influence such pay back, a significant one seemed to be the volume at stake, only 14 000kg. 2021 being impacted by covid, we looked at prior data to see if the picture would be different.

Proceeding same as described above, we ended up with following results, gaps driven by the product mix

- 2020: 5 000kg
- 2019: 4 000kg
- 2018: 5 000kg

Conclusion

The analysis confirms that directionally with today's returns units, setting up grinding operations at the sorting centre is not an option from an economical viewpoint and therefore, the best option is to remanufacture those laser cartridges and maintain their value as long as possible in the economy. For most of its qualified products, Lexmark consider that its laser cartridges can be remanufactured up to 10 times, assuming proper process and materials are used.

5.4. Follow up on 3D printing

In deliverable 4.3, in partnership with Syncreon and Particula, an activity (5.1.2 3D printing for spare parts/refurbishment) was run with the aim to 3D print selected plastic parts which are subject to be changed when refurbishing a printer. The first challenge encountered was to select the parts and then to 3D print them and reach necessary functional specification. The outcome of the activity was unfortunately not successful, conclusion was as follow "As a conclusion, for the purpose of B2B printer refurbishment while 3D printing technology may be appropriate for small parts (and this demo did not investigate this area) it is probably not a breakthrough option to cut cost. Indeed, mechanical spare part cost is driven by large cosmetic parts, the covers, which cannot be effectively 3D printed and other large parts which are subjected to be changed during the refurbishing process seem to be not appropriate for 3D printing. Based on this demo, it has been decided to not pursue 3D printing testing for printer refurbishing."

While the conclusion was to not pursue 3D printing testing for printer refurbishing, in the meantime, Syncreon identified a potential candidate: a “packaging” part. A part which is placed to lock some piece of the printer together to avoid damages during transportation and which is removed by the customer before using the printer. Technical requirements for these parts are much different and lower than a functional part of the printer and aesthetical requirements (one of the major bottlenecks of the previous activity finding) is not an issue. Not only technical and aesthetical requirements are lower but also access to the original supplier of these parts was a challenge and no more possible to get parts from original supplier which is the trigger to the described activity.

Figure 22. In red, the parts used to lock the cartridges(left) and the drawer (right) during transportation

Based on above as well as findings of previous activity, it was decided to try 3D printing for these parts. Three different parts were printed with ABS filament and tested successfully. 3D printer was procured accordingly and located withing the refurbishing area to allow to use it in “hidden time”, meaning that the labour time involved is low (about a minute to launch a new part or new series of part (several parts of the same design), driving parts cost between 1 and 1.5 € per unit based on material content. This cost will go down with volume going up.

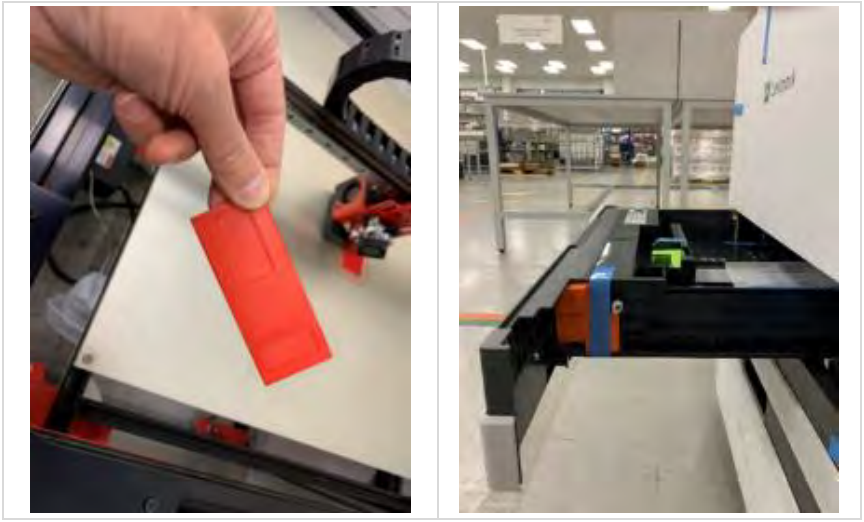


Figure 23. 3D printing of the cartridge locker (above) and the drawer locker (below)

5.5. Gathering customers' feedback - Refurbished printers testing at customer locations Lexmark

This section reports on the outcome of an activity initiated during the time frame of the previous stage in the printer and toner cartridges demo, aimed at assessing customer acceptance in terms of cosmetic defects on refurbished printers, see deliverable 4.3 section 5.1.5. 'Refurbished printers with cosmetic defects').

In the beginning of 2021 Lexmark conducted several qualitative interviews with customers and partners located in France, Italy and Germany. The survey intended to collect their opinion, needs, requirements towards refurbished products. These companies were distributors/dealers or customers with Lexmark printer fleet. Some of the involved companies showed interest to test refurbished devices. Not all the companies had the chance to try and assess such products, and the C-SERVEES project seemed a good opportunity to offer refurbished Lexmark products for testing and gather more valuable inputs, mostly focused on the cosmetic appearance. Visible parts mainly made of molded plastic covers and housings are expensive as they are ordered by large Minimum Order Quantity due to the injection molding technology and also they are coming from far east Asia which drive high freight cost, therefore, would customer acceptance evolve as it relates to cosmetic defect, it may positively impact the cost of refurbished printers. As all the refurbished products were tested in advance and the various spare parts have been replaced, following Lexmark refurbished processes and protocols, Lexmark was not looking for functional issues but rather for the acceptance of customers/partners related to small cosmetic defects like scratches, bumps, dents, discoloration on the printer cover what Lexmark would consider as not acceptable defects. The expectation was to receive valuable information based on practical experience of users. The idea was to install 1printer at selected customers/partners who would voluntarily use it for 3 months. In order to collect all relevant information, the Lexmark team has created an online anonym survey form which has been distributed among the users and in the end of the test period Lexmark also has scheduled face-to-face (video-call) one-hour interviews with each involved company. It has to be said that

as it relates to the cosmetic, issue, the test was a blind one, meaning that none of the customer knew in advance that we build those printers with Lexmark out of specification cosmetic issues.

Cosmetic defect can be judgement can be a challenge as there is subjectivity in determining if a damage is acceptable or not. Lexmark therefore developed specifications as per bellow table to remove as much as possible (hard to remove entirely) the subjectivity part of the judgement.

DEFECTS OF SURFACE	CLASSIFICATION OF SECTIONS					
	A	I A	II A	B	C	D
	LEXMARK LOGO, DISPLAY	SCANNER GLASS	TOP COVER, ADF	FRONT COVER	SIDE COVER, REAR COVER	BOTTOM, HIDDEN ELEMENTS
Burns / Ink smears	N	N	N	N	N	N
Abrasions / Discoloration	N	N	Max. 1: Max. area: 6,4 mm x 25 mm	Max. 1: Max. area: 6,4 mm x 25 mm	Max. 2 on side: Max. diameter: 51 mm	Max. 2: Max. diameter: 64 mm (in area 1m²).
Gouges / Pits / Nicks	N	N	Max. 2: Max. diameter: 6,4 mm	Max. 2: Max. diameter: 6,4 mm	Max. 4 on side: Max. diameter: 6,4 mm	Max. 6: Max. diameter: 25 mm
Scratches	N	N	Max. 2: Max. length: 51 mm	Max. 2: Max. length: 51 mm	Max. 4: Max. length: 51 mm	Max. po 2: Max. length: 76 mm Max. length: 152 mm (in area 1 m²).
Cracks	N	N	N	N	N	N
Foreign objects or Stickers	N	N	N	N	N	N

How does it work?

Each visible areas of the product is named: A, IAI, IIA, B and C (first raw) and described in few words (second raw). The various kind of potential defect are listed (first column)

Then for each visible area the table mentions whether the defect is acceptable or not through a color code, acceptable if yellow not acceptable if red N. If the kind of defect is acceptable, then the table states the Max limit of the said defect, as an example, take a scratch, on side or rear covers (C), 4 of them can be accepted assuming they measure less than 51 mms. This has proven to be easy to understand and implement by operators to determine if a given defect pass or not.

Selected product models

Lexmark has chosen two product models representative of mid-range mono and color products. Finally, two models have been selected, namely the CX725de and MS823dn. Lexmark also provided customers with necessary cartridges to run the testing.

Lexmark CX725de

Lexmark MS823dn

Figure 24. Lexmark printer models selected for the customer experience.

To proceed we asked the Lexmark sorting and refurbishing center to refurbished 2 of each printer as per Lexmark specifications. In parallel, visible parts with cosmetic issues, out of Lexmark specifications were put aside to then pick and choose the one to be assembled on the 4 printers. While subjective the choice was made on 2 criteria 1/for a given printer, chose defects from as many categories as possible (dents, scratches, discoloration…) 2/ defect that we, as customers would easily accept

All 4 printers got covers with similar kind of small defects.
Here are few examples of cosmetic defects shown by these printers.

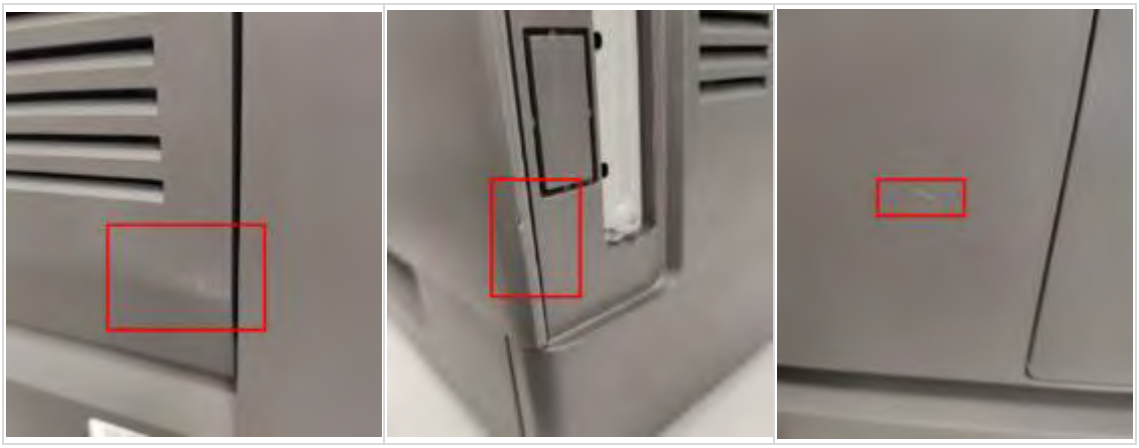


Figure 25. Cosmetic defect samples on housings used for the activity

Test instructions

The users were instructed to:

- Install the printer
- Print a Device Statistics report before and after the test period, which counts the printed pages.

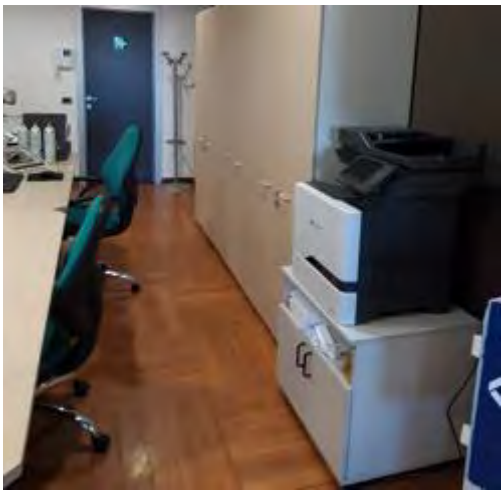
- Fill in the online survey after 6 weeks, distribute it internally to get as much feedbacks as possible
- Fill in the online survey again after 3 months
- Participate in a face-to-face (online) interview with Lexmark after completing the test

Interviews with Customers/Partners

The 4 entities involved in this activity had to test the refurbished printers for 3 months. They have received the printers in the end of October 2021 and used them until end of January 2022. Lexmark used two sources to get the feedback from the companies. An online survey has been distributed among the users then interviews have been conducted afterwards with each entity in February-March and Lexmark obtained all relevant experience/feedback from the interviewees.

In the followings we are going to refer to the involved entities as Company 1, Company 2 and Company 3 and Company 4.

Company 1 based in Italy is a producer responsibility organization providing regulatory compliance services, management of all waste from electronic products. It is in charge of collection of end-of-life equipment, management of logistic issues, treatment of EoL products and recovery of secondary raw materials.



The role of the interviewee was a Project Innovation Specialist who could provide valuable feedbacks. The company has received a CX725de printer which was installed at the entrance of the office, next to the reception. It was used by people working at the reception and also by the people who has their offices around the reception area. No one mentioned cosmetic issues and it has not been told in advance to the users that it is a refurbished printer. The cosmetic defects were not noticed by the various users, and they all were happy to use the printer. Even if they would have recognized cosmetic defects it would not be an issue or bothering for them since the company also promotes refurbished products and mostly everyone is aware of this kind of topics which has to be taken into account in the conclusion of this activity As per the interviewee, in the business life, at offices the users have very small, few minutes long interaction with the printer and the aesthetics is not that important compared to domestic usage. The company nevertheless missed a manual user/user guide which was not included to the package, but it can be something useful since it was a bit hard to change to another device and understand the functions. They raised the idea of a QR code which leads to an online user guide. User guides being anyway available on the website, we took note of making sure that an information is passed to customers of refurbished products that user manual is available on Lexmark webpage. Currently refurbished printers are packed in brown boxes without any marketing artworks. The

interviewee reported various slight issues encountered while using the printers, mainly linked to lack of knowledge of using such printer and need to go through a learning curve but nothing major as printer performed as per expected specifications.

Company 2, based in Germany, the company manufactures equipment for landscape maintenance. They have installed the printer in a logistic area which has a rough, dirty environment and they used it 16 hours a day, 5-6 days per week. The users did not know that they are using a refurbished product. They have not experienced any issue in the functionality, they have not identified any cosmetic issues, it looked like a new device and worked as expected. Users were not using paper but label type paper which is 3x heavier than the usual paper. As per the interviewee, there are certain departments where they may be reluctant to install refurbished printers, such as main lobby, commercial areas were they welcome customers as an example, but in most areas, they would not mind using refurbished products. Their expectation towards a refurbished printer would be to get the device delivered faster than a brand-new product. The availability is important criteria for the company.

Company 3, based in Spain is devoted to research and offering innovative technological solutions for corporations. They contribute to technological development and technology transfer on the area of biotechnology, sustainable composites and functional polymers.

The printer was installed in their main office, and it was available for around 25 people who work in the technical department, mostly researchers. In this department it was the only printer they used which means it was under an intensive use. People were encouraged to use it as much as possible. The users mostly did not report any issue, the only comments were that the printer is a bit noisier than the other printers and they had some small paper jams which they think could have also happened due to wrong paper loading. They were satisfied with the printing quality, it printed fast, and the users has no issue with the black and white printing. They used normal A4 papers. The users were aware of that they received a refurbished product, and it was well-communicated to use as much as they can and record all the remark. Nobody observed any cosmetic issues, only one small scratch was highlighted by the interviewee who mentioned that it requires a closer, careful look on the cover. They would not have noticed that it was a refurbished product if nobody had told them. All in all, they were happy to use it and they were satisfied, nobody complained. In this department they did not care about cosmetic issues, their only expectation towards to the refurbished printer to operate correctly. The printer was not exposed to client's or customer's eyes, and for internal usage the smaller cosmetic defects are not relevant. Few years ago, they would have had a different perception to purchase refurbished products but today they are more conscious about the

environment and committed to contribute to the waste reduction by recycling, refurbishing the products. In this segment of the business cosmetic aspects are not that important. Currently they do not have refurbished products in their premises, but this is something that would be well-accepted. The acceptance of businesses towards refurbished products has changed a lot in the past few years. Earlier their perception was that these kinds of products are not reliable.

Company 4

A CX725 printer model has been shipped to Lexmark Budapest offices in Hungary and was installed in the Lexmark office at the reception area, which is easy to approach from any part of the office. There are several printers installed in the office but there is only one per floor which can print in color. The refurbished printer can print in color and also has settings which make it more attractive to use compared to the other printers in the office, for example the OCR (optical character recognition) tool which can transform printed documents into digital image files which means the text on a scanned document will be searchable and can be copied. The printer arrived with some small cosmetic defects, but it was not easy to identify these. There are 380 employees working on the site and due to the better situation in the covid crisis, the termination of restrictions and the application of the new "return back to the office" company policy, the employee office presence has raised, and printers are more in usage again. In order to call the colleague's attention to the new refurbished printer an article which introduces the printer has been posted in the internal newsletter. An online survey to collect feedback was also circulated.

Main conclusions of the online survey

- The users did not **perceive any cosmetic issue** or only noticed small scratches, and these were hardly visible and completely acceptable. It could have happened during unpacking.
- As a user they would **accept cosmetic issues** on a refurbished printer like small damage to the exterior parts of the product, small bumps, scratches, opaque plastic, decolorization, dents. One feedback was that it depends on the place where they install the printer. If they install in the offices, small scratches and decolorization is acceptable, but for domestic use they would not accept cosmetic issues on the product. Some of them would not care about the defects if it does not compromise printer use and functionality. Price is also a driving factor.
- Mostly the users did not encounter any **printing issues** during the test period but in few cases, they mentioned small issues like paper jam, slowness, noise.

- Almost every user responded that the **printing quality** was the same or similar as a new printer. One comment was that the printer worked good enough but the fact that the product is refurbished helps to accept possible and not so frequent defects in the printing quality.
- 2/3 of the users used the refurbished printer with the same **printing/copying usage** as a new device. They did not change the printing habits and did not differentiate between a new and a refurbished product. In those cases when the usage was lower, they mentioned reasons like, the refurbished printer was not enough close to the person's desk, they could not print coloured documents, the other printer they have is a higher range, the menu was not user-friendly. There were users who tried to use more on purpose to test it and they used only that device.

- For the question if they are willing to use more refurbished printers in the future

Printing usage of the refurbished device

all of them responded yes, except one person whose reasoning was that it does not depend on her/him if they would use such kind if products at work, but it would be nice, so basically every user would support to use refurbished printers in the future. We got diverse explanations for choosing refurbished products.

They support to use refurbished products:

- If the printing quality remains good at a lower cost
- Because they have not encountered any problem, there is no reason to say no
- Because it has less environmental impact, generates less waste, more sustainable
- If the operational performance (as it seems) is the same as that of a new printer
- Because of the extension of product life and consequent WEEE generation reduction
- Because re-use of materials is important, and consumers must support that

Based on the test period they would use refurbished products with conditions:

- it has the same or lower price than a new product. **The main drivers are the price**
- It has the same **printing performance and quality as a new one**, it works perfectly
- it has **warranty as for a new one** / maintenance guarantee
- there are no paper jams
- the printer comes in a good status (in one case it has arrived with an "error status")

- the menu is more user-friendly
- it prints all type of documents
- Being aware of the „history" of printer which help to evaluate the purchasing.

Major findings of this activity

- Performance of the refurbished device is the highest criteria for the users: as far as the printer performed as expected and especially as a new one, users are satisfied
- Price was still mentioned as a key element in decision making to use or not a refurbished unit: this confirms findings made in earlier activity in Deliverable 4.2 and 4.3, it therefore reinforces the need for OEMs such as Lexmark in identifying opportunities to make such devices more cost attractive, which is the purpose of this activity

Printer locations is seen as being an important criterion to determine if refurbished device is an option or not. Indeed, when located in areas where potential visitors, customers may come, there is still reluctancy / questioning on installing such refurbished device. While there is no strong rational from the interviewee related to this last comment, it has to be taken into account as it seems to be a paradigm driven by the image some people and therefore also decision makers still have related to refurbished products (bad looking and lower quality products) and this needs to evolve. Having that said, vast majority of printers are installed in areas where no visitors goes and even more, as per the survey outcome in most instances, printers are devices which are in areas where people do not mind to much about the appearance of the device but much more on the performance.

- The last finding which drove significant traction at Lexmark is that that customer acceptance level of cosmetic defect has evolve and customers are now willing to accept defects that do not pass Lexmark actual cosmetic specifications. Indeed, to one exception (one defect), users did not notice any cosmetic defect. This last finding drove the team to investigate the impact of revisiting the cosmetic specification, see below analysis.

Cosmetic defect specification change analysis

For a given printer model, a study was conducted to determine the cost impact of revisiting to cosmetic specification. In the bellow table, Grade A is the base line, in other words, today's specifications which are quite stringent and drive an equivalent to new printer looking. Grade B is including a revised cosmetic specification

For each grade, 3 yield points are used, 45, 60 and 80%. A yield point is representative of the ratio between received units and refurbished one. Higher the ratio is, lower is the opportunity to recover parts from received printers higher is the cost of replacing part

And then for each yield, 3 refurbished techniques were identified, from the standalone one which consist in refurbishing a printer from a to z by the same operator to the progressive line which is the most optimize option (see deliverable 4.3)

No surprise and consistent with the results shown in deliverable 4.3, labor cost decrease as we implement improvement in the refurbishment technique

More interestingly, the "Cosmetic" cost driven by the cost of changing covers of the printer is decreasing significantly, from 121.7€ to 79.1€ a unit, a 40+€ cost cut as an example for a yield of 80%, or from 49.5 to 28.8€, a 10+€ cost cut for a yield of 45. Target being of course to reach the highest yield point, but this is a tradeoff between what customer is ready to pay and the volume, indeed, higher is the yield (number of printers refurbished out of a given lot), higher is the cost and therefore the selling price but also lower is the waste

GRADE	YIELD	PRODUCTION	Labor	Cosmetic	BF	MK	Packging	TOTAL with MK	Cost gap	Volume initial	Volume final
		Standalone	€ 150.8	€ 121.7	€ 12.9	€ 60.5	€ 40.0	€ 386.0	100%	3500	2800
		DSM + Stand Alone	€ 117.0	€ 121.7	€ 12.9	€ 60.5	€ 40.0	€ 352.2	91%	3500	2800
	80%	Progressive line	€ 110.3	€ 121.7	€ 12.9	€ 60.5	€ 40.0	€ 345.5	90%	3500	2800
		Standalone	€ 150.8	€ 90.1	€ 12.9	€ 60.5	€ 40.0	€ 354.3	92%	3500	2100
		DSM + Stand Alone	€ 117.0	€ 90.1	€ 12.9	€ 60.5	€ 40.0	€ 320.6	83%	3500	2100
	60%	Progressive line	€ 110.3	€ 90.1	€ 12.9	€ 60.5	€ 40.0	€ 313.8	81%	3500	2100
		Standalone	€ 150.8	€ 49.5	€ 12.9	€ 60.5	€ 40.0	€ 313.8	81%	3500	1575
		DSM + Stand Alone	€ 117.0	€ 49.5	€ 12.9	€ 60.5	€ 40.0	€ 280.0	73%	3500	1575
A	45%	Progressive line	€ 110.3	€ 49.5	€ 12.9	€ 60.5	€ 40.0	€ 273.3	71%	3500	1575
		Standalone	€ 150.8	€ 79.1	€ 12.9	€ 60.5	€ 40.0	€ 343.3	89%	3500	2800
		DSM + Stand Alone	€ 117.0	€ 79.1	€ 12.9	€ 60.5	€ 40.0	€ 309.6	80%	3500	2800
	80%	Progressive line	€ 110.3	€ 79.1	€ 12.9	€ 60.5	€ 40.0	€ 302.8	78%	3500	2800
		Standalone	€ 150.8	€ 47.4	€ 12.9	€ 60.5	€ 40.0	€ 311.7	81%	3500	2100
		DSM + Stand Alone	€ 117.0	€ 47.4	€ 12.9	€ 60.5	€ 40.0	€ 277.9	72%	3500	2100
	60%	Progressive line	€ 110.3	€ 47.4	€ 12.9	€ 60.5	€ 40.0	€ 271.2	70%	3500	2100
		Standalone	€ 150.8	€ 28.8	€ 12.9	€ 60.5	€ 40.0	€ 293.0	76%	3500	1575
		DSM + Stand Alone	€ 117.0	€ 28.8	€ 12.9	€ 60.5	€ 40.0	€ 259.2	67%	3500	1575
B	45%	Progressive line	€ 110.3	€ 28.8	€ 12.9	€ 60.5	€ 40.0	€ 252.5	65%	3500	1575

Based on this study, we can conclude that cosmetic defect acceptance level is a significant driver to make printer refurbishment more cost attractive. The other way round, looking at proposing refurbished printers looking like new is a significant cost constraint

Next step

- As a follow up activity, the subject matter driving traction from the sales team, it was decided to install an MS8XX refurbished model in a showroom at the Lexmark office in Frankfurt in Germany. The printer is planned to have several small cosmetic defects (like the printers detailed in this activity and shipped to 4 entities) which would be categorized as a "Grade B" refurbished product.
- A specific review was done with a cross functional team composed of marketing, sales, engineering, and manufacturing to share the activity outcome/findings
- The subject matter being of high interest, a pilot of several hundred units is under discussion to be scheduled in the coming months for specials bids purposes.
- In parallel, a cross functional team composed of marketing, sales, engineering, and manufacturing is now working on getting a new set of cosmetic defect specifications to adapt Lexmark offer

As a conclusion, there is a significant positive outcome out of this activity as it will help to maximize the output of refurbished printer out of what is collected by replacing less covers, reduce cost by potentially increasing yield as well as recovering more acceptable parts and therefore swing negative cases to positive and bottom line enhance the Circular Economy

5.6. Promotion of CE in the printer business Lexmark

5.6.1. C-SERVEES project presentation to Competition

On 30th November 2021 Lexmark organized a meeting with the copier manufacturer company, Ricoh. The C-SERVEES project had been already introduced previously and this time the aim was to share practice and ideas related to best Circular Economy practices, to share Lexmark's experience and findings on the project and ask Ricoh to bring feedback/comments within an interactive session. The main topics were the demand generation, EOL product availability and cost to collect/refurbish products.

Demand generation

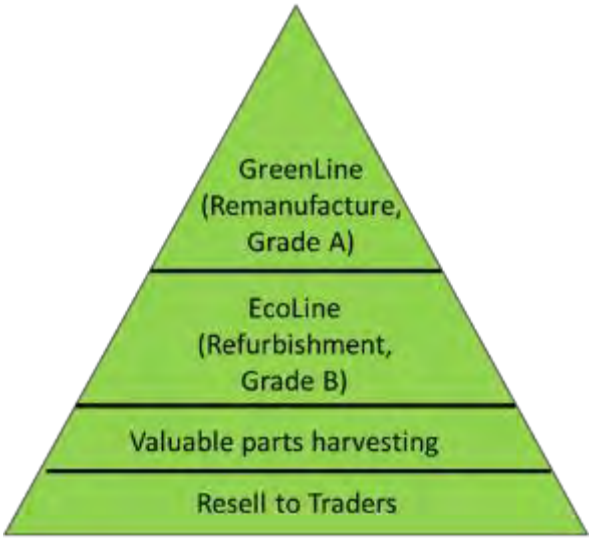
Lexmark conducted a survey with customers (resellers, distributors) which shows that some do inhouse refurbishment on high-end devices, but Lexmark does not have a clear view on what they are doing with them. Based on Lexmark experience and the above-mentioned survey, it appears that very few users return their end-of-life printers (or printers they do not use anymore) to the respective OEMs. Indeed, for various reverse logistic reasons, only few buy-back programs exist, and most customers don't even know about these programs when they exist. Another important topic is the reverse logistic cost which seems to be a significant issue.

Questioning Ricoh on their inflow of "end of life" products for refurbishing, Ricoh does not have buy-back system for low-end copiers (small devices) since the business model is not there yet, the products are too cheap, and their individual parts do not offer enough value even for parts recovery which is consistent with Lexmark view and approach. When Ricoh gets back such low -end device, it sells it as it is to brokers. For other devices, upfront checks are performed and if the device is eligible then it goes to a remanufacture program, if not, Ricoh harvest valuable parts. Bottom line, Ricoh's demand approach" is to only collect units for which there is a demand (currently companies sell what the customer needs, current equivalent is the "pull" approach). Therefore, refurbished products should be aligned with new ones, and sales need to be convinced to sell, but it's a challenge because the sales community wants to provide the best and latest product generation and they mainly have a bonus system for selling new devices. As per Ricoh, the sales team is a key stakeholder, not only they must be convinced that the product offer has the right performance/reliability but mostly, the sales team must be incentivised to sell refurbished products.

Interestingly, Ricoh's market approach for second-hand products is as bellow and Ricoh distinguished remanufactured products (Grade A) offering same performance and warranty than new one and Refurbished products offering potentially lower performance and warranty than new ones

Ricoh has the "GreenLine" remanufactured products offering and the 'EcoLline" offering which are refurbished products.

Ricoh model



Not providing the latest product generation (being new or remanufactured products) disappoints sales representatives and causes frustration. For the sales community remanufactured products are more preferred than refurbished ones. Also, when Ricoh has a product in their current portfolio, they do not put that product to the refurbished section, not to confuse customers who could get a higher performance/quality products (new or remanufactured).

EoL Product availability

The product is considered waste as soon as it leaves the customer. The aim is to increase product return rates and create awareness. Lexmark currently has the LCCP (Lexmark Cartridges Collection Program) LINK 2 platform which aims to facilitate and maximize the return of empty cartridges for the purpose of being remanufactured and the implementation of extending it to printers is in progress (the estimated completion date is in Q1 2022)

Ricoh does not have yet a data driven process. Data exists in various systems, managed by various parties. Ricoh's view is to use artificial intelligence in the future. Data management is the future, it would drastically help minimise the risk of cost loss (e.g., calculating the value of device at the customer place). Now they do what fits the actual customer demand. If no demand, Ricoh does not bring the product back to the factory, if no need, they sell it to brokers.

Cost to collect /refurbish products

Lexmark conducted a disassembly demo with recyclers with the purpose of analysing the financial case of getting the valuable parts harvested quality checked and shipped to the OEM. Through a communication channel the OEM could tell what cost it is willing to give for certain parts. This could not only enhance circularity but also be a positive business case of cost reduction. An additional help could be to use a list of valuable parts,

dismantling manual and colour codes on components. This would require a recycler significant change in term of skills and processes.

Collection platforms reduce the collection cost. Ricoh has a collection program called RAM (Ricoh Assets Management System). They do not give instruction what is valuable, since the resellers, dealers already know what is valuable. Ricoh has a collection program in place for its valuable devices, this program targets Ricoh's dealers/resellers. To the question: do you think recyclers can be a player here, Ricoh's view is that recyclers mostly get only what dealers/resellers don't want and they are the one who knows what has value, therefore the likelihood for recyclers to get valuable device is low, at least for Ricoh's product line

Lexmark investigated 3D printing as a possibility to cut costs, but the test showed processing a part with 3D printing is too expensive and the quality is not acceptable. Ricoh does not use the technology either, they rather harvest other devices. They see a future for 3D printing, but not in 2022.Ricoh's view is that as long as virgin plastic is relatively cheap there is no business case for 3D printing in the Imaging Equipment industry.

Within the C-SERVEES project Lexmark used recycled material from different sources. Ricoh agrees that in the future it would be worth to invest to recycled resin. Recycled products will be preferred, and a "green scoring" approach could be used like in the food industry.

The main challenges are the labor costs, the volume (few products drive higher costs, more products drive lover costs) and the automatization (which can be applied e.g., in quality check).

5.6.2. C-SERVEES project presented to a "resource recovery" actor in the industry.

In the background of our C-SERVEES project and the conclusion of our previous work (reported in deliverable 4.3, see 5.1.1 section 4) related to dismantling at recycler's location "but would require recyclers to adapt to such new activity", we had the chance to interview Tom Ogonek and David Blaine, respectively CEO and Sales Director at Close the loop (Ctl), a Lexmark supplier used to recycle toner and laser cartridges in Europe and well as in North America and Australia. While Lexmark uses Close the loop as a recycler, it is much more than a simple recycler. Tom Ogonek would describe the company as a Resource Recovery company.

The company started with recycling capabilities, setting up expertise in recycling laser cartridges under control atmosphere/water to avoid explosion risk when shredding such products.

Having the expertise developed and proposed to laser cartridges OEMs, Ctl quickly proposed additional services, quite similar to the Lexmark Cartridges Collection Program (LCCP, see more details on Lexmark.com) processes. Indeed, Ctl contracts with OEMs or large distributors to collect used products and manages the entire reverse logistic (procuring, delivering, and collecting collection boxes) to then sort and process

cartridges. Ctl then provides their OEM customers with sorted and clean products, spare parts as well as proper recycling service for products which cannot be reused.

The business model is quite different from standard recycler ones. Indeed, Ctl does not receive all kind of WEEE products mixed, which is what classic recyclers like Indumetal and Greentronics (C-SERVEES partners) manage, instead, Ctl manages the reverse logistic, including product sorting and disposal on behalf of OEMs and large distributors. Motivation of Ctl customers being to enhance the Circular Economy in their sector with all associated benefits.

As stated above, the model presents significant similarities with Lexmark LCCP program, main difference being that Lexmark subcontracts the reverse logistic to a third-party forwarder and manages the sorting internally.

The key point here is that those models (Ctl and Lexmark ones) are pretty effective and drive OEMs to collect their end-of-life products and get them remanufactured or properly recycled as appropriate and therefore enhance and boost the Circular Economy of this sector.

Ctl service is of course coming at a certain cost for their customers. Are their customers able to offset the cost with the Circular Economy benefits (mainly products and parts recovery)? This information is not available, but we estimate they are not yet able to fully offset the additional circular economy related costs.

Specialized in printing cartridges (both ink and laser technologies), Ctl has recently diversified with cosmetics, eyeglasses, and cell phone case products and as per their representatives, much more to come. For these diversifications, Ctl manages the reverse logistic as well as the recycling.

We presented C-SERVEES project to Tom and David asking for their view.

The key point, to be cost effective is (as in many industrial processes) and remains volume.

What the future will/should be in this field?

As we have seen in the C-SERVEES dismantling activity, getting products which can bring value for OEMs at conventional recyclers is a challenge for both cost and availability reasons. Therefore, actions should be taken upstream to ensure proper packaging and handling, having OEMs to organize separate collection of their used products is certainly an interesting path.

5.7. Use ICT to enhance printer's circularity during the end-of-life phase

5.7.1. ICT Smart Questioning

Circularise, Lexmark and its supply chain partners carried out a second demonstration to test the Circularise ICT platform, in this case the Smart Questioning functionality. Previously the tracking and certification of recycled plastic material was demonstrated, see detailed in Deliverable 4.3. The aim of the Smart Questioning tool is to offer a possibility for the suppliers to communicate their material data safely to their supply chain stakeholders. Since the platform is based on blockchain technology, all data are stored decentralized on the company's own servers, and this allows to communicate and share data in a safe manner. Material data knowledge can increase circularity and for this reason sharing information through the supply chain actors is an important factor.

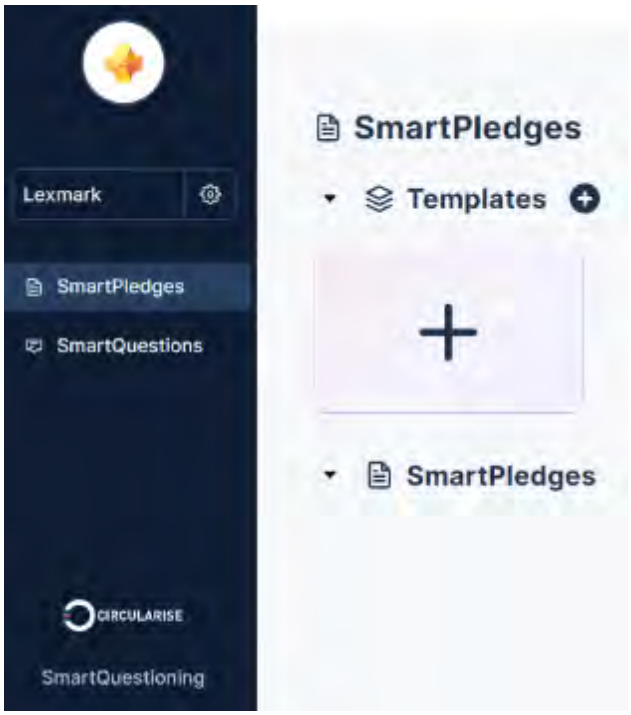
The main goal of the demonstration is to put material data of the supplied component on the data management system and be further traced along the supply chain. The system is based on the idea that everyone is responsible for their own data and product information and ideally not only direct suppliers would be brought in the system but also suppliers in previous product stages. In the demo Lexmark has been testing the platform together with 3 direct suppliers.

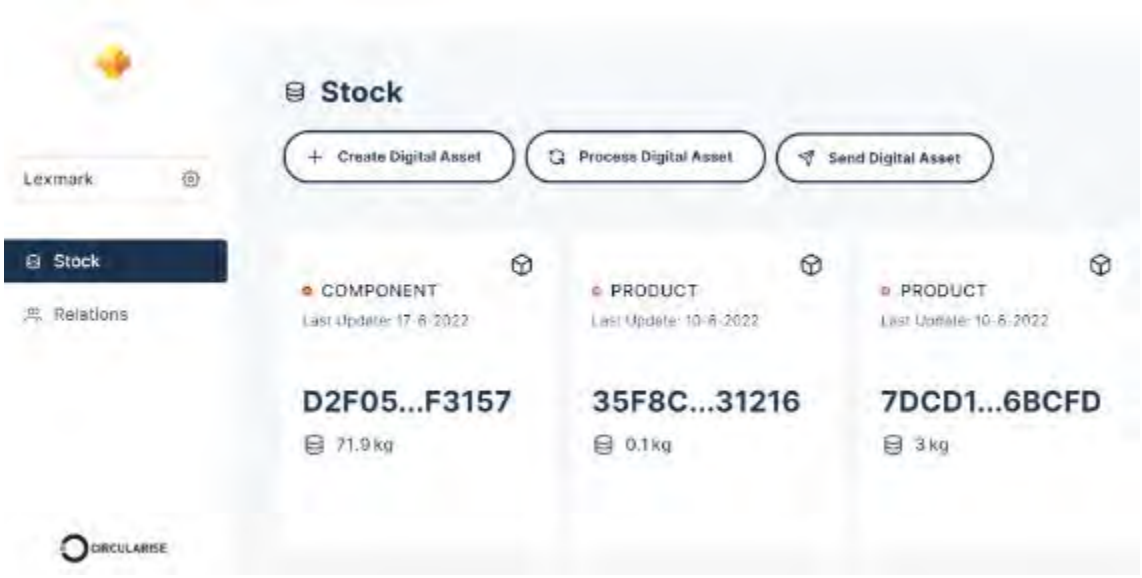
The Circularise dashboard has two elements. To keep the data 100% safe, the dashboard has a public and a private interface. The public system is connected to the blockchain and communicates data. In the private one the supplier is able to create encrypted pledge about the material which means here a lot of specific material and component information needs to be added and then an encrypted link will be created which reflects to the whole material information without actually showing them and then it is possible for people to ask questions about materials. As a first step the supplier needs to enter data to the private system where so-called Smart Pledges have to be created, which makes the data unreadable for a human. These are unique fingerprints of the product. The Pledges have to be downloaded from the private interface and then to be uploaded on the public one and creating new digital assets, basically crating the material with the related weight. On the public dashboard the exact component or material name is hided as the below picture shows it only has a unique identification number and a group name if it is a component or assembly etc. The supplier and its customer make relation on the platform and the supplier will be able to send certain amount of digital assets to the customer which reflect to the products provided to the customer. The customer then uses the received data to create the new assets produced on the next product stage and add their own material data then with the same methodology send the encrypted data to their customers. The last actor in the product supply chain is going to create the finished product in the system.

The input needed from the participants is a material list with chemical elements or materials that has been added in the production at their supply chain stage. Then participants can ask questions about the material existence in other participant's material list and get information about the quantity range. For example, they can ask whether the product contains Aluminium and if yes what range of quantity (e.g., 3-10 g) and suppliers

of the various components can answer if the products contain that specific material or not and if yes, what is the range. The person who receives the answer will also get proof that the answer is correct without ever seeing any confidential documents like a bill of material which is proof of truth.

To be aligned with the recycled resin demo tracked by ICT tool, Lexmark has identified the suppliers which are plastic, carton packaging and label providers for the cartridge model which Lexmark used for the previous ICT demo activity. After introducing the subject matter, the three suppliers of Lexmark have been asked to provide a material list which they are comfortable to share within the demo. They created their own accounts on the Circularise platform. Separate meetings have been organized with each of the participants to go through the steps on the platform and do a demo to test how the Smart Questioning function works with real data. For the time being two suppliers have created the Smart Pledges based on their material data communicated and sent the encrypted items to Lexmark. As the next step the same data entry needs to be done with the third supplier and then in a joint Smart Questioning demonstration with all the three suppliers, questions of materials will be possible to ask through the system.





QR code

Another activity what Circularise has carried out is creating QR code which contains several useful information and pictures about Lexmark products, link for the Lexmark sustainability webpage and a link for a short video of the LCCP program. By scanning the QR code, the user will easily have access to the informative webpages about product, processes or anything Lexmark would like to communicate to its customers, stakeholders.

5.7.2. Information Exchange Platform

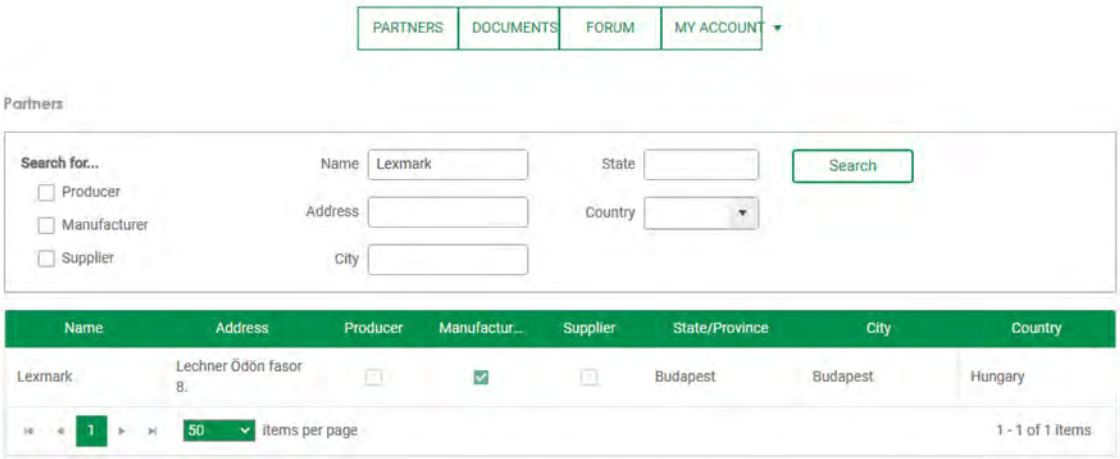
Soltel has developed an Information Exchange Platform where registered users can have access to documents and to information shared by other companies. The main objective is to enhance the circularity by enabling the companies and different actors to share and have access to useful information about products, processes, services etc. (eg. installation guides, manuals, process descriptions…)

On the login page it is possible to register a “user” account or a “master” account. Companies need to register a master account to be able to share documents, see other registered partners and make associations with them. By registering a “user” account the user will register not as a company but as a private person and will have access only to the publicly shared documents. The registered companies need to give basic information about their organizations like address, name and if they are a producer, manufacturer or supplier and this info makes it easier to search for the different companies afterwards among all users. Companies can send association requests to each other, confirm it, and this way everything which they share publicly or privately, will be available and can be downloaded by any associated partner. For non-associated users only the publicly shared information will be visible. When users want to upload a file or a quick guide, they can select public or private way of sharing. When adding a new document, the user needs to give the file name, descriptions, add labels which makes the file more identifiable when someone is looking for a topic. It is possible to create a quick guide which is a step-by-step process description, for example how to remove a cartridge from a printer. A title,

short description, introductions need to be added, and the user can attach pictures to illustrate the different steps and make the process more understandable. Users can leave comments related to the documents or quick guides which help to collect remarks, feedback, questions from other actors. Another useful function is the Forum, where all questions are listed, and anyone can publish new topics or search for keywords. The questions can be answered, and the answer can be marked as a "solution" in case it was fully useful for the interested users and can also be "liked" by anyone.

In the demonstration, Lexmark, Gaiker and the two recycler companies Greentronics and Indumetal have registered accounts on the information exchange platform. All accounts have been registered as "master" accounts which means companies are able to search for each other and send association requests. By accepting the requests, companies get connected and will have access to all documents uploaded by the associated company, either to public or private data. Within the demo the users tested the different functions of the platform. They made associations, shared different extension of documents (e.g., PDF, xlsx, docx), created quick guides, used the Forum function. The platform offers a quick and secure way to share and access information through the supply chain and can be used as a repository to ensure the users have access to the latest version of a given document instead of storing them on computers and manually sending updated versions for example vis e-mail It lower the risk of using obsolete version or invalid data. For example, a dismantling manual can be updated time-by-time based on recycler's inputs and recommendations and can be shared on the platform so other recyclers could have access to the updated version of the documents which makes the dismantling process more efficient.

A recommendation to improve the platform is to have a possibility to share information with only selected users, since currently if a user wants to share a document, all associated parties will have access to it. For example, if Lexmark wants to share a dismantling manual only with recycler partners, then any other, maybe not preferred associated partner is going to have access to it.



5.7.3. Reverse logistic ICT platform

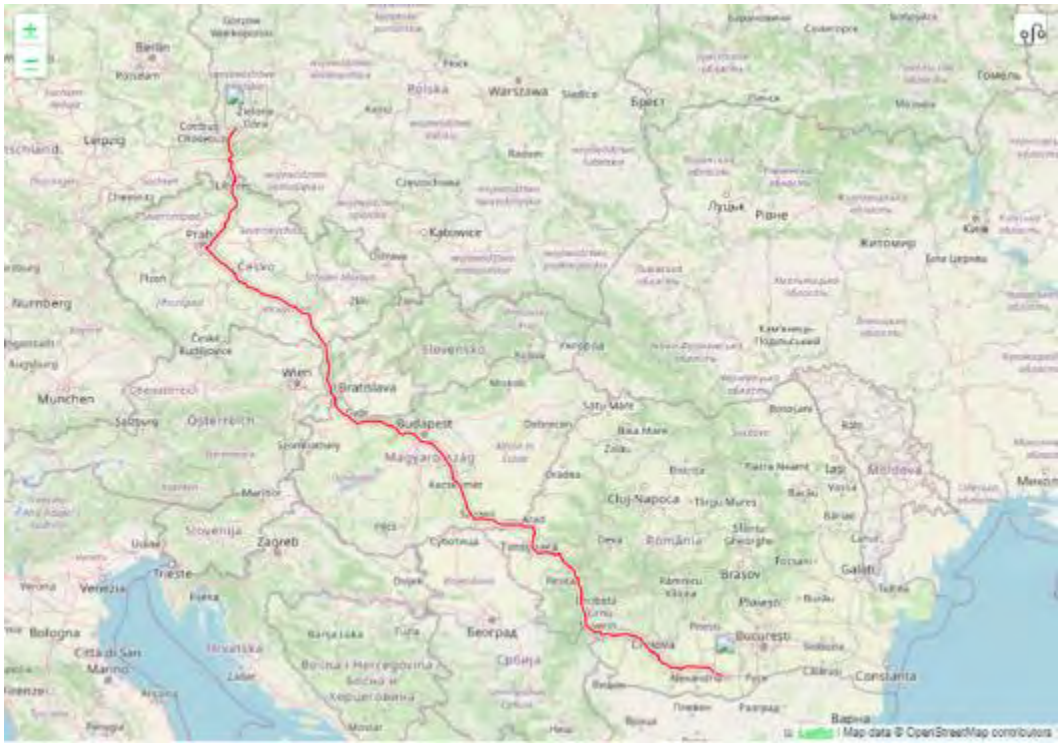
The logistic platform developed by RINA-C aims to optimize the sustainable and cost-effective transportation of WEEE from the collection points to the treatment/recycling sites and to manufacturers for re-use the recovered material. Inefficient management of the reverse logistic makes the circular economy business less attractive, improving it is a key element to support the CEBM. The platform aims to enhance the circularity by offering a cost-efficient and environmentally beneficent management of waste transportation.

The platform calculates the best route between several pick-up addresses and the final destination. It shows the delivery time, distance, air pollutant emissions like CO2 (kg), NOx (kg), PM10 (kg), number and type of trucks needed, and also takes into account the preferred shipment date. The tool lists a combination of possible paths between the addresses and displays them on maps. By optimizing the transport between locations, the related costs and emissions can be reduced.

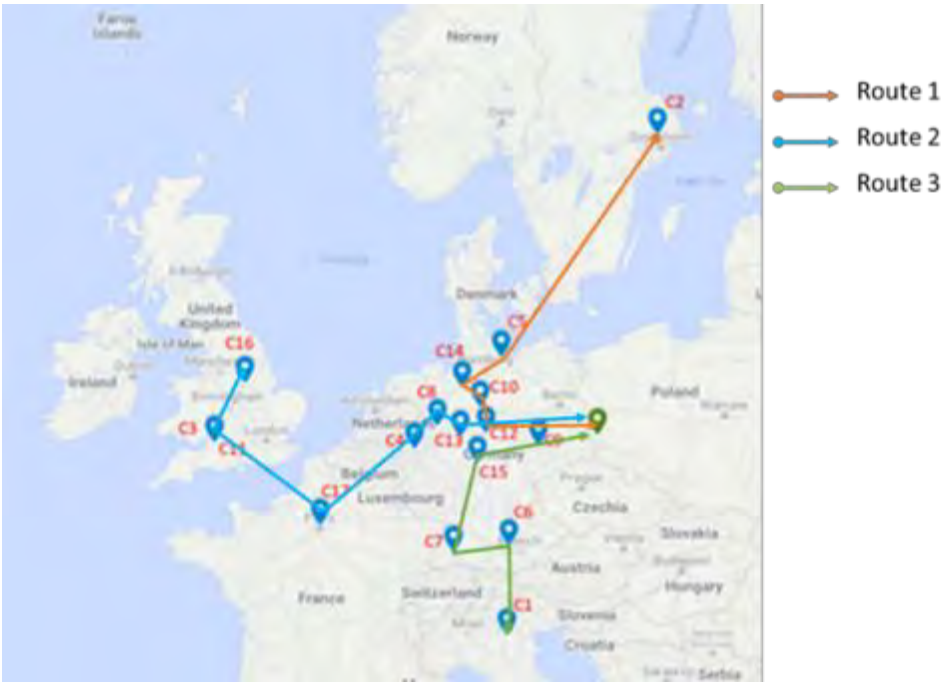
Currently Lexmark has a business model where end-of-life products are collected separately from the different locations. Whenever Lexmark receives a take-back/ buy back request, the transportation of used goods is arranged in the following few days and does not apply consolidated shipments. Mostly the customers do not have storage places or have storage costs and want the products to be shipped as soon as possible. Further investigation is needed to assess customer's openness to align the transportation requests and make consolidated shipments which could be a more cost-effective way of reverse logistic but on the other hand the lead time can extend which might be not favorable for the associated parties.

Previously Rina-C and Lexmark have carried out a demonstration on the reverse logistic ICT platform, assessing the best route offered by the tool in case of 4 pick-up locations with the destination of Zary, Poland (see in D4.3). As an extension of the demo, two more activities have been carried out to widely examine the tool.

The first activity is linked to the spare part recovery demo with recyclers where the main objective was to dismantle the printers and recover predetermined valuable parts which then have been shipped to Syncreon, Zary for further examination and to compare different business cases (see in section 5.1). Based on the transport details (parts, weights, pick-up address, destination address), the Rina-C platform calculated the best route from Greentonics, located in Romania to the re-manufacturer company Syncreon, Poland. Rina-C provided a comparison of the actual transportation route, the route suggested by Google Maps and the route calculated by the platform. The outcome was that the actual transport took for 21h and 1632 kms, the route suggested by Google Maps shows 17h 30 mins and 1512 kms and the Logistic Platform calculated 19h and 1521 kms.



A second activity was carried out to test the platform with more data and get a more representative result on how the platform connects and calculates the best routes between several addresses and the destination. Lexmark provided transport details based on 17 pick-up requests from customers who wanted their end-of-life products to be taken away. The preferred collection dates are fictitious but all other information like weights, number of products, model type, number of pallets are real life examples. The majority of the collection locations are in Germany, but there are some addresses in the UK, Sweden, Italy and France. The final destination is Syncreon, Poland.



In a first scenario the platform calculated the best routes with the less CO_2 emission. One route has the collection points of Company 2-5-14-10-12, the second route has Company 16-11-3-17-4-8-13, and the third route has Company 1-6-7-15-9. Results are reported in the following figure and in the Annex.

In a second scenario the best routes were calculated according to the availability of printers. Based on the product availability the companies have been categorized into 3 groups. In Group1 there are available products at Company C 2-5-14-10 and C 11-17-1. For the transportation 2 trucks would be needed. In Group 2 there is Company 4-13-15-12-9 + 6, for this solution also 2 trucks are needed. In Group 3 only 1 truck is enough to collect products from Company 16-3-8-7. Results are reported in the following figures and in the Annex.

1° Group: Availability of products 13-19 May

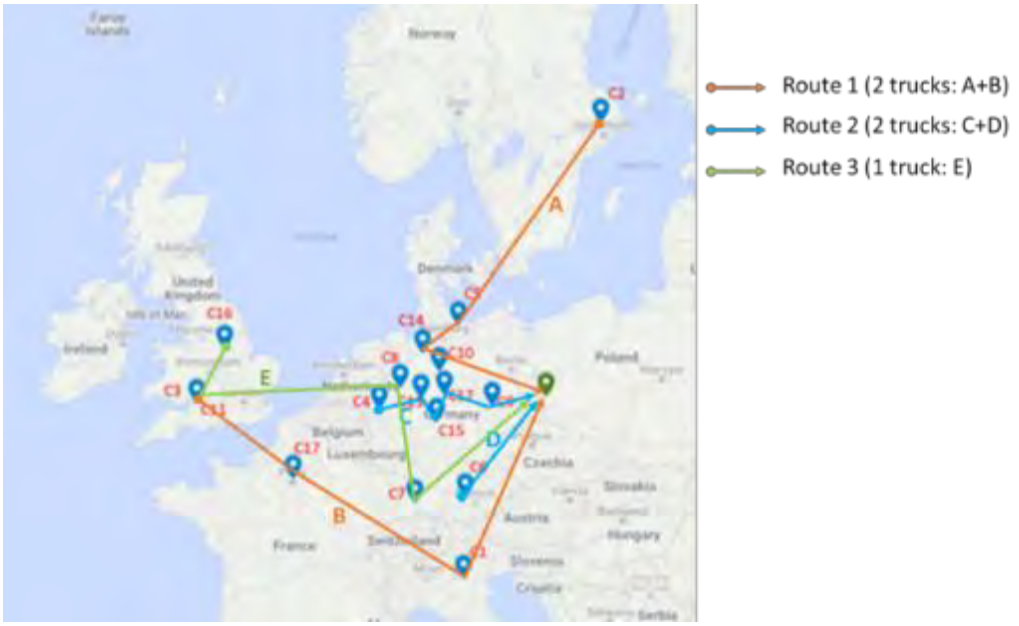
Supplier name	Preferred pick-up date	City	Country
Company 5	13/05/2022	Lübeck	Germany
Company 10	16/05/2022	Langenhagen	Germany
Company 1	17/05/2022	VERONA	Italy
Company 11	17/05/2022	BRISTOL	UK
Company 17	17/05/2022	SAINT DENIS	France
Company2	18/05/2022	Arlandastad	Sweden
Company 14	19/05/2022	Weyhe	Germany

2° Group: Availability of products 23-25 May

Supplier name	Preferred pick-up date	City	Country
Company 4	23/05/2022	Neuss	Germany
Company 6	23/05/2022	Ried	Germany
Company 12	23/05/2022	Northeim	Germany
Company 9	24/05/2022	Leipzig	Germany
Company 13	25/05/2022	Lichtenau-Atteln	Germany
Company 15	25/05/2022	Niederaula	Germany

3° Group: Availability of products: 26-31 May

Supplier name	Preferred pick-up date	City	Country
Company 3	26/05/2022	BRISTOL	UK
Company 16	27/05/2022	Mansfield	UK
Company 7	30/05/2022	Villingen-Schwenningen	Germany
Company 8	31/05/2022	Münster	Germany



In the scenario of "the best solution to minimize CO_2" the total distance was 5725 km with 4414 kg CO_2 emission, which is 33% less than in case of the other scenario where the best solution was calculated according to the product availability. It was 8484 km and 6541 kg of CO_2 emission and in total it took 10 hours more. It shows that the calculations of consolidated shipments which focus on the emission efficiency, in total take less transport time, shorter distance, and reduce emissions, however the customers may need to wait longer time to have their used goods shipped.

A comparison has been made between the current business model **"single shipments to Zary"** in red in the bellow table and the two consolidated scenarios calculated by the logistics platform (calculation of the best routes in term of the less CO_2 emission and based on printer availability) in yellow and green.

Currently Lexmark and its reverse logistic partner organize single shipments for each pick-up request they receive. Lexmark receives requests from different countries, different locations and it is not predictable from where, when and with what number of products. The destination in all cases is Poland where Syncreon (Lexmark manufacturer) is located. For the time being it is not possible to synchronize the different transportations since the locations and volume of requests and are not known in advance and the customer expects the products to be shipped within few days.

Comparison between single shipments and consolidated scenarios

17 pick-up locations	Single shipments to Zary	Best consolidated solutions to minimize CO2 TOTAL	Best consolidated solutions according to the availability of printers TOTAL
Total CO2 (kg)	10822	4414	6541
Total distance (km)	14036	5725	8484
Total delivery time	6 days 5:15:18	2 days 15:32:22	3 days 20:18:05

The best solution in term of CO_2 emissions, distance and total delivery time is the scenario which does not consider the pick-up dates (marked in green) and assumes the customer does not have an urgent demand to ship the goods, this way the tool can calculate the best possible routes among the locations.

In case the platform calculates with the desired pick-up dates and apply consolidated shipments, the emissions, distance, and delivery time increase. Based on preferred pick-up dates, 3 groups have been created in this scenario and the yellow column shows the summarized numbers. These values are a bit higher compared to the other consolidated scenario.

The numbers are significantly higher in case of single shipments as locations are not connected, the transportation is direct between the pick-up locations and the destination. This way the transportation of goods is organized immediately when Lexmark receives a request and in few days the carrier picks them up. Generally, the customers are not able to store the used devices and because of unpredictable volume of requests Lexmark applies the single shipment reverse logistic model which has more than double CO_2 and other emissions compared to the scenario with the least CO_2 emissions. Total distance and delivery time are much higher and therefore the related costs are higher too. If the distance and delivery time is longer more fuel is needed, the cost of human resource increases, and other additional factors can increase the expenses which is directly related to extra kilometers. For example, in this demo case instead of 17 trucks for the 17 pick-up locations, only 5 trucks could be enough if the shipments are consolidated, and we assume that the customer accepts longer storage time at their premises until their goods get shipped. With consolidated reverse logistic business model thousands of kilograms of emissions could be avoided and with optimized distances between locations the related expenses could be reduced.

Conclusion

The all-over conclusion of the reverse logistic platform demonstration is that the tool could be a good help to calculate best routes, optimize CO_2 and other emissions in case of several pick-ups within a shorter period with addresses relatively close to each other, however the current business case shows that it is not worth to wait several days or weeks to organize consolidated transports since it is not predictable from which locations Lexmark will receive the pick-up requests and timing is also an important aspect. Lexmark generally gets 20-25 take-back/buy-back request from different countries. The customers usually have limited storage places or have increased costs by storing the products and prefer to get them transported the soonest. The tool worked well with several theoretical pick-up locations, which were mostly on the territory of Germany, but here we need to assume that the customers accept longer time to store the products until they get shipped within consolidated transport, but for the time being it is not feasible. To fully take advantage of such reverse logistic tool, the company which wishes to implement it to their business, should get more TB/BB request from customers and change to a business model where consolidated shipments are arranged, taking into account that the customer cannot store the goods for long and needs to be picked-up in a short timeframe, this last point maybe a paradigm which needs to be revisited. Therefore, a key element is to increase the number of printers collected back from customers which would also support to enhance the refurbished business. Automatized or semi-automatized collection platforms, like the Collected by Lexmark platform (summarized in D4.4) could facilitate the collection processes and could increase the volume of collected products.

6. ALM products demonstrator

6.1. Extension of the lifetime optimisation analysis

During the last phase of the C-SERVEES project, we extended the analysis on the use-phase-over-production-phase GWP ratio UPR_{10} to EEE other than ICT equipment. This covered a TV set, a washing machine and a B2B laser printer from the project partners. It further covered different EEE where we could find the necessary LCA data (use phase energy or emissions plus production-phase emissions). This comprised

- Class A+ refrigerator (Electrolux ERB3105)
- Data-center storage device (Seagate SP2584)
- Hard-disk drive (HDD, Seagate Savvio 10K.5)
- Server (Dell R740).

Where applicable, we varied the respective device's utilization to emphasize the influence of device utilization. This holds for the TV set, the washing machine, and the server. For the B2B laser printer, we used the target utilization according to the manufacturer's specifications. For the remaining equipment, utilization was determined already, e.g., by the default 24/7 always-on use mode.

Similar to the ICT equipment that was described in a previous deliverable (D4.3 Demonstration of distribution and use phase for target products) already, we also investigated the influence of the electricity emission factor. For equipment where replacement for reason of increased energy efficiency was clearly advisable when using grid-mix electricity, we repeated the analysis with 100% renewable energy (RE) to verify if replacement was still advisable. The latter was the case for our TeraFlex system as already described in Deliverable 4.3.

6.1.1. Recap

In order to generalize our analysis and the consideration if and when products should be replaced by more efficient successors, we defined the **U**se-phase-over-**P**roduction-phase **R**atio UPR_{10} for the GWP:

$$UPR_{10} := \frac{\text{GWP of the first 10 years in the use phase}}{\text{GWP of the production phase}} \quad (1)$$

UPR_{10} is the ratio of 10 years use-phase GWP (global warming potential) and the production GWP according to LCA. *The first 10 years* in use shall be considered since over time, the use-phase GWP decreases due to improving emission factors. We consider 10 years of use to allow certain averaging of the emission factors and sufficient time for successor product generations to be developed.

The main reason for the restriction of UPR_{10} to the GWP – which is not necessarily the most relevant LCA midpoint parameter in the CE context – is the similarity of the results for GWP and abiotic resource depletion (ARD) in LCA. This similarity, i.e., use-phase dominance for both, GWP and ARD, can be found for almost all LCAs that we conducted in the past years. It means that GWP can be considered a suitable measure also for resource depletion.

UPR_{10} does depend on the applicable emission factors. Due to the fact that emission factors for grid-mix electricity and renewable energy develop differently, UPR_{10} cannot be normalized to the emission factor. Instead, it has to be calculated for different emission factors separately.

In general, products with UPR_{10} **clearly** below 4 (grid mix) or **clearly** below 0.9 (RE), respectively, do not require replacement. Products with UPR_{10} **clearly** above 4 (grid mix) or **clearly** above 0.9 (RE), respectively, do require it. Products with UPR_{10} near the crossover values 4 (grid mix) or 0.9 (RE), respectively, should be analysed in more detail to identify the optimum replacement scenario. Similar considerations hold for the preference on energy efficiency in ecodesign. Products with high UPR_{10} require consideration of energy efficiency first, followed by circular-economy consideration. For products with small UPR_{10}, it is vice versa.

UPR_{10} may have an influence on the choice of the most-suitable product-service system (PSS) as the supporting CE business model. In cases of very high UPR_{10}, it may be beneficial to select a PSS that supports (improvements of) operational efficiency, namely energy efficiency. In turn, certain PSS can have a strong influence on UPR_{10}. In particular, PSS that aim at substantially improving product utilization, e.g., by better sharing, may also lead to substantially increased lifetime energy consumption, thus increasing UPR_{10}. In these cases, it should be checked whether the respective products need to be replaced because of energy-consumption reasons after certain periods.

6.1.2. Laser printer

The first application example of UPR_{10} beyond our ALM and TeraFlex products is an MX826 laser printer manufactured by project partner Lexmark. This printer is intended for B2B applications. We used the manufacturer's specifications for our analysis. The printer is an example of ICT *end-user* equipment.

The *maximum* duty cycle for this machine is 350,000 pages per month.

With production GWP of 446 $kgCO_2e$ and average lifetime power consumption of 20 W, UPR_{10} = 1.22 results. This indicates that the printer should never be replaced for reasons of energy efficiency improvements. This is confirmed in the detailed analysis in Figure 26.

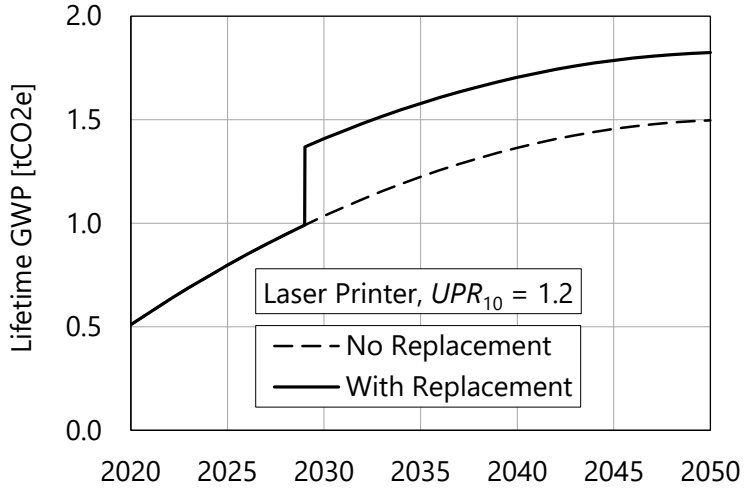


Figure 26. Lifetime emissions of B2B laser printer. Grid-mix electricity was used here.

Obviously, the replacement scenario never matches the no-replacement scenario, which confirms that replacement is not advisable.

We used efficiency gain here that deviated from the one used for our ICT equipment in D4.3. The efficiency gain for the laser printer is slower, it is based on data from the laser-printer manufacturer. Yearly gain started at 2% and is decreasing over time in a way similar to the one for ICT equipment. This leads to an efficiency increase of 10% after 10 years, according to the manufacturer. The typical lifetime of these printers is smaller, it is around 5 years. From LCA and energy viewpoints, it could be given longer life.

We used average (EU) grid-mix electricity emission factors for the results of Figure 26. We did not repeat the calculation with 100% renewable energy and lower resulting emission factors since the result already indicated that replacement is not advisable. This would only become even clearer when using renewable energy.

It has to be noted that a substantive part of the total printer's lifetime GWP must be assigned to the paper it prints. Over the lifetime, the printer prints ~4,000,000 pages (it does not continuously work at maximum duty cycle). This equals ~20 tCO_2e of GWP. It means that ~90% of the printer's lifetime GWP are determined by the paper it prints. We did not consider this here due to the assumption that in both cases (with and without replacement), the number of printed pages is the same.

6.1.3. TV set / flat-panel monitor

The next example for ICT end-user equipment is a flat-panel TV / monitor. We used the specifications provided by the project partner Arçelik.

The production GWP of this device is 226 $kgCO_2e$. We started our analysis with an average power consumption of 6.1 W, which equals an average utilization of ~2.5 hours per day. In that case, UPR_{10} = 0.73 results, which clearly indicates that again, no replacement for reasons of energy-related emissions should be done. This is confirmed in the detailed analysis in Figure 27.

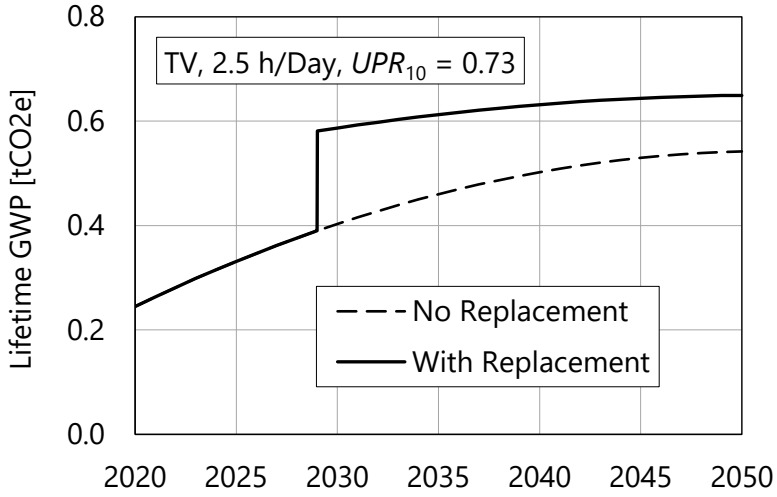


Figure 27. Lifetime emissions of TV running 2.5 h/day (grid-mix electricity)

Again, we used average (EU) grid-mix electricity emission factors for the results of Figure 27. We did not repeat the calculation with 100% renewable energy and lower resulting emission factors since the result already indicated that replacement is not advisable.

The utilization of 2.5 hours per day is relatively small, it may be valid in many private households. However, very similar flat-panel technology is also used in commercial applications, displaying information over much longer daily periods. Therefore, we increased daily utilization in three steps to analyse the impact of increased utilization. As noted in the Recap chapter, such increased utilization might result from certain PSS.

In the first step, daily utilization was increased to 9 h. This resulted in an average power consumption of 22.8 W and UPR_{10} of 2.73 for grid-mix electricity, assuming that production GWP stayed stable. This is relatively close to the UPR_{10} crossover range between replacement and non-replacement scenarios. The detailed analysis is shown in Figure 28.

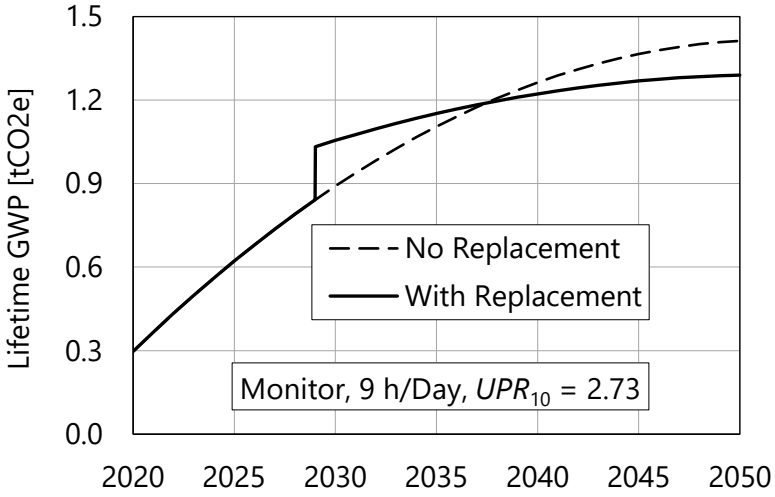


Figure 28. Lifetime emissions of monitor running 9h/day, grid-mix electricity

The analysis shows that replacement becomes GWP-net-positive after less than 10 years. We used the efficiency gain that was already used for the ICT infrastructure equipment, as derived in D4.3. The reason is that very similar (semiconductor) electronics are used.

Using grid-mix electricity led to replacement for energy-efficiency reasons being advisable. Therefore, we also investigated the case of usage of 100% renewable energy with very small emission factors as discussed in D4.3. This reduced UPR_{10} to 0.35. The resulting analysis is shown in Figure 29. For renewable energy and utilization of 9 h/day, replacement is not (yet) advisable.

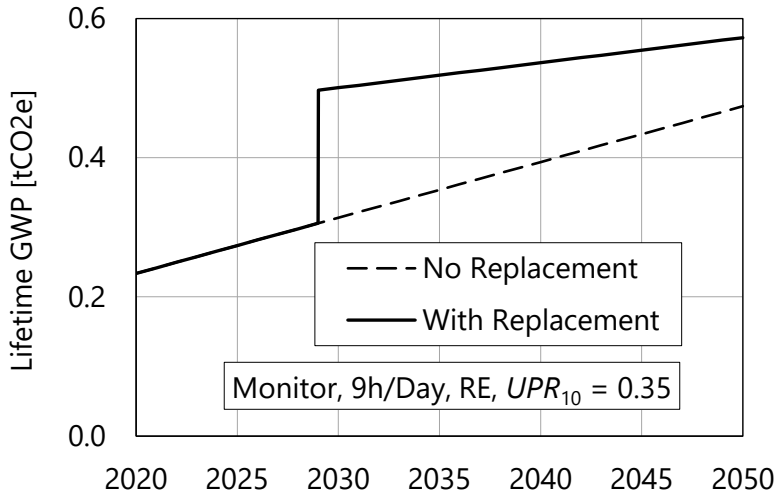


Figure 29. Lifetime emissions of monitor running 9h/day, renewable energy

Next, we changed the daily utilization up to a value of 18 hours per day. This changes average power consumption to almost 46 W, which increases UPR_{10} to 5.46 for grid-mix electricity. This indicates that for this energy type, the device should be replaced for GWP-optimization reasons, which is confirmed in Figure 30. Here, we also investigated two replacement scenarios. As can be seen, the use phase is now so dominant that even a second replacement at least needs to be considered.

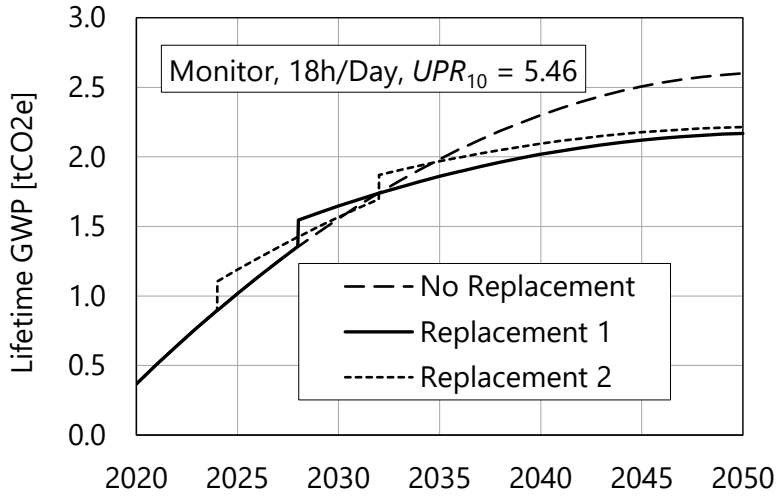


Figure 30. Lifetime emissions of monitor running 18h/day, grid-mix electricity

We repeated the analysis for usage of 100% renewable energy. Because of its dependence on the emission factor, this changed UPR_{10} to 0.71. The result is shown in Figure 31.

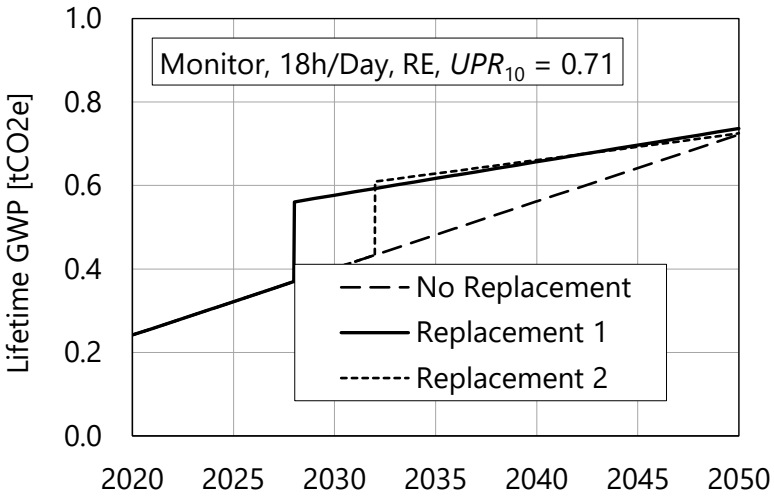


Figure 31. Lifetime emissions of monitor running 18h/day, renewable energy

Now, replacement after around 20 years makes sense even when using renewable energy. Note, however, that the energy-efficiency gain decreases over time due to certain physical limitations, as described in D4.3. Also note that the curves in Figure 31 can be linearly extrapolated since the emission factor for renewable energy is constant, as also described in D4.3.

Finally, the utilization of the monitor was increased to 24/7 always-on. This increased the (average) power consumption to ~58 W, which leads to an increase UPR_{10} to 6.96. This clearly indicates that the device, at this utilization, should be replaced, possibly even more than once (similar to the TeraFlex system). This is confirmed in Figure 32.

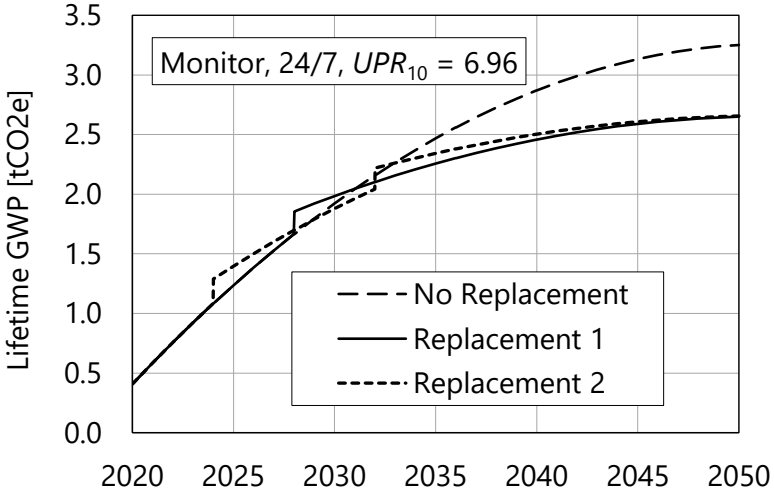


Figure 32. Lifetime emissions of monitor in 24/7 mode, grid-mix electricity

Now the two replacement scenarios – one vs. two replacements – achieve the same result in 2050. Beyond, the two-replacements scenario would achieve the better results. According to our assumptions regarding the efficiency gain (gain saturates and finally comes to an end around 2050), a third replacement would not make sense unless new, disruptive developments regarding the energy efficiency can be exploited.

The result for 24/7 utilization and the usage of renewable energy is shown in Figure 33. Now, UPR_{10} increased to 0.90. It can be seen that replacement after 8 or more years reduces total-lifetime emissions. Earlier replacement is not advisable since the gain in energy efficiency is too small.

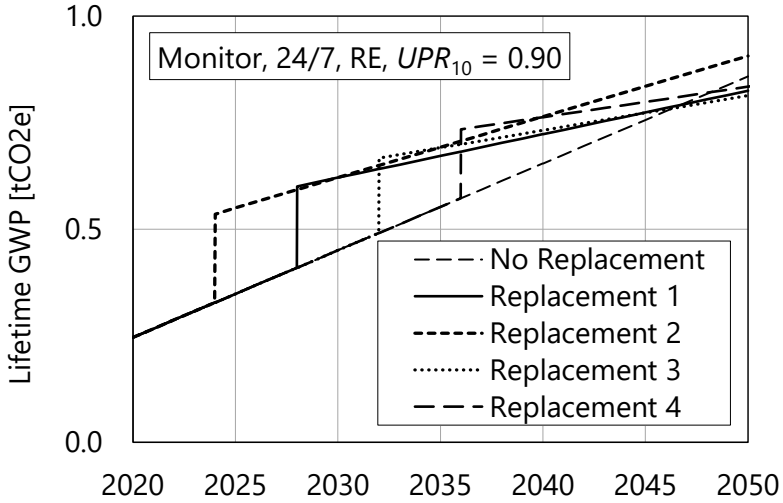


Figure 33. Lifetime emissions of monitor in 24/7 mode, renewable energy

Unlike the older analysis in D4.3, we also decreased the production GWP in all cases described in this document. Compared to constant production GWP this is closer to reality since production processes will also produce less emissions over time following the broader use of renewable energy, more efficient processes and the emission gains of recycled material over virgin material.

In our studies, we used a decrease in production GWP of 8% per every 4 years. This is regarded conservative since production in 2050 would still produce severe emissions.

The increase of the daily utilization of the monitor as described above and its impact on GWP and lifetime optimization or limitation is an example of the PSS discussion at the end of the Recap chapter. If PSS are applied that intend to increase utilization in order to reduce material intake, it should be checked if replacement might make sense for total-lifetime emission reduction.

6.1.4. Washing machine

The next EEE example that we analysed was a washing machine from project partner Arçelik. The production GWP was specified to 355 $kgCO_2e$. In a first utilization mode, the yearly energy consumption was specified to 148 kWh, which equals an average (!) power consumption of 16.9 W. This results from relatively low utilization, which can be found in medium-sized households. Therefore, it results in a UPR_{10} of 1.39 for average EU grid-mix electricity. This value indicates that at the given utilization and electricity emission factor, replacement for reasons of energy efficiency should not take place. This is confirmed in the diagram in Figure 34.

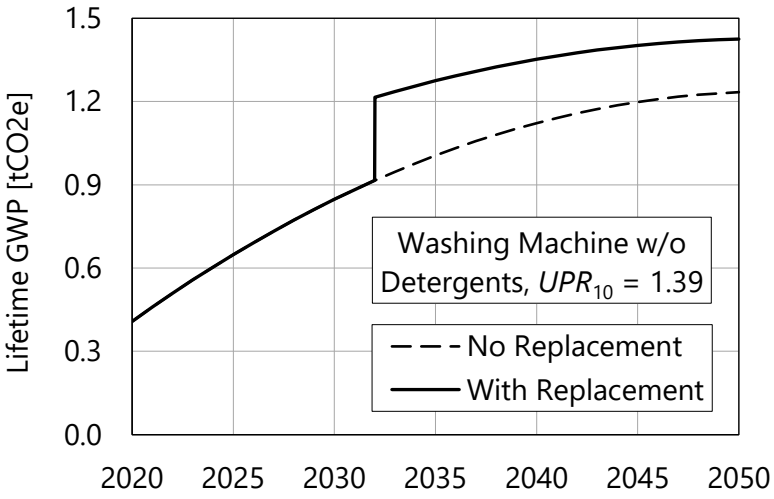


Figure 34. Lifetime emissions of washing machine at low utilization

Note that we did not consider the detergents. The assumption is that the amount of detergents is the same for both scenarios. (This is similar to not considering the paper for the laser printer.)

For the washing machine, slower energy-efficiency gain compared to the infrastructure ICT equipment was used. The reason is that total energy consumption (and hence, consumption reduction) is less dependent on semiconductors. It is rather driven by heating water, where efficiency gain is assumed to be slower. The yearly gain starts with 6.5% and flattens toward zero in 2050.

Next, the utilization of the washing machine was increased by a factor of 5. Such a utilization can result, e.g., from shared usage in respective PSS. The increased utilization increased the average power consumption to 85.6 W and UPR_{10} to 6.51 for the case of using grid-mix electricity. This clearly indicates that replacement now (at high utilization) is recommendable for total-lifetime emissions reduction. This is confirmed in Figure 35.

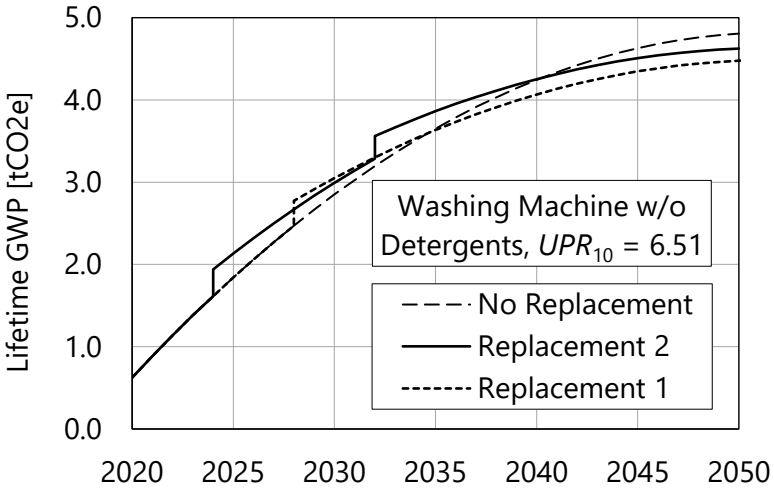


Figure 35. Lifetime emissions of washing machine at high utilization (grid mix)

The high-utilization scenario was also assessed for the case of using 100% renewable energy. This changes UPR_{10} to 0.85 for renewable energy with its emission factor of

0.042 $kgCO_2e/kWh$ (see the related discussion in D4.3). For renewable energy, the resulting UPR_{10} is close to the crossover region between replacement vs. no replacement. The more detailed analysis in Figure 36 reveals that replacement for reasons of energy efficiency and total-lifetime emissions reductions is not recommendable in this scenario.

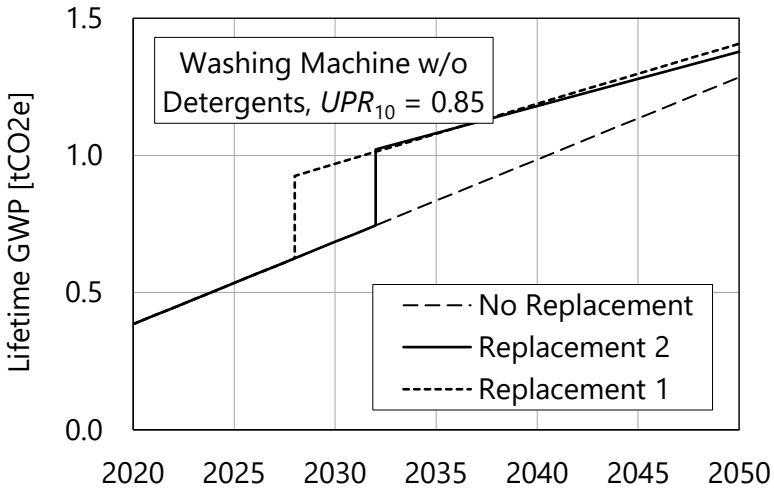


Figure 36. Lifetime emissions of washing machine at high utilization (renewables)

The analysis shows that the concept of UPR_{10} can also be applied to washing machines. Another household appliance (a refrigerator) is analysed in the next chapter.

6.1.5. Class A+ refrigerator

In order to use and verify the UPR_{10} concept, one needs the production GWP of a product and the use-phase GWP over 10 years. The production GWP must come from an LCA, the use-phase GWP can be calculated from energy-consumption specifications together with appropriately forecasted emission factors. The respective discussion of emission factors can be found in D4.3. Therefore, the required effort for UPR_{10} calculations is smaller as compared to conducting a full LCA. Both parameters, energy consumption and production GWP, may be requested in the future from the respective manufacturers.

We verified the applicability of UPR_{10} for all project-partner products so far. In the next step, we repeated this exercise for EEE where we could find the two GWP parameters mentioned above. This is necessary since without very detailed knowledge, it is not possible to derive the production GWP. Therefore, the latter must be stated in publicly available information, together with the energy-consumption specification.

The first example of non-project-partner EEE is a Class A+ Electrolux ERB3105 refrigerator [1]. Average continuous power consumption of this device is 22.1 W. Production GWP is stated as 256 $kgCO_2e$, which leads to UPR_{10} = 2.33 for grid-mix electricity. This suggests that no replacement for energy-efficiency reasons is recommendable. This is confirmed in Figure 37.

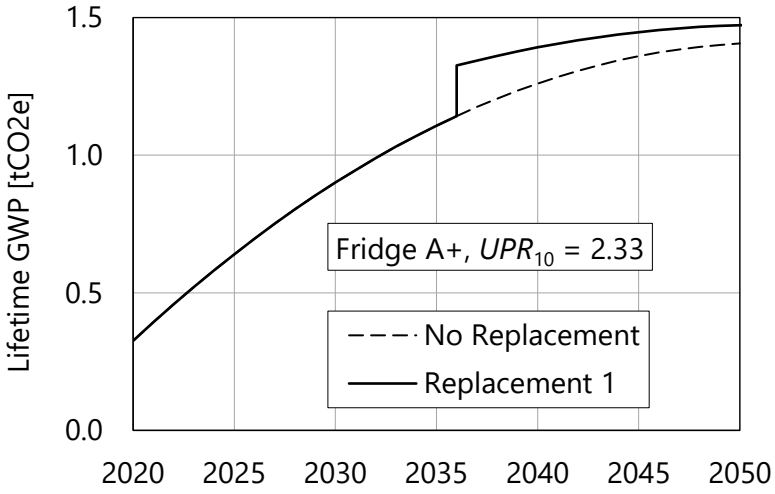


Figure 37. Lifetime emissions of Class A+ fridge [1]

In [2], an increase of the energy efficiency for refrigerators of 60% in 25 years is stated. This equals a yearly efficiency gain of ~10.5% in 2020, which then decreases year over year until it reaches almost zero in 2050. Like in the other EEE cases, it is assumed here that without any new, still unknown, disruptive new developments, the efficiency gain must come to a stop somewhere in the future because any physical processes (like cooling in this case) cannot undercut certain lower energy bounds determined by physics.

A Class A+ refrigerator obviously is efficient enough not having to be replaced for efficiency reasons. This is in line with [1]. However, this is not true for a scenario where the Class-A+ refrigerator replaces an old device with high power consumption. Such a scenario is shown in Figure 38. Here, an old device with power consumption of 35 W is replaced by the Class-A+ refrigerator after longer usage (the first implementation of the old device is not shown in Figure 38). This increases UPR_{10} to 2.69 for grid-mix electricity.

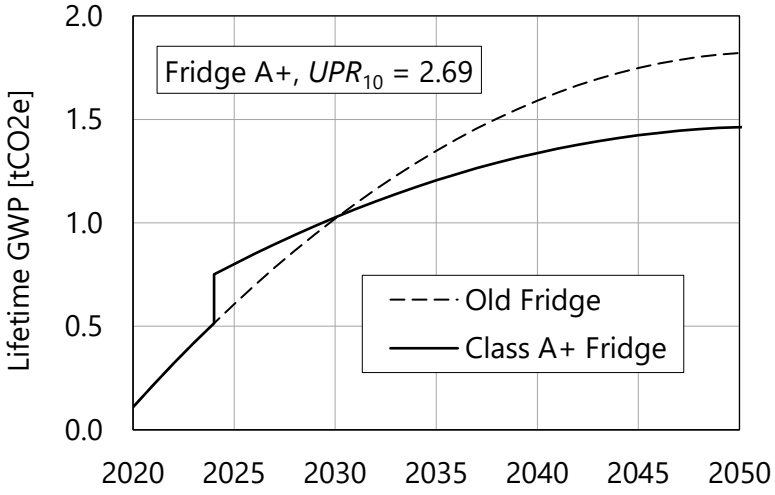


Figure 38. Lifetime emissions of Class A+ fridge replacing old fridge

It can clearly be seen that old devices should be replaced!

6.1.6. Storage device

We found production-GWP and energy-consumption data for three other electronic devices, all of which fall into the B2B ICT data-centre area. These devices are a storage platform, a hard-disk drive (HDD), and a high-end server.

We first analysed the storage platform. This device is intended to accommodate up to 84 drives in storage pools in data centres. Its production GWP is 5.0 tCO_2e, target lifetime is 10 years, and average power consumption is 1690 W [3]. From this, UPR_{10} = 9.12 for grid-mix electricity results. This clearly indicates that the storage platform should be replaced somewhere after the target lifetime for reasons of energy-efficiency improvements. This is confirmed in Figure 39.

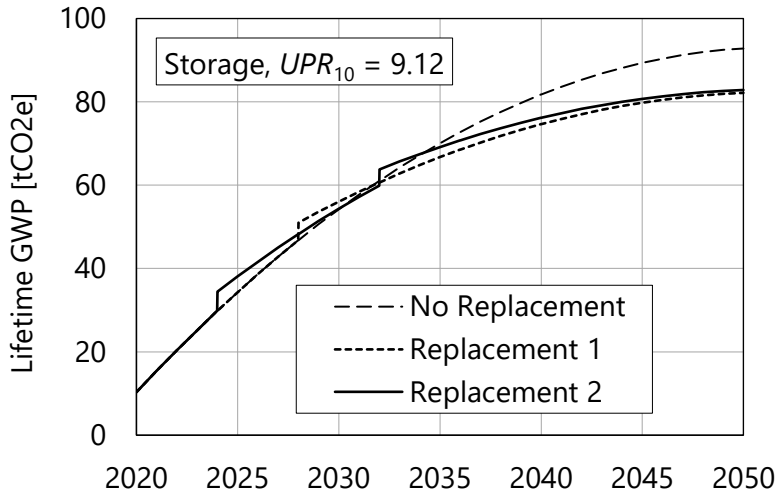


Figure 39. Lifetime emissions of a storage device (grid-mix electricity)

For the storage platform, we used efficiency gain that was reduced compared to the one for core-network equipment (TeraFlex, ALM). The reason is that the power consumption of the storage platform is partially driven by the HDDs it accommodates. The HDDs' power consumption in turn is partially driven by the stepper motors. Here, we assumed that efficiency gain is slower compared to solid-state semiconductors. We used a gain in efficiency of 27% in the first 10 years. This equals 8.1% in the first year and a decline of the gain to close to zero in 2050, as for the other devices and as discussed before.

Due to the clear replacement recommendation in the grid-mix use case for the storage platform, we also investigated the case of using 100% renewable energy. This changes UPR_{10} to 1.18. This is slightly above the threshold where replacement becomes recommendable for using renewable energy, as discussed in D4.3. This is confirmed in Figure 40 for two different replacement scenarios.

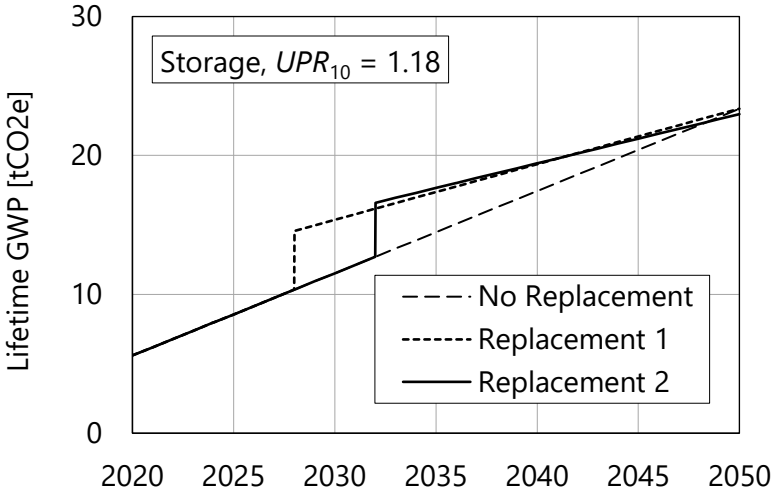


Figure 40. Lifetime emissions of a storage device operated with renewables

It can be seen that replacement after *at least* 8 years lifetime makes sense even when using renewable energy. Earlier replacement does not make sense due to efficiency gain which is too small. Later replacement does make sense due to efficiency gain that is still increasing (albeit nonlinearly as discussed). Note that the intended lifetime is 10 years.

6.1.7. Hard-disk drive

The next device is a single HDD from the same manufacturer than the storage platform, Seagate [4]. It is intended for enterprise (B2B) applications. It has a nominal lifetime of 3 years (only). Its average power consumption is 4.6 W. The production GWP is 44 $kgCO_2e$, which leads to UPR_{10} of 2.81 when using grid-mix electricity. This value suggests that no replacement is required for energy-efficiency-improvement reasons. However, the nominal lifetime, according to the manufacturer, of this device is 3 years. This leads to the lifetime GWP development shown in Figure 41.

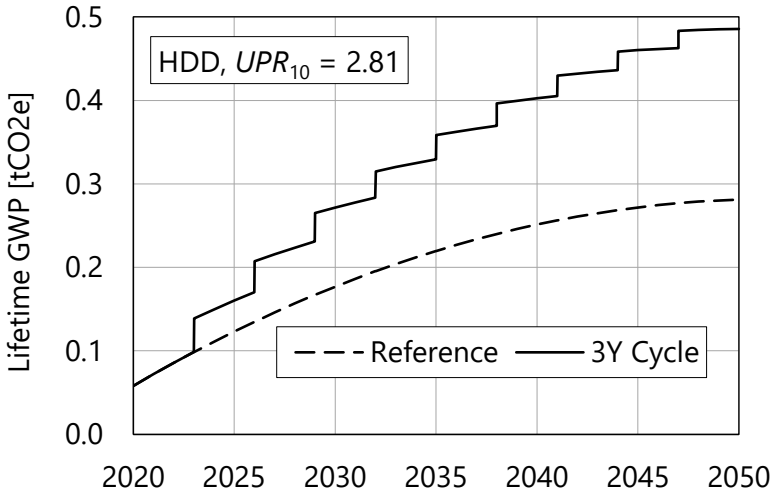


Figure 41. Lifetime emissions of a hard-disk drive (HDD)

Here, the same efficiency gain was used as for the storage device, i.e., a gain of 27% in the first 10 years. We also assumed that production GWP decreases by 8% every 3 years. It can be seen that the short lifetime requires a fast replacement cycle which clearly

increases lifetime GWP. In this case, the device should be given a longer nominal lifetime or allowed to be reused, possibly in less-demanding data centres.

6.1.8. Server

The last device from the B2B data-centre area is a high-performance server with maximum configuration of two 28-core CPUs and three GPUs [5], [6]. Target lifetime of this device is four years, production GWP is 4.3 tCO_2e, and average power consumption is 308 W, respectively. This translates to UPR_{10} = 1.94 for grid-mix electricity. The low use-phase impact results from the average utilization as per the specifications (100% load: 10% of the time, 50% load: 35%, 10% load: 30%, idle mode: 25%). The small UPR_{10} indicates that the device should not be replaced and could hence be given longer lifetime. This is confirmed in Figure 42.

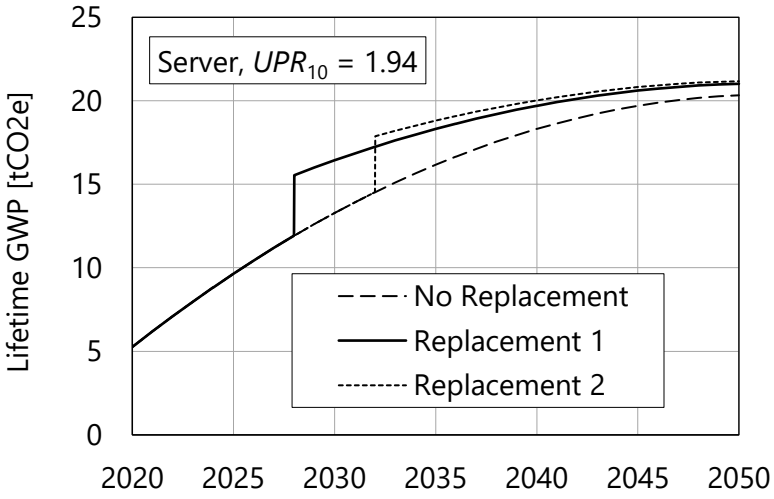


Figure 42. Lifetime emissions of a server (medium utilization, grid-mix energy)

Possibilities for life extension may be restricted for high-end data-centre equipment. For example, the server might be given a second life in a smaller data centre with less demanding duty cycle.

We also analysed the effect of increasing the duty cycle. We changed it to 100% load at 30% of the time, 50% load at 50% of the time, and 10% load and idle state at 15% and 5% of the time, respectively. This changed the average power consumption to 387 W and UPR_{10} for grid-mix electricity to 2.44. Now, one replacement after 8 years achieves a similar result than the no-replacement scenario.

In addition, we analysed the replacement scenarios for the case of usage of 100% renewable energy. This changed UPR_{10} to 0.32. This indicates that no replacement should be done, which is confirmed in Figure 43.

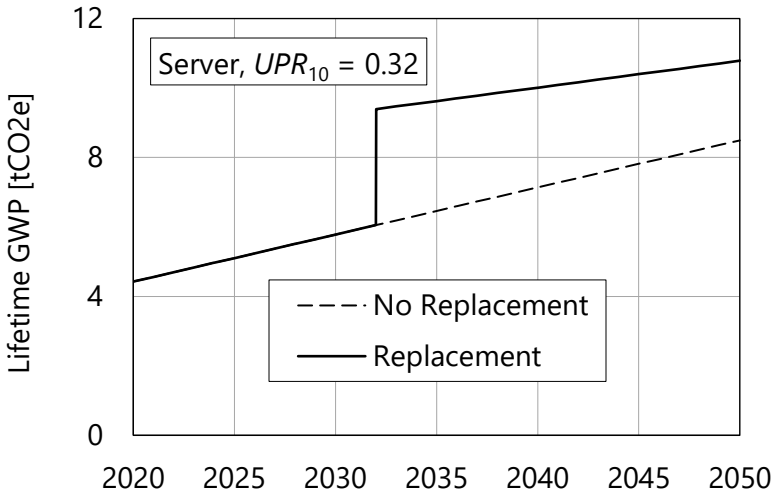


Figure 43. Lifetime emissions of a server (high utilization, renewable energy)

We used slower efficiency gain here, compared to core-network ICT equipment, but higher gain compared to HDDs or storage equipment. This considers that the server can be equipped with hard disk drives and that CPU efficiency scaling has already slowed down significantly [7], [8]. Efficiency gain after 10 years was 39%, which equals 8.8% in the first year (2020) and a decline toward almost zero in 2050.

6.1.9. Further generalization

The UPR_{10} concept has been proven as applicable in order to find out quickly whether EEE should be replaced for energy-efficiency and related GWP reasons or should be given long or even extended lifetime.

UPR_{10} can be used for different classes of EEE. However, it needs to be adopted to the type of electricity used due to the dependence of UPR_{10} on the related emission factors. Some further imprecision results from the differences that EEE has regarding its gain in energy efficiency. This leads to an improvement of UPR_{10} by normalizing UPR_{10} to the predicted energy-efficiency gain in that period (the first 10 years).

$$UPR_{10\mathrm{EE}} \coloneqq UPR_{10} \cdot G_{\mathrm{EE10Y}} \tag{2}$$

$UPR_{10\mathrm{EE}}$ is the former UPR_{10}, multiplied by the gain in energy efficiency in the first 10 years of usage, G_{EE10Y}. For higher gains in efficiency (see, for example, TeraFlex), $UPR_{10\mathrm{EFF}}$ is reduced stronger as compared to smaller gains. Thus, differences in efficiency gain are partially equalized. (Exact equalization is not possible since the assumptions regarding the different gains contain errors or approximations.) This yields more robust results in cases where the gain assumptions used in this document cannot be applied. Similar to the emission factors, the efficiency gain then has to be adopted individually, and the respective gain needs to be known. Therefore, $UPR_{10\mathrm{EE}}$ requires additional knowledge and must be regarded as slightly more complex.

The values of UPR_{10} and $UPR_{10\mathrm{EE}}$ of the EEE examples analysed so far are summarized in Table 7. The table also contains the summary of the replacement recommendations that were derived so far.

Table 7. UPR_{10} and UPR_{10EE} of the EEE products investigated in D4.3 and D4.4

	Efficiency Gain	Grid mix		Renewable		Replacement? Grid-mix / RE
		UPR_{10}	UPR_{10EE}	UPR_{10}	UPR_{10EE}	
ALM64 (OTDR)	0.45	1.69	0.76			n / n
TeraFlex (WDM)	0.45	27.0	12.1	3.51	1.93	y / y
MX626 Laser Printer	0.90	1.22	1.10			n / n
TV Set	0.45	0.73	0.33			n / n
Monitor 9 h/day	0.45	2.73	1.23	0.35	0.16	y / n
Monitor 18 h/day	0.45	5.46	2.46	0.71	0.32	y / 0
Monitor 24 h/day	0.45	6.96	3.13	0.90	0.41	y / y
Washing Machine (single household)	0.69	1.39	0.96			n / n
Washing Machine (shared)	0.69	6.51	4.49	0.85	0.58	y / n
ERB3105 Class A+ Fridge	0.54	2.33	1.26			n / n
SP2584 Storage Device	0.63	9.12	6.29	1.18	0.82	y / 0
Savvio 10K.5 HDD	0.63	2.81	1.77			n / n
R740 Server (medium utilization)	0.61	1.94	1.18			n / n
R740 Server (high utilization)	0.61	2.44	1.49	0.32	0.19	0 / n

From Table 7, we can derive the crossover value range for UPR_{10EE} that separates the replacement and no-replacement regimes. These value ranges are summarized in Table 8, together with the ones for UPR_{10}.

Table 8. Crossover value ranges for UPR_{10} and UPR_{10EE}

	Grid mix		Renewable	
	UPR_{10}	UPR_{10EE}	UPR_{10}	UPR_{10EE}
Crossover range	2.5…5	~1.5	0.7…1.1	~0.6

The new crossover values between replacement vs. no replacement for UPR_{10EE} are ~1.5 for grid-mix electricity and ~0.5 for renewable energy, respectively. Not surprisingly, they are smaller than the original values for UPR_{10} since the latter were derived for core-network ICT equipment with comparatively high energy-efficiency gain. The new values for UPR_{10EE} are also in line with the graphical representation of the crossover time as a function of UPR_{10EE}. In both cases (grid-mix electricity, renewable energy), the crossover threshold is in the area of highest change of the slope of the curves. The diagrams have been derived similarly to the ones for UPR_{10} as described in D4.3.

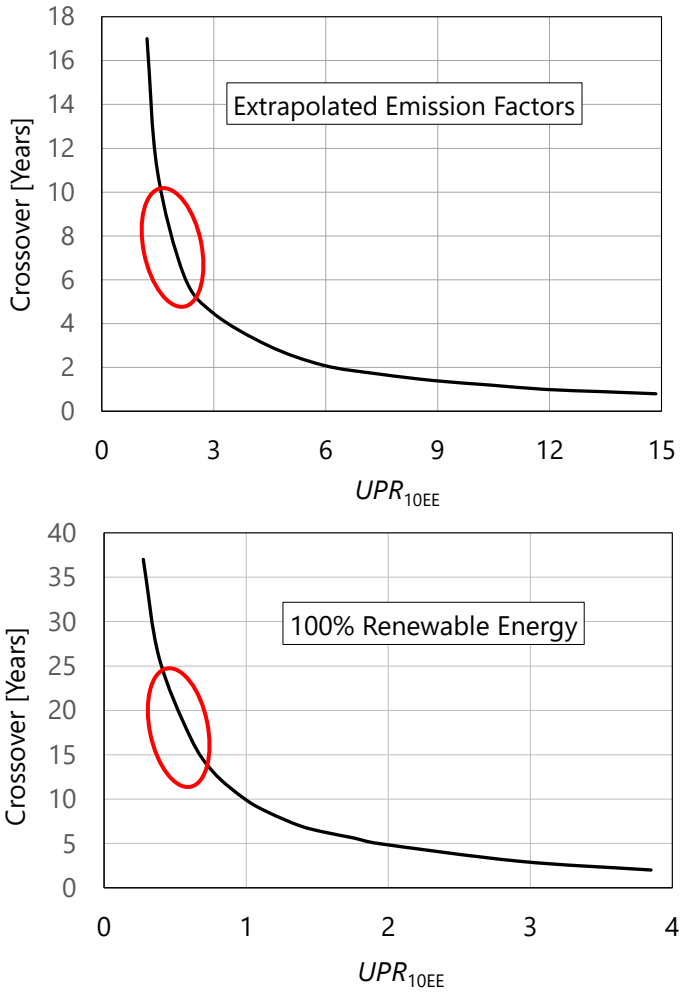


Figure 44. Modified ratio UPR_{10EE} for grid-mix electricity (top) and renewable energy (bottom, respectively. The crossover range between replacement and non-replacement is marked red.

For comparison, Figure 45 compares the *yearly* energy-efficiency gains used in here.

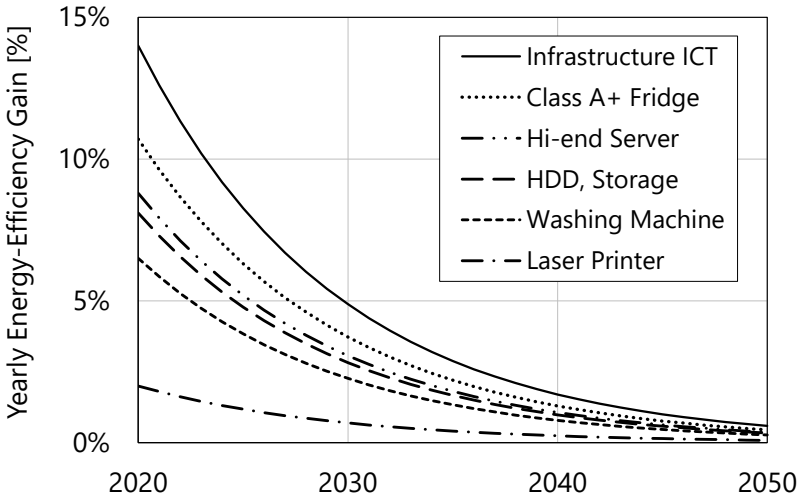


Figure 45. Yearly energy-efficiency gains used in our lifetime analyses

6.1.10. Discussion of UPR10

Circular economy aims at reducing raw-material consumption and waste generation through the concept of longevity. However, lifetime may be limited, for certain electronic products, by use-phase energy consumption and the efficiency gain that is to be expected by successor products. This effect is time-dependent since both, the efficiency gain and the electricity emission factors that are to be applied decrease over time.

For the related product classification, the use-phase-over-production-phase GWP ratio UPR_{10} has been defined. For certain electronic products, it clearly indicates that replacement for reasons of increased efficiency and reduced emissions is advisable. This can even be true for the case of using renewable energy.

For such products, continued work toward better energy efficiency is required. The resulting lifetime GWP optimization may contradict generic CE requirements for longevity and the respective ecodesign efforts. However, in particular, as long as average emission factors are clearly above the ones for renewable energy, the product discrimination enabled by UPR_{10} should be applied in order to avoid net-negative CE rebound effects on global warming. This is particularly true for potential new regulations. These must apply similar electronics-products discrimination or classification. Products with very strong use-phase dominance, like TeraFlex, must be allowed to be taken out of service for reasons of energy-related emissions, even if they could be re-used for extended periods from the viewpoint of functionality. Of course, this means that at their end of life, these products have to be recycled to the best-possible extent.

The UPR_{10} concept is applicable to a broad range of EEE in order to find out quickly whether the respective EEE should be replaced for energy-efficiency and related GWP reasons or should be given long or even extended lifetime in the sense of the circular economy.

Usage of UPR_{10} is relatively simple, e.g., compared to conducting full lifecycle assessments since only the production-phase GWP (i.e., a subset of an LCA) and the use-phase GWP (i.e., the power-consumption specification plus emission factor and use mode) need to be known.

In addition – extension to UPR_{10EE} – knowledge or good prediction of future energy-efficiency gain will provide somewhat more stable results. This prediction requires some analysis of the past behaviour of energy efficiency, together with knowledge of future challenges like physical saturation effects, for example the Shannon-von Neumann-Landauer limit [9], [10].

In total, the UPR_{10} concept is regarded simple and applicable.

The concept of UPR_{10} is also regarded novel. It resolves the ambiguity that the exclusive consideration of LCA even in cases of clear use-phase dominance still leaves. It provides a single, simple parameter that helps to identify if longevity / lifetime extension is the correct way forward.

UPR_{10} can have relevance for future regulations. This is particularly true in case such documents regulate quota for reuse, lifetime extension or similar concepts for electronic equipment. In order to prevent environmental harm, certain product classes must be

exempted from such regulations. With the help of UPR_{10}, these product classes can be clearly identified.

6.1.11. Feedback on UPR10

In the last phase of the project, we introduced the UPR_{10} concept to several customers, i.e., telecommunications network operators and service providers [11]. In one of these discussions – with British Telecom (BT), an international network operator and service provider that is relatively advanced in its sustainability concepts and actions – explicit interest in the UPR_{10} concept was expressed. BT wants to use this parameter to differentiate between products that primarily require consideration of energy efficiency and products that require dedicated CE considerations. BT is the first European network operator with dedicated CE targets. They want to be fully circular by 2030. In addition, they support that the European ICT sector (i.e., the former European national monopolist network operators like BT, DTAG, France Telecom etc.) are jointly circular in 2040.

6.1.12. Future development of UPR10

In the future, with impact of GWP declining thanks to increasing portions of renewable energy used, the UPR_{10} concept might be complemented by considering the abiotic resource depletion (ARD) as a relevant LCA midpoint parameter that considers raw-material depletion. This might still lead to a simple parameter and might balance GWP vs. ARD in the future case where GWP gets less important. As a minimum recommendation, the similarity of GWP and ARD in LCA should be checked every 5-10 years. If the two midpoint parameters start to clearly deviate, UPR_{10} should be complemented by ARD.

6.2. PSS analysis extension

In this chapter, the final results of the PSS analyses are presented. This is based on the results that were presented in deliverable D4.3, chapter 6.1.4. The analyses in that chapter started with the ALM (an ICT fibre-plant monitoring device). They were then complemented by another ICT device from the ADVA portfolio, TeraFlex, which is a latest-generation, high-capacity, coherent fibre-optic long-haul transmission device.

Regarding the lifetime-evaluation ratio UPR_{10}, the ALM and TeraFlex are at the two opposite ends of the scale (ALM fairly low, TeraFlex very high), thus spanning almost the complete range of EEE products with different use-phase-over-production-phase carbon emission ratios. The PSS analyses were then further generalized by defining a ratio CMR_{10}:

$$CMR_{10} := \frac{\text{CapEx of the product}}{\text{Maintenance OpEx over 10 years}} \qquad \text{(Eqn. 1)}$$

CMR_{10} is the ratio of the product CapEx to the OpEx generated by 10 years of maintenance. The ratio CMR_{10} allows generalization beyond the ICT products considered. This generalization was supported by an analysis of ICT-product specifics, both in terms of challenges (e.g., fast functional obsolescence) as well as supporting features (e.g., inbuilt monitoring and supervision functions).

Basically, variants of two PSS were analysed:

- PSS1. Product sold, together with maintenance, without take-back at EoL
- PSS2. Product sold, together with maintenance, with take-back at EoL
- PSS3. Leasing with take-back at EoL
    - Only product leased (including maintenance)
    - Service offered by the product leased (including maintenance)

Certain PSS from [12] had to be discarded for ICT products since, e.g., virtualisation of certain ICT products is impossible (the opposite is true, ICT products allow virtualization of other, more resource-intense systems). Main findings were that basically, all PSS can work for ICT equipment and other EEE, and that there is a potential dependency between sharing or utilization that is increased by certain PSS and optimum product lifetime as derived by UPR_{10}.

Here, a more detailed analysis of different PSS with particular respect to cost and environmental performance in dependence of end-of-life (EoL) recycling or reuse yield is provided.

Starting point is the analysis of the cumulative net-present value (NPV, i.e., cumulative manufacturer earnings after interest and depreciation) and the cumulative customer cost for the three different PSS listed above. These are repeated for the ALM with one of the newly developed sensor types (fire sensors) from D4.3 in Figure 46.

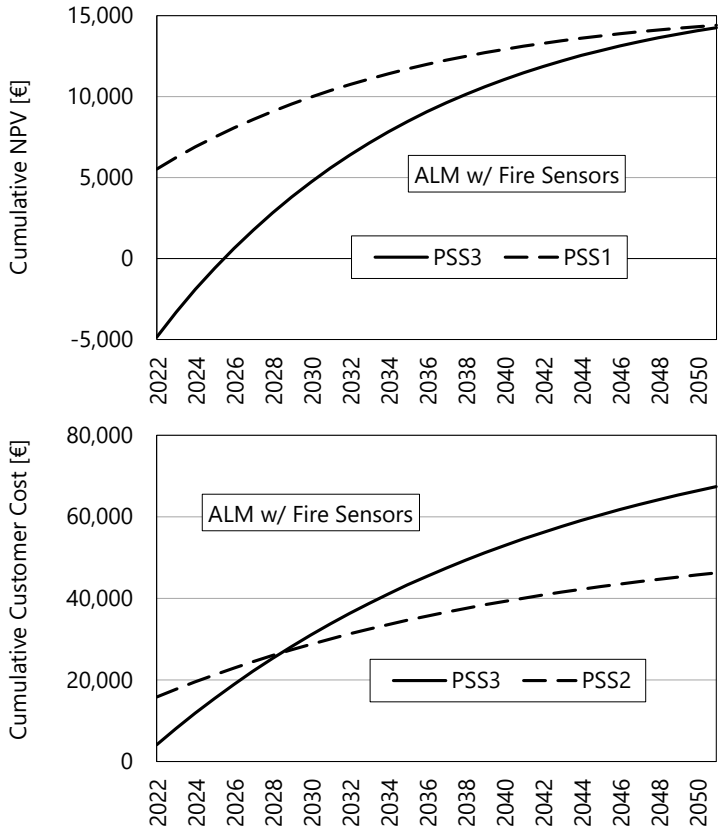


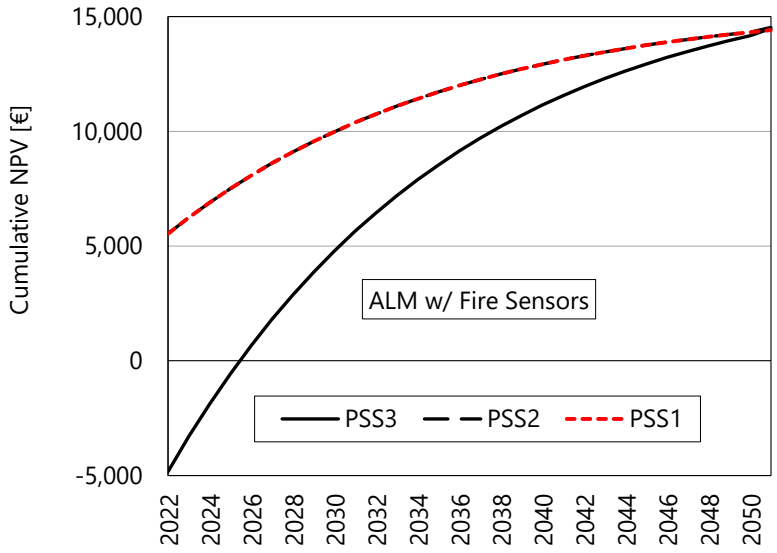
Figure 46. Cumulative NPV (top) and customer cost (bottom) for different ALM PSS. For PSS3, the monitoring enabled by the ALM was leased as a service ("Monitoring as a Service").

Relevant parameters (HW, maintenance and leasing price) have been adjusted to achieve the same NPV at the end of the analysed period. Other parameter adjustments are possible, e.g., constant customer cost. In the case of the PSS3 customer cost in Figure 46 (bottom), the mark-up for the monitoring service over the cost of buying the product is regarded relatively small, in particular if the respective customer does not have similar monitoring facilities (similar to an ICT network monitoring centre).

Next, the PSS are analysed in more detail with special consideration of the EoL. The relevant parameter considered here is the EoL recycling or reuse yield. Based on older analyses of the ADVA reverse-logistics process, a percentage range of 8…12% of the initial product cost has been considered so far, as described in D4.3. According to ADVA's experience, this range is regarded very optimistic and so far has not been matched in reality (reality approximately is half of that range). Even the optimistic range of up to 12% did not lead to substantive differences between the PSS, in particular between selling a product together with maintenance and EoL take-back (PSS2) and product or service leasing (PSS3).

From that, no clear preference of leasing can be derived.

Now, the EoL yield is massively increased to better demonstrate differences between the PSS. The upper EoL-yield value is now 50%, which is regarded completely unachievable in particular for B2B ICT equipment. Results are shown in Figure 47.



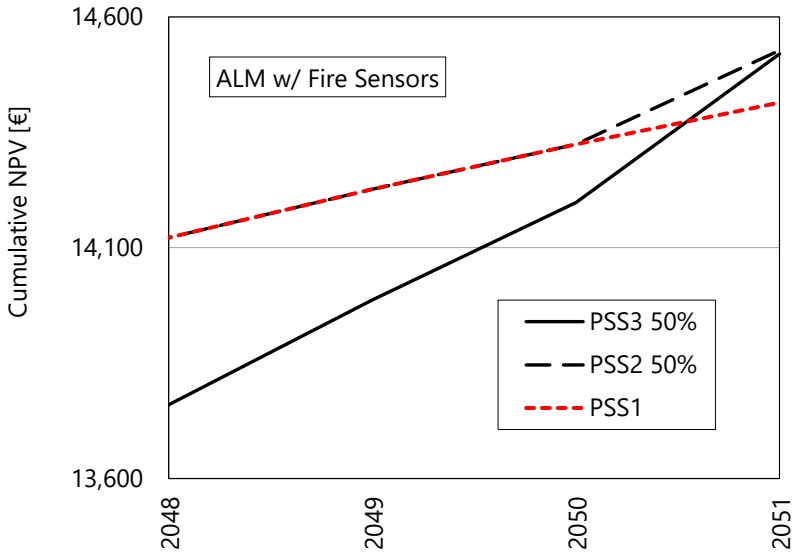


Figure 47. Cumulative NPV (top) and zoom into cumulative NPV (bottom) for different ALM PSS and 50% EoL cost yield.

The analysis, in particular the zoom into the last year of the considered period in the bottom part of Figure 47, shows that there is no difference in NPV for the manufacturer between PSS2 (selling the product with maintenance and EoL take-back) and leasing the product's main function as a service. The relevant assumption is that for both PSS, the EoL yield is the same (50% here, which is considered too high).

However, given there is the obligation for take-back in both cases, and other relevant parameters like cost, considered period etc. remain the same as well, then there is no fundamental mechanism why the EoL yield should differ between selling and leasing a product. In other words, it is the EoL take-back mechanism that is relevant, not the leasing. Therefore, leasing can be regarded a purely financial mechanism that is vastly independent of any circularity or EoL gains. It can and should be applied if financially viable, but the circularity gains are driven by take-back and successive recycling or reuse.

Next, the analysis is repeated with EoL yield for PSS 3 (40%) which is higher by a factor of 2 compared to PSS2 (20%). At least for ICT equipment, both values are still considered too high. Results are shown in Figure 48.

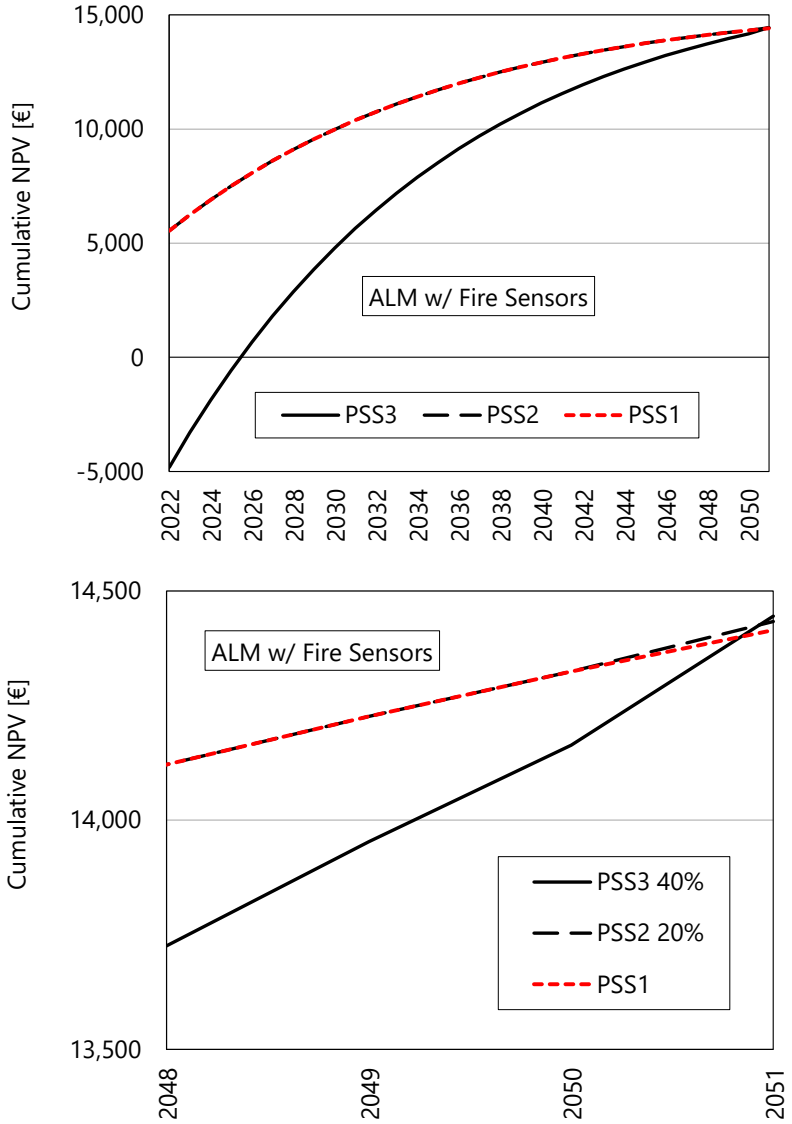


Figure 48. Cumulative NPV (top) and zoom into cumulative NPV (bottom) for different ALM PSS and 20% and 40% EoL cost yield, respectively.

In the full view (Figure 48 top), the difference compared to Figure 47 is hardly visible. The zoom into the last year (Figure 48 bottom) shows that despite the difference of 20% EoL yield (PSS2) vs. 40% EoL yield (PSS3), there is no substantive difference in the NPV. This again underpins that it is not the financial mechanism that is relevant but solely the EoL yield, which is influenced, amongst others, by an EoL take-back obligation.

These analyses confirm the D4.3 finding that take-back plus reuse/recycling is the relevant mechanism for high circularity gain, not leasing.

Independent of this, leasing can and shall be implemented if it has financial advantages.

Finally, the PSS impact on the most relevant environmental parameter, carbon emissions (GWP, global warming potential) is shown in Figure 49.

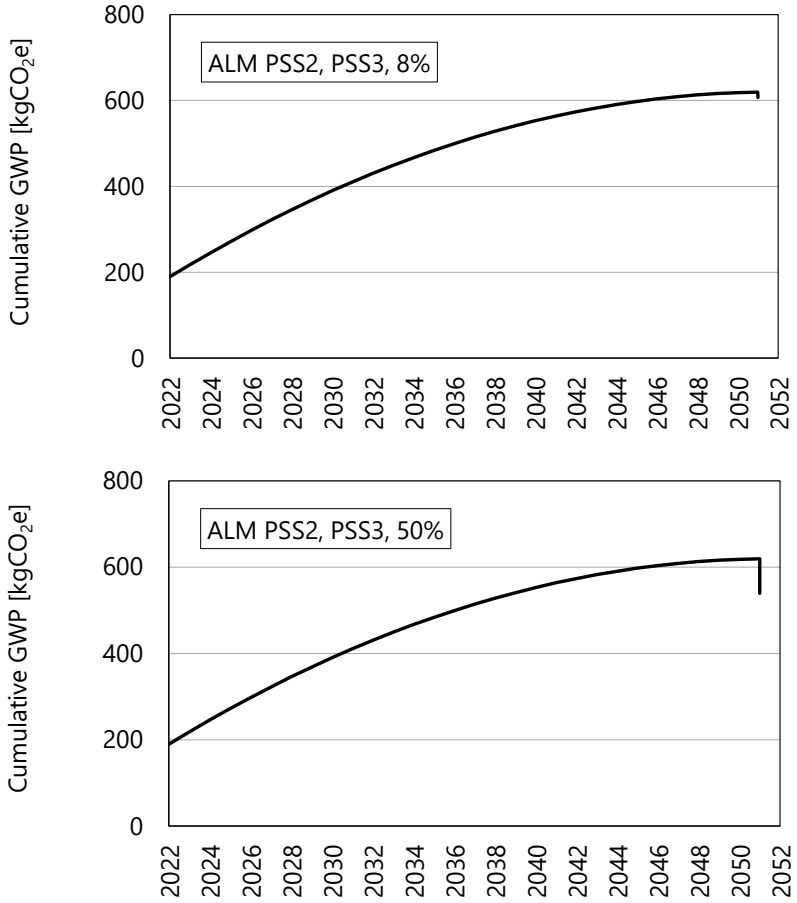


Figure 49. Cumulative GWP for different ALM PSS at 8% (top) and 50% (bottom) EoL yield, respectively.

The GWP curves show identical values for PSS2 and PSS3, respectively. The steep decline at EoL (year 2051 in the diagrams) marks the EoL GWP "gain" (avoided emissions) due to recycling/reuse at EoL enabled by take-back. Again, note that we regard 8% EoL gain more likely to be achieved than 50%.

6.3. Reuse guidelines for ICT products

In this chapter, reuse guidelines for ICT B2B products are compiled. These guidelines are not restricted to the ALM. However, certain aspects may be explained with the ALM as an example.

The guidelines follow the findings according to an optimum-lifetime analysis based on UPR_{10}, see the previous chapter. That is, for UPR_{10} clearly above or below the crossover thresholds for replacement scenarios that minimize total-lifetime emissions, different guidelines and focus for reuse result. For products where optimum lifetime is less clear, generic guidelines are difficult to state. In such cases, product-specific considerations may have to be followed. However, certain generic guidelines like design for disassembly and design for recycling should be followed in any case. To certain extent, these support reuse, e.g., of components.

Products with UPR_{10} < 2.5 or UPR_{10EE} < 1.5 (grid mix)

For this product class, the ALM is a good example. Its UPR_{10} is 1.69, and its UPR_{10EE} is 0.93, respectively. These products do not need to be replaced for reasons of energy efficiency and reduced lifetime use-phase emissions. They should be given a maximum lifetime, which has to be supported by respective ecodesign, that is, design for longevity. This ecodesign comprises at least the following aspects:

1. Performance monitoring, failure diagnostics, failure prediction (ICT, B2B only)
2. Modularity, all modules are hot pluggable during operations (ICT, B2B)
3. Resilience of critical modules, e.g., PSUs, fans (ICT, B2B only)
4. ICT network elements stay functional in case of shelf-controller failure
5. Design for disassembly
6. Design for partial reuse
7. Design for recycling.

The first four aspects support long, uninterrupted usage and certain maintenance / repair without deactivating the product. They allow certain repair actions during use, e.g., replacement of a PSU or the shelf controller. Key is the modularity and the capability to plug / unplug hot, powered modules. Replaced modules, e.g., a failed PSU are sent back and repaired. They only go into recycling if there are no repair options.

The other aspects support partial reuse or recycling. Disassembly is described in more detail in the next chapter. Its aim is to recover parts or to separate the respective device into material fractions that are compatible in recycling (so that no or only small recycling losses occur). Design for recycling supports this by avoiding material compounds or clustering that cannot be separated prior to recycling. It also avoids certain materials completely, for example, hazardous substances where possible.

Partial or parts reuse may be limited, in Particular after long lifetime. One reason are physical degradation effects like electromigration that cannot be avoided in semiconductor materials and that limit components lifetime [13], [14]. Ultimately, the respective components must be recycled.

The second reason for limits in parts reuse is a combination of cost or feasibility and functional obsolescence. It depends on the components type:

- Electronic components. Trend to functional or energy-efficiency obsolescence.
- Optical components. Passive optics do not age significantly (in the sense that they start failing). They seem to be well-suited for parts reuse, but
  - Complex and costly optical filters, gratings etc. become obsolete quickly
  - Simple, cheap 3-dB couplers etc. already pose a disassembly-cost hurdle
- Mechanical components. This is the smallest components fraction regarding both, cost and LCA environmental contribution.
  - Reuse of small plastic parts, screws etc. is regarded difficult / cost-prohibitive
  - Shelf / chassis reuse. Might require unification across several product lines

Despite the challenges with components reuse, there are certain cases where this reuse is very beneficial. This is the case when certain components will not be produced anymore which are relevant to products that are not produced in large quantities and where redesign for a replacement component would be costly. In these cases, and given the

respective components are physically still fully functional, the components can be extracted from EEE taken back and reused in new products. This can help extending the lifetime of certain products.

In general, all EEE taken or sent back shall be analysed for any components that can be reused. For the reasons listed above, this is limited so that finally, recycling and design for recycling must be considered as well. The respective process is depicted in Figure 50. It shall be extended to maximum extent.

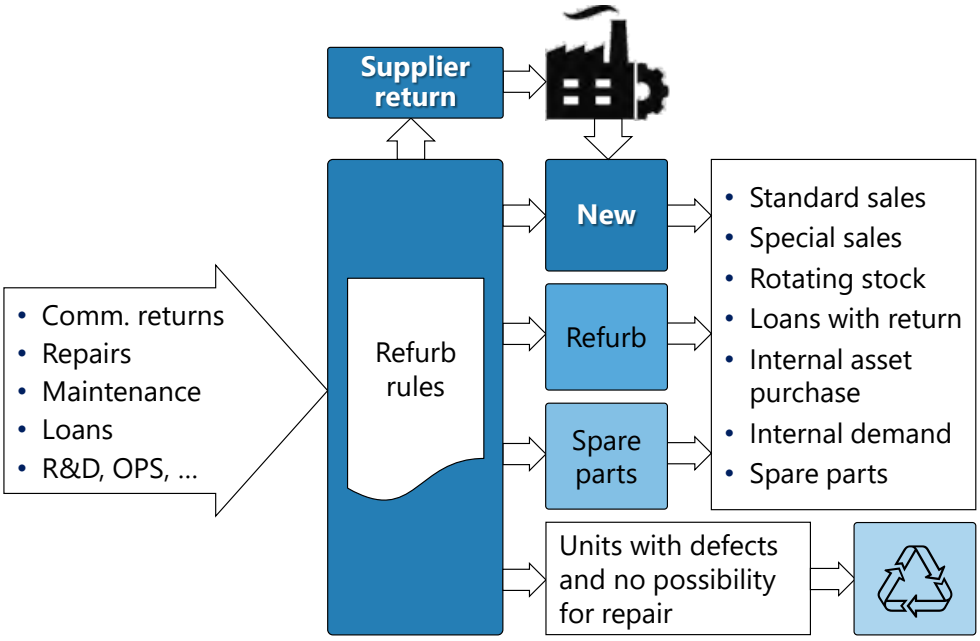


Figure 50. Take-back and analysis for further reuse

Similar guidance holds for renewable energy usage and respectively low UPR_{10} / UPR_{10EE}.

Products with UPR_{10} > 5 or UPR_{10EE} > 1.5 (grid mix)

For this product class, TeraFlex is a good example (although TeraFlex has an exceptionally high UPR_{10}). Its UPR_{10} is 27, and its UPR_{10EE} is 14.8, respectively. These products really should be replaced for reasons of energy efficiency and reduced total-lifecycle emissions. They should not be given an arbitrary life extension or maximum lifetime. Ecodesign should primarily focus on highest energy efficiency.

For the same reason, parts reuse is even further limited as before. Many more-valuable electronic components like ASICs, FPGAs etc. have energy efficiency that is quickly getting obsolete so that reuse is not advisable. Therefore, design for recycling is relevant as well.

Similar guidance holds for renewable energy usage and respectively high UPR_{10} / UPR_{10EE}.

6.4. Disassembly guidelines for ICT products

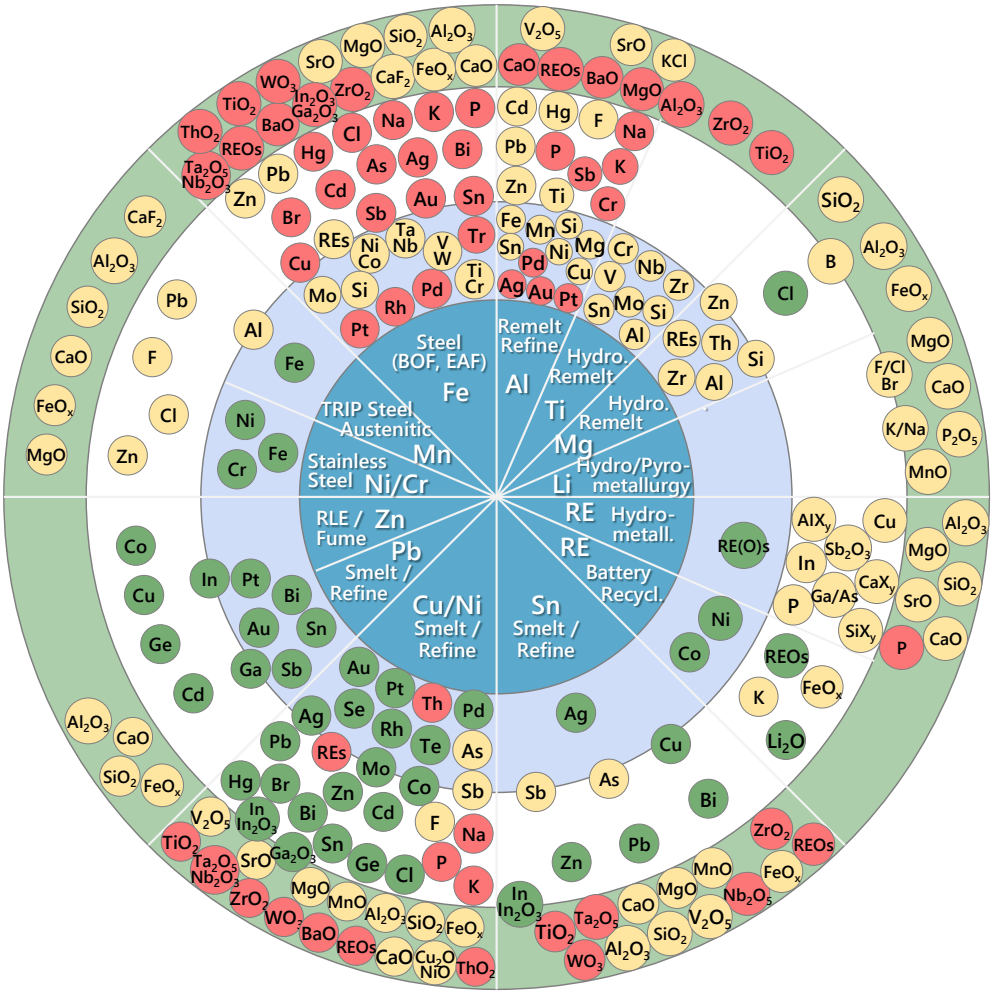
In this chapter, a generic disassembly guide for ICT and electronics equipment is provided. This disassembly is intended to support most efficient WEEE recycling. The intention is to collect generic rules or guidelines that hold for a broad range of electronic equipment. Certain electrical equipment like household appliances are out of scope of these guidelines. The guidelines have been compiled from literature and from discussions with WEEE recyclers [18], [19], [20]. The pictures provided were mainly taken from the ALM product, however, they are meant as illustrative examples only and are not restricted to the ALM or ADVA-specific ICT products.

Disassembly into minimum set of material fractions

So far, and with only a few exceptions like smart phones, efficient WEEE recycling requires manual disassembly or dismantling for best efficiency [15]. The reason is that materials that are incompatible in recycling must be separated before recycling to avoid losses of recycled material. The second reason is that only products sold in large quantities (like smart phones) can feasibly and economically be disassembled by robots.

Incompatibility means that certain material is lost in recycling and cannot be recovered. A relevant example is iron, which in general needs to be separated from components that contain precious metals since the latter would be lost in recycling pathways that aim to recover precious metals if iron is present and no further care is taken.

An overview of different metal recycling pathways for WEEE recycling, together with the main target materials and the main losses, is given in Figure 51 [16]. The capabilities and losses of the recycling pathways shown there are the reason for manual disassembly and separation of certain material fractions prior to recycling.



Society's Essential Carrier Metals: Primary Product
Extractive Metallurgy's Backbone (primary and recycling Metallurgy: Hydro-, Pyro-).
Metallurgy infrastructure enables closed loop, i.e., resource efficiency

Dissolves mainly in Carrier Metal if Metallic (mainly to Pyrometallurgy)
Valuable elements **recovered** or **lost** (metallic, speiss, compounds or alloy functionality in EoL also determine destination as do reactor process conditions). EoL contain numerous metals, a few of them good for alloys, the rest not.

Compounds mainly to Dust, Slime, Speiss, Slag (mainly to Hydrometallurgy)
Collector of valuable minor elements as oxides/sulphates etc. and mainly recovered in appropriate metallurgical infrastructure if economic. EoL material and reactor conditions also affect this.

Mainly to benign Low-Value Products
Low value but enevitable part of society and materials processing. A sink for metals and loss from system as oxides and other compunds. *Limit of Recycling!*
Comply with environmantal legislation!

X **Mainly Recovered Element**
Compatible with Carrier Metal that can be recovered in subsequent processing. Cu due to its nobility recovery of elements via metallurgical refining infrastructure. Steel and Al do not have such infrastructure to recover elements as they produce alloys.

X **Mainly Element in Alloy or Compound in Oxidic Product, possibly lost**
Not detrimental to Carrier Metal or product. Metals from complex recyclates dissolving in less noble carrier metals such as Fe and Al cannot generally be recovered. Dilution may be required to produce required alloy specifications. *Required dilution is then a furter limit of recycling!*

X **Mainly Element lost, not always compatible with Carrier Metal or Product**
Detrimental to properties and cannot be economically recovered from, e.g., slag etc. unless, e.g., iron is a collector for PMs/PGMs and goes for further processing to Copper metallurgy

Figure 51. The Metal Wheel of recycling [16]

An example of resulting recycling-pathway compatibility is given in Figure 52 for LED recycling [16].

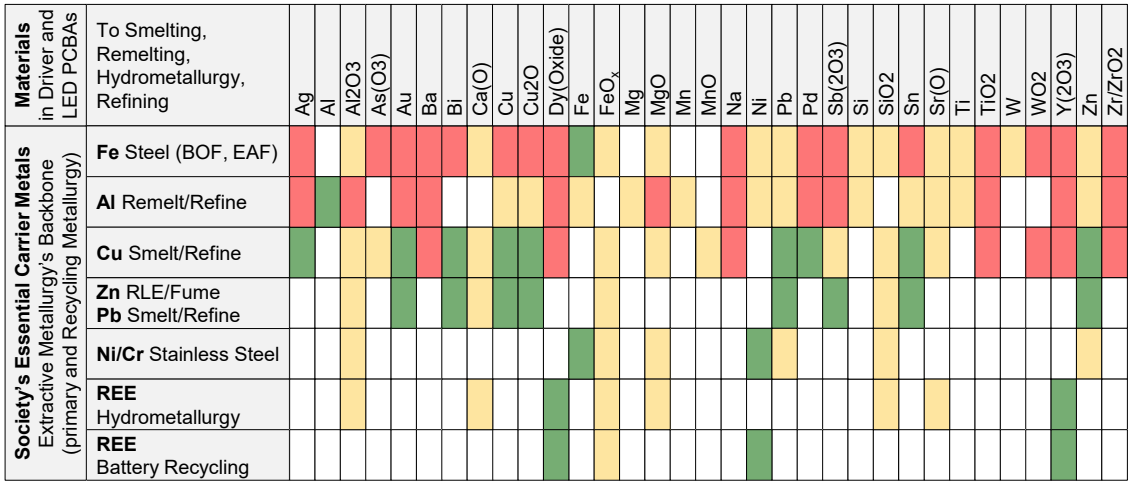


Figure 52. Compatibility matrix for LED recycling [16]

From discussions with a WEEE recycler [20], the following **material fractions** that should be separated in manual dismantling can be derived:

1. PCBAs
2. Batteries, large (Tantalum) capacitors
3. Plastic parts (one or two fractions, see compatibility matrix hereinafter)
4. Cables (copper)
5. Metal parts (chassis, screws, heat sinks, EMC shields)
6. Power-supply units.

In addition, for fibre-optic equipment, fibre-optic (patch) cables may be separated. Likewise, other parts like rubber parts or thermal pads may be separated as well.

Tools required

In general, manual disassembly or dismantling shall require as few tools as possible, and it shall not require any specialty tools. In product ecodesign, this must be supported by the avoidance of any fixed connections, i.e., rivets, welds and adhesives, and minimization of screws. A standard tool set may then be comprised of:

1. Screw drivers
2. Pliers, tweezers
3. Side cutter
4. Magnet.

When dismantling products, warnings for sharp edges etc. must be considered.

Generic disassembly steps

Following, generic disassembly steps are listed that can lead to the separation of the material fractions stated above. The respective pictures are meant as illustrative examples only, the steps are not restricted to the ALM product.

1. Remove all screws

The first step of the disassembly/dismantling process is to remove all screws. This is necessary to get access to the (sub-) modules and to remove screws as metal parts. The effort related to this first step is also the reason why in ecodesign, the number of screws shall be limited. Figure 53 shows several examples of screws to be removed.

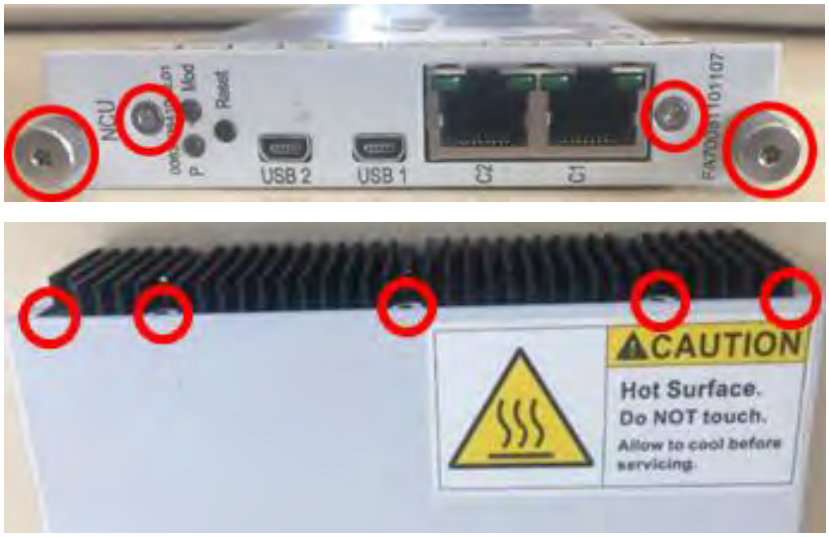


Figure 53. Examples of screws (at front panel, chassis)

Fixed-connection alternatives to screws like rivets, welds and adhesives shall be avoided because they make dismantling more complicated and may require specialty tools.

2. Remove all mechanical parts. Segregation of aluminium and steel.

The second step consists of removal of mechanical metal parts. In general, these may consist of both, aluminium and steel, which can be segregated with the help of a magnet. These parts can comprise of chassis / covers, heat sinks, EMC shields and other mechanical parts. Figure 54 shows an example of a part of a chassis.

Figure 54. Example of (sheet-metal) covers

Figure 55 shows one example of a heat sink, mounted to a chassis. Heat sinks often consist of aluminium. Therefore, they should be separated, e.g., from steel parts.

Figure 55. Example of heatsink

EMC shields protect sensitive components like certain ICs from electro-magnetic interferences. An EMC shield example is shown in Figure 56.

Figure 56. Example of an EMC shield

EMC shields are made of metal, but sometimes also contain red phosphorus. The latter may have to be considered in disassembly and recycling under the viewpoint of substances of very high concern.

3. Remove submodules from the main PCB

The third disassembly step is the removal of submodules or daughter boards from the main PCB. This may not be necessary in all cases, e.g., when main PCB and daughter boards contain similar components and could go into the same recycling pathway. However, examples exist where separation should take place, e.g., the removal of PSU (power supply unit) boards from the main PCB. PSUs should be separated because they often have a certain steel content and may contain large (Tantalum) capacitors. An example of an electronics (non-PSU) submodule mounted on and dismounted from the main PCB, respectively, is shown in Figure 57.

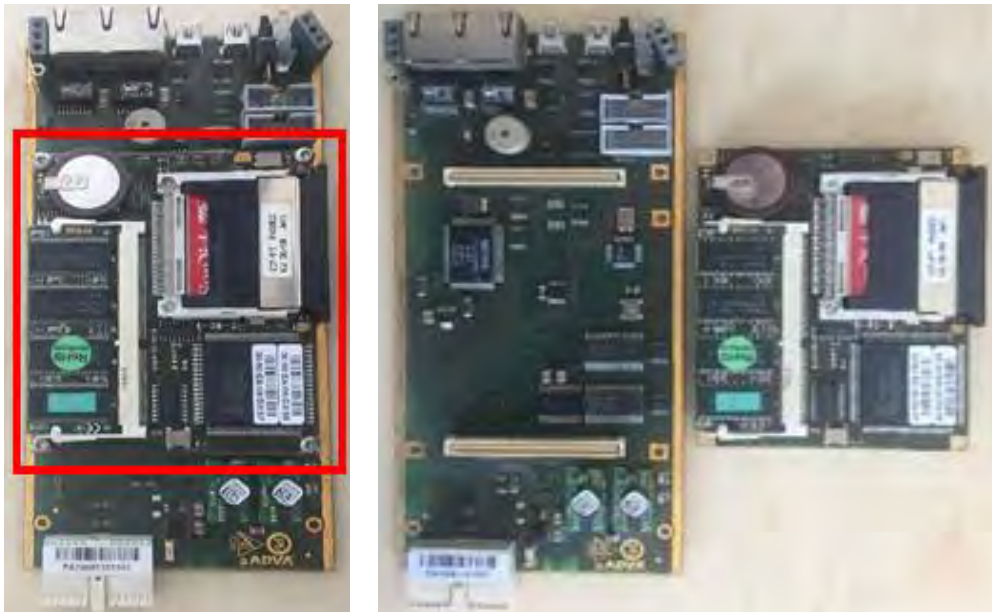


Figure 57. Example of a submodule mounted (left) on a main PCB, and separated (right)

Note the battery that is part of the submodule (upper left corner).

4. Remove thermal pads

The fourth disassembly step is the removal of any thermal pads. Thermal pads are sometimes used to improve the heat dissipation of ICs. Examples are shown in Figure 58.

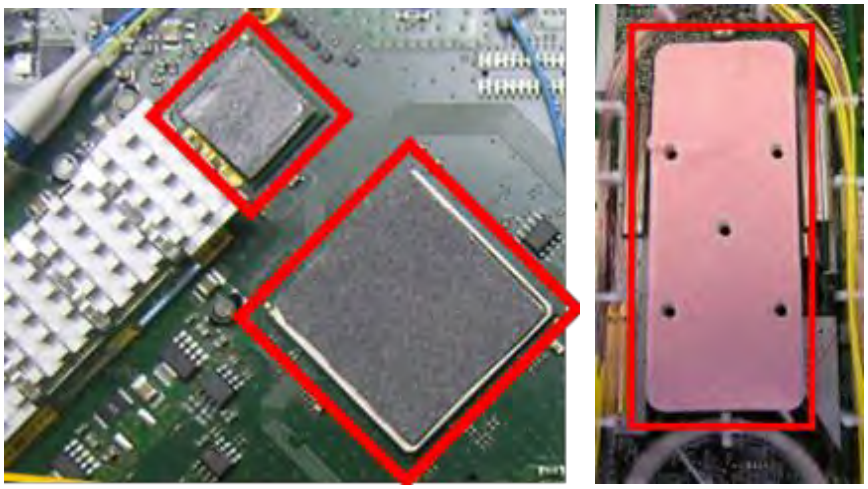


Figure 58. Examples of thermal pads

Thermal pads consist of silicon or polymers.

5. Remove all optical and electrical cables

The fifth disassembly step is the removal of all electrical and optical cables. Obviously, optical (patch) cables may only be found in opto-electronic equipment like certain classes of ICT equipment. Optical cables in most cases are metal-free. They contain the glass fibre, plastic primary buffer and sheath, and may also contain Kevlar strength members. Electrical cables contain copper and plastic. Often, relatively thick cables can be found connecting the PSU to the main PCB. Examples are shown in Figure 59.

Figure 59. Example of cables connecting submodules

Connectors of cables that connect PSUs to other parts of equipment may contain red phosphorus. Similar to EMC shields, this may have to be considered in disassembly and recycling.

6. Remove batteries

The next step in disassembly is the removal of batteries. Batteries have to go into dedicated recycling pathways for optimum material recovery, see Figure 52. Often, micro cell batteries are used which may not be visible immediately. An example is shown in Figure 60.

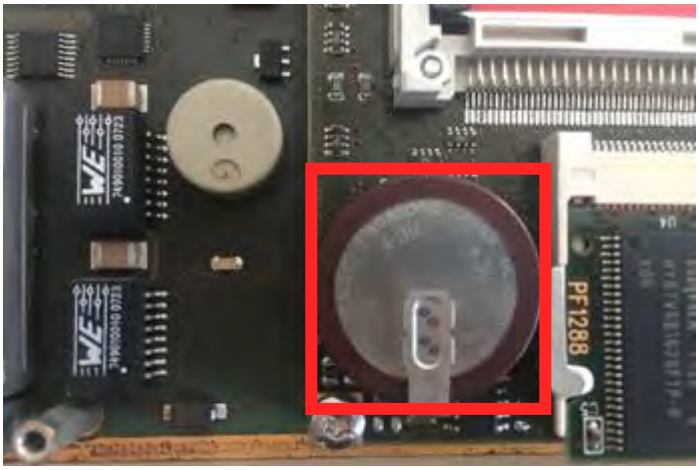


Figure 60. Example of a battery on a PCBA

Most mother boards or main PCBs contain a battery.

7. Remove plastic parts

The final step in disassembly is the removal of plastic parts. Ideally, no different plastic materials are used according to related ecodesign rules. If different plastic materials are used, preferably they are separated according to the compatibility matrix in Table 9 [17]. Obviously, PE and PP are mostly incompatible with other plastic materials and ideally should be separated as a material fraction on their own.

Table 9. Plastic compatibility matrix [17]

		Excess Component																		
Mixture Component		ABS	ASA	PA	PBT	PBT+PS	PC	PC+ABS	PC+PBT	PE	PET	PMMA	POM	PP	PPE	PPE+PS	PS	PVC	SAN	TPU
	ABS		+	0	+	+	+	+	+	0	0	+	0	0	0	0	0	+	+	+
	ASA	+		0	+	+	+	+	+	0	0	+	0	0	0	0	0	+	+	+
	PA	0	0		0	0	-	-	-	0	0	0	0	0	-	0	0	-	0	+
	PBT	+	+	0		+	+	+	+	0	0	0	0	0	0	0	0	-	+	0
	PBT+PS	+	+	0	+		+	+	+	0	0	0	-	0	0	0	0	-	+	+
	PC	+	+	-	+	+		+	+	0	+	+	-	0	0	0	0	-	+	0
	PC+ABS	+	+	0	+	+	+		+	0	+	+	0	0	0	0	0	-	+	+
	PC+PBT	+	+	-	+	+	+	+		0	+	+	0	0	0	0	0	-	+	+
	PE	-	-	0	-	-	0	-	-		-	-	-	+	-	0	-	0	-	0
	PET	+	+	0	+	+	+	+	+	0		0	0	0	0	0	0	0	0	0
	PMMA	+	+	0	-	-	+	+	+	0	0		0	0	0	0	0	0	0	0
	POM	0	0	0	0	0	-	-	-	0	0	-		0	0	0	0	0	0	0
	PP	-	-	0	-	-	-	-	-	0	-	-	-		-	0	-	0	-	0
	PPE	0	0	0	0	0	0	0	0	0	0	0	0	0		+	+	-	0	0
	PPE+PS	0	0	+	0	0	0	0	0	0	0	0	0	0	+		+	-	0	0
	PS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+		0	0	0
	PVC	+	+	-	-	-	-	-	-	0	-	+	+	0	-	0	0		+	+
	SAN	+	+	0	+	+	+	+	+	0	0	+	0	0	0	0	0	+		0
	TPU	+	+	+	-	+	+	+	+	0	+	+	+	0	0	0	0	+	+	

ABA: Acrylonitrile-butadiene-styrene
ASA: Acrylonitrile-styrene-acrylate
PA Polyamide
PBT: Poly (butylene terephthalate)
PC: Polycarbonate
PE: Polyethylene
PET: Poly (ethylene terephthalate)
PMMA: Poly (methyl methacrylate)
POM: Poly (oxymethylene)
PP: Polypropylene
PPE: Poly (phenylene ether)
PS: Polystyrene
PVC: Poly (vinyl chloride)
SAN: Styrene-acrylonitrile
TPU: Thermoplastic polyurethane

\+ Good compatibility over wide range of mixtures

\- Incompatible

0 Limited compatibility for small excess component amounts

It is important to mention that the morphologies of ICT waste are very complex. They include wires, cables, springs, plates, fragments, and fine powder. Most metallic items are coated with a different metallic or non-metallic material. Some metallic wires are encapsulated in plastic cables or embedded between plastic boards. Except for copper,

most of the metals are in alloys or trapped among other materials. Such conditions may highly decrease the degree of liberation and extraction efficiency [21].

6.5. Potential for ICTs to enhance circularity during the end-of-life phase

Interviews with three WEEE recycling companies were conducted. The objective of these interviews was to determine if full material declarations (FMD) and ICT tools could be useful to support – or even improve – their WEEE recycling processes. The interviewed companies were the C-SEERVES project partners, Greentronics and Indumetal Recycling, and ADVA's contract recycling partner in Germany, TDE Recycling GmbH.

Regarding FMDs, TDE Recycling GmbH affirmed that these could be useful for the [20]:

1. Avoidance of conflict with downstream recyclers
2. Omission of complex WEEE analyses
3. Avoidance of discrepancies between customer information and analysis results.

In return, Greentronics and Indumetal Recycling do not find FMDs helpful. This is because material declarations do not provide the complete data required to implement a proper EEE product's End-of-Life procedure (for instance, disassembly instructions, reusable parts, etc.). These companies need information that considers their recycling business needs, and not just data focused on the manufacturer's needs.

Regarding ICT tools, Greentronics stated that they have already implemented an ICT tool for their EoL procedures. In this tool, the manufacturer creates and constantly updates a database with the parts and subassemblies of interest. These components are identified by a barcode label. The database is accessible through an application installed on a computer/tablet at the recycling company premises. When the label is scanned by the recycler, the application indicates if the component is suitable for reuse. The components that are suitable for reuse are returned at a cost to the manufacturer. The rest of the parts and materials enter the normal waste stream of the recycling company [18]. On the other hand, Indumetal Recycling stated that they do not have industrial experience with the implementation of ICT tools for recycling. Their experience with these tools comes from their participation in the C-SEERVES research project. This company confirmed that an ICT tool could be useful for 1. giving information/instructions about the presence of hazardous components, their locations, and the dismantling procedure, 2. providing information/instructions about the presence of spare parts or components, their locations, and the dismantling procedure, 3. giving information about how to check the quality of spare parts in order to assess whether they are acceptable for reuse or not, 4. creating an identification code, e.g., QR or barcode, to trace the recovered spare parts. This barcode could be stuck in the packaging [19].

To summarize, WEEE belongs to a waste group with high recycling potential. After disassembly, the materials can be recycled, bringing economic and environmental benefits. The critical issue in the reverse supply chain is the exchange of information between manufacturers of EEE and disassembly plants about products entering the

market, the raw materials, and the hazardous substances used. That is why the facilitation of material inventory data exchange between manufacturers and disassembly plants is essential. Such data can be useful at the disassembly stage to make decisions about what kind of strategy or disassembly variant should be selected [22]. ICT tools can facilitate a reliable and up-to-date product information exchange. Moreover, they also help with the mitigation of human and environmental risks, reduction of costs [23], and in general, the enhancement of circularity during the EoL phase of EEE products. Actually, the three companies agree it is practical to have an ICT tool that provides complete information about the product. However, even though they have similar activities, their recycling process approach is different. Therefore, since we found different messages from the recycling companies, we recommend further investigation into this topic.

The final content of ICT tools in the EEE value chain remains unclear for now. This is partially due to the fact that we got contradicting statements regarding the use of FMDs in ICT tools. This requires further work, which ultimately will lead to the so-called Digital Product Passport (DPP). Despite the complexity of FMDs, ADVA believes that they can be useful in recycling. One associated problem is that so far, it is very difficult to compile a 100% complete FMD for complex products. This is mainly due to the fact that in Particular small components suppliers often are not in a position to deliver FMDs. In case FMDs become part of the DPP, care must be taken to avoid prohibitive cost in particular for small suppliers.

6.6. References

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7. TV sets and displays demonstrator

The activities conducted in the end-of-life phase were derived from the TV-CIRCMODE short-term actions validated in WP2. The final list of short-term CE actions to be implementated in WP4 were selected based on SMART objectives at the end of the CEBM validation process and included in D2.5. The table below presents the TV-CIRCMODE canvas sub-components and their validated short-term CE actions corresponding to the end-of-life phase, as presented in Table 24 in D2.5.

Table 10. Validated short-term TV-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the end-of-life phase.

TV-CIRCMODE Canvas Sub-Component	TV-CIRCMODE validated short-term Circular Economy Actions
TV_C1.1 Diversify circular activities	TV_A1.1.5 Devise a strategy to collect and remanufacture end of use TV sets
TV-C1.4: Develop circular logistics and distribution	TV_A1.4.1 Enable collection of TVs back from customers with a partner in Europe
TV-C1.5: Provide Repair and Maintenance Services, Including Using New Tech Such as 3D Printing	TV_A1.5.1 Use 3D printing for TV components
TV_C1.6 Optimise end-of-life circularity	TV_A1.6.2 Increase circularity of TV waste plastics
TV-C1.7: Implement and/or enhance practices and tools to track materials and components	TV_A1.7.1 Enable traceability of remanufactured TV parts
TV-C2.2: Develop circular economy enhancement skills and training programmes	TV_A2.2.1 Develop dismantling and repair training programmes
TV-C2.3: Introduce and/or expand the use of ICT to foster circular economy	TV_A2.3.1 Use QR codes to provide information about materials and company's circularity to all the value chain
TV_C3.3 Address partnerships' cultural issues that would encourage circular economy business models to be widely adopted	TV_A3.3.1 Create awareness among TV B2B consumers via the help of QR codes inserted in products
	TV_A3.3.2 Capture customer feedback on the use of circular economy business models
TV_C4.1 Adopt circular economy activities to suit B2B and/or B2C ensuring customer segments are wide and varied to capture additional market	TV_A4.1.1 Expand partnerships with Arçelik dealers and retailers to sell remanufactured B2C TVs
TV-C4.3: Target B2C different social classes and various demographic segments with offerings tailored to different price brackets	TV_A4.3.1: Target low-income customers, such as students, pensioners, for the sale or rent of refurbished TVs
TV_C7.2 Introduce and/or enhance offerings of leased, rented or shared product options	TV_A7.4.1 Develop circular end-of-life recovery strategies for end of use TVs outside Turkey

CE actions TV_A1.1.5, TV_A1.4.1, TV_A2.2.1, TV_A4.1.1 and TV_A4.3.1 are all related to the development of a new business line to recover, refurbish and give a second life to used WMs and TVs with Emaús in Spain and are covered in section 7.1.

CE action TV_A1.5.1 is related to the testing of the 3D printing technology to facilitate refurbishment operations and is described in Section 7.2.

CE actions TV_A3.3.1 and TV_A3.3.2 are related to the customer feedback collection at the living labs and covered in section 7.3.

CE actions TV_A1.6.2 and TV_A7.4.1 are related to the dismantling operations to improve the recycling process and obtain eco-design proposals and described in sections 7.4 and 7.5.

CE actions TV_A1.7.1 and TV_A2.3.1 are related to the testing of ICT tools to support EoL operations and described in section 7.6.

7.1. Improve and expand repair and refurbishment operations

7.1.1. Preparation for Refurbishment experience

Emaús has developed refurbishment processes and carried out trainings for Emaús workers through a collaboration with Telenis, a company dedicated to providing technical services to electrical appliances for Beko in Spain.

The refurbishment protocols have been established in order to standardize the most common operations and the most profitable ones. Below it is shown an example (the rest of the procedures can be found in Annex 3).

1. The TV will be placed in a flat and protected surface to avoid damages to the panel. Unscrew back cover.	

2. Continue unscrewing the screws of the main PCB cover.	
3. Continue with the screws that hide the threads where a wall support would be fixed.	
4. In some models we can find screws with difficult location as shown in the picture.	
5. Once all screws are unscrewed, back cover should be removed. All parts that need to be removed to access the LED bars should be disassembled.	

6. Unplug and disassemble the speakers.	

The training on the development and implementation of new refurbishment procedures did not only expand the knowledge of the technicians, the training was also useful and applicable to WEEE refurbishment procedures in general.

The actions taken have benefited EMAUS in terms of improvement of the protocols. Thanks to the actions carried out, the WEEE refurbishment/recovery rate was increased from 3% to 3,5% which is above average.

It has been observed that the washing machine refurbishment process is more suited to the EMAUS employees who risk social exclusion instead of TV recovery because of the technical difficulties in TV recovery process. In case of TV refurbishment, procedures of TVs are more meticulous and delicate, taking longer to be refurbished. Certain process guidelines should be followed to prevent accidental discharge. Additionally, special equipment must always be used to prevent the transmission of static electricity when refurbishing electronics. These requirements make operations more complex as some operations require specific knowledge of electronics.

All refurbished TV components such as PCB, plastic covers, plastic stand, led bar, cables, led modules speaker boxes that have been subjected to the refurbishment process have proved to be feasible in terms of profitability, software update being the easiest one.

As a conclusion on TV refurbishment procedures and guidelines, the refurbishment process of TV's is more complex compared to washing machines. Due to the technical expertise required as well as the safety concerns related to the refurbishment of the TVs, machinery investment as well as technical competency trainings for employees is needed.

Potential to implement eco-design for repair/refurbishment

To determine potential eco-design measures to be implemented in the TVs for ease of use and repair, Telenisa (Beko's technical service support company in Spain) has carried out a technical study reviewing of all its components from the point of view of the technician in charge of repair or refurbishment operations. Below some of the aspects that have been studied:

1. Selection of equipment by technology

1.a- Some manufacturers specify the technology used by the equipment in their labels.

1.b- Plasma TV: By touch it can be detected that a plasma screen does not flex. The weight of this equipment is usually much higher than any of the other two technologies at equal inches, as well as its power consumption.

Figure 61. Plasma vs. LED display in terms of energy consumption

The advice is against the recovery of this technology (plasma).

Between LCD and LED equipment there are few aesthetic differences, they usually have a similar weight and both types of screen flex to the touch. The most significant difference may be the thickness of the equipment, with LED technology being thinner in most cases.

1.c-Through the Internet you can get a lot of information about the meaning of the letters and numbers that make up the model of the equipment, especially in the most popular brands.

2. Equipment recovery

2.a-Verify fault: It is fundamental for the diagnosis and later repair the clear observation of the fault affecting the equipment. It is necessary to be rigorous in this aspect, avoiding guesses at the failure and changing a piece just in case.

2.b- Determine the faulty PCB: A minimum knowledge is needed to determine which components or boards are the cause of a fault.
As a very general and approximate rule, in both technologies the most frequent failure is the absence of image.

LED: The most frequent cause is a problem in the LED backlight.

LCD: The most frequent cause is a problem in the Inverter PCB.

Excluding these two incidents in both technologies will tend to fail more power stages and to a lesser extent the PCB MAIN.

Once the repair is finished, it is necessary to verify the correct general operation of the equipment, to verify reception of DTT and satellite (if available) all inputs (HDMI, SCART etc ...) and the functionality of the Smart Tv (if available).

It is also advisable to have an electrified shelf to test the equipment for a few hours.

2.c- Disposal of equipment for scrapping: The direct recommendation is not to recover equipment with plasma technology.

Equipment with screen damage (thin vertical or horizontal lines, stripes, etc.) will be discarded, as well as screens with physical damage (blow), since the replacement of the screen is very expensive.

The impossibility of finding spare parts (due to lack of supply, model disappearance etc.) may lead to discard the equipment in some cases.

Below is a general image of an LCD and LED TV panel.

Figure 62. Plasma vs. LED display

3. Storage and identification of recoverable materials.

It is very useful for future repairs to have recovered spare parts. The boards coming from discarded equipment should be stored in suitable conditions. There are different ways of classification, by brand and model, part code etc.

If lacking experience, perhaps the most effective method is to store all material from the same equipment together (e.g., in boxes) and leaving the equipment's own label as identification.

It should be taken into account that there may be materials common to several equipment models of the same inches and brands.

Normally all manufacturers have their own coding for the materials they use. The use of the internet and spare parts supplier sites are very helpful in all matters relating to PCB identification.

Based on Arçelik's own expertise in its refurbishment centres, the LCD panel has the highest exchange rate among other components. As one of the most critical components, it becomes extremely important to diligently dismantle the product without harming the panel so that the panel can be recovered if possible.

Based on information provided also by dismantlers, the recovery of the LCD panel is extremely important as well. It has been observed that the connectors of the electronic board to the LCD panel cannot be removed without damaging the LCD panel. Removing the LCD panel is a process which takes time and effort and requires expertise. If the wild cables attached to the LCD panel are damaged, this makes the whole panel useless and therefore great care should be given not to damage these cables in order to enable the recovery of the LCD panel.

The risk of electric shock during the dismantling process coupled with risk of static electricity damaging the sensitive electronic circuits as well as the high risks of harming the LED panel due to extremely sensitive connectors, TV repairing process takes more time and effort and is more risky compared to washing machine repair process and in terms of recovery of components, applying an eco-design for TV's becomes even more critical and the items discussed above show that the highly complex recovery process has further room for improvement at the design stage.

7.2. Collect customer's feedback (living labs)

The description of the living labs can be found in section 4.3. The living labs were carried out jointly for WMs and TVs, although separate surveys were prepared and distributed among the participants to gather feedback related to refurbished products and renting or leasing models.

Results of the survey for the TV living lab experience can be found in Annex 3.

7.3. Use 3D printing for refurbishment or customisation

7.3.1. Selection of suitable parts/components for 3D printing tests

During the TV demonstration period, Particula worked in cooperation with Arçelik and Gaiker to develop a methodology to obtain and validate 3D printed TV sets spare plastic parts (stands). After receiving samples from plastic materials used for TV stands from Arcelik while visiting the premises in Istanbul in February 2020, 3D scanning was applied in order to determine most suitable 3D printing technology for the TV stands parts. As for the washing machine parts, PARTICULA received three-dimensional objects (3D objects) in digital format (.stp CAD file) that were then converted into suitable digital formats (.stl) to inspect in the slicer software and finally produce the suitable G-code format.

Configurations and several tests were conducted in order to prepare appropriate file formats (.stl) and to determine the most suitable technology for trials and 3D printing TV sets and displays.

In February 2020 Particula managed to visit Arçelik headquarters to arrange and elaborate R&D tasks within WP4 and ways to produce optimal 3D printing parts and to select and receive the most suitable models to create the final prototypes using suitable printing technology takin into consideration model's characteristics, the object to print, the quality and the cost required. On-site visit to Arçelik premises in Istanbul showed to be very important for understanding of possibilities for including 3D printed parts into TV sets and displays prototypes.

Before selecting the suitable parts Particula conducted several testes with ABS based plastic filaments, and PETG filaments. Material choice can affect certain aspects of the design, and that was taken into consideration for the test results. After another set of testing trials, scanning the functionality of the models, and surface, optimization, and selection of the proper 3D printing technology, PARTICULA conducted tests on several 3D printers (Prusa i3 MK3 and Zortrax M200).

Trials have resulted in relatively good results with low cost FDM 3D printers. Finally, Particula selected the most suitable parts for the 3D printing technology for TV sets and displays demonstration sent by Arçelik: 1. TV stand left and 2. TV stand right. Both parts are shown in Figure 63.

Figure 63. Selected and suitable TV parts for 3D printing

7.3.2. Results from 3D printing tests

Off-the-shelf filaments 3D printing tests

The main point of the test trials was to establish the right protocol and to optimize the slicer options and functions in order to properly adjust the standard and advanced settings to deliver very complex and challenging to print, 3D printed models using FDM 3D printing technology – printing layer by layer. During the trials Particula experimented with the slicer software settings adjusting the right layer thickness, the better quality of a 3D print, fine-tuning to get to know printer and filament choices, changing and adjusting one setting option at a time before conducting a new print, tracking the changes and progress of how the new print differs from previous one, testing different temperature of the nozzle, Z offset and bed adhesion properties (conducting tests on different surfaces using adhesive products such as spray, glue and other adhesives). Particula tested and adjusted slicer properties to convert a 3D model into the instructions G-code.

Particula also conducted optimization in 3D print slicer programme to add proper support materials, to customize support material and save the filament, adjusting too long bridge or the too high angle of an overhang to avoid sagging due to the very demanding 3D models.

After the first trials and printed models with PLA, ABS, PETG, rPETG, Facilan C8, Particula coordinated with EEE manufacturers and WEEE managers in Arçelik and focused on their feedback on the production of the product, their quality and functionality. After the feedback and first testing period in Arçelik, first results of the tests showed that the selection of rPET and PETG filament are the most suitable for TV sets and display spare plastic parts production.

Particula continued to conduct more tests to adjust the slicer programme settings options and print models with the different infill density and different perimeters. In 3D printing, infill plays an important role in a part's strength, structure, and weight. Also Infill density can significantly affect material consumption and time required to print. SO, to improve strength of FDM 3D prints in several other testing Particula used rectilinear infill, increased infill to a maximum 50 %, increases the number of perimeters, and use thinner layers to 3D print stronger 3D prints models.

Particula delivered the final prototypes (TRL6) to Arçelik, a total of 54 testing models trials using PLA, PETG, rPETG, ABS and Facilan C8 including failed printing models and the ones that were sent to the testing facility in Arçelik for further analysis and testing (mechanical balance and safety tests result, General Configuration/Marking Control, Needle Flame Flammability Test). After the feedback and the first testing period in Arçelik, first results of the tests showed that rPET and PETG filament are the most suitable for TV sets and display spare plastic parts production, the ones that were sent to the testing facility in Arçelik for further analysis and testing (mechanical balance and safety tests result, General Configuration/Marking Control, Needle Flame Flammability Test).

Figure 64. FDM 3D printed prototypes of TV stands

Raw material extruded filaments

In June 2020 standard raw materials for the production of TV sets and display plastic parts were delivered from Arçelik. Particula then conducted compounding in a single-screw extruder to produce filaments for potential 3D printed parts as already described in the washing machine demonstration of this deliverable. In cooperation with Gaiker and Arçelik 3D filaments were produced to be used for TV sets parts and trials were conducted.

Particula conducted tests with successfully extruded black MATERIAL 15, and printed cube model. Angles raised from the work surface; adhesion of larger pieces was questionable. The attempt to print out the larger model in a closed FDM 3D printer due to the better adhesion to the surface resulted with extrusion difficulties, clogged extruder, and high risk of damaging the extruder. The results were oscillations in diameter, brittleness of the material and very easy to crack when bending.

Test trial with raw material black extruded MATERIAL 15

Temperature of the nozzle/bed tested with 243/30 and 245/50 30 °C
Settings: ABS BASED FILAMENT
Layer thickness: 0,29 and 0.09
3D parts printed with a layer thickness of 0.09 mm had a better finish, while those printed with a 0,29 mm layer thickness had a rougher appearance and some parts are not successfully printed.
Temperature nozzle. 243 / 245
Platform temperature: 30 °C / 50 30 °C
Speed – default settings – manually adjusting the speed during the print
First layer gap – 0,25 mm
Platform raft gap – 0,20 mm
Size: 50 % and 30 % of the real size

Figure 65. Test trial with raw material 15 for TV stands

7.3.3. Validation of 3D printed parts/components

A total of 54 testing models were produced during the demonstration with different infill density and different perimeters using PLA (polylactic acid), ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene Terephthalate Glycol), rPETG (recycled Polyethylene Terephthalate Glycol), Facilan C8 and PLA Strongman (polylactic acid) materials.

After the feedback and the first testing period in Arçelik, first results of the tests showed that the selection of rPET and PETG filament are the most suitable for TV sets and display spare plastic parts production, from the ones that were sent to the testing facility in Arçelik for further analysis and testing (mechanical balance and safety tests result, General Configuration/Marking Control, Needle Flame Flammability Test).

3D printed TV stand was printed for customization purposes, and these parts have been tested according to Arçelik standards.

	Mechanical balance and safety tests result	General Configuration/Marking Control*	Needle Flame Flammability Test
Smoked color feet: 1. PETG %20 0.2 part1 2. PETG %20 0.2 part2	OK	NOK	Going on
White color feet: 1. facilan C8 30% infill 2. facilan C8 30% infill	NOK**	NOK	
White color feet: 1. rpetG 30% infill 2. rpetG 30% infill	OK	NOK	
Smoked color feet: 1. PETG infill 30% 2. PETG infill 15% 3. PETG infill 20%	OK	NOK	

First set

The first set of the testing set includes the material and density prototypes below:

1.1. FACILAN C8 material, 30 % infill density

1.2. FACILAN C8 material, rPETG 30 % infill density

1.3. PET G material - 20 % infill density and 0.2 layer

1.4. PETG material - infill density of 30 %, 20% and 15%

Each of the material and density type has failed at the first safety test due to the deformation, bending and crushing of the stand.

Figure 66. 1.1 FACILAN C8 material, 30 % infill density

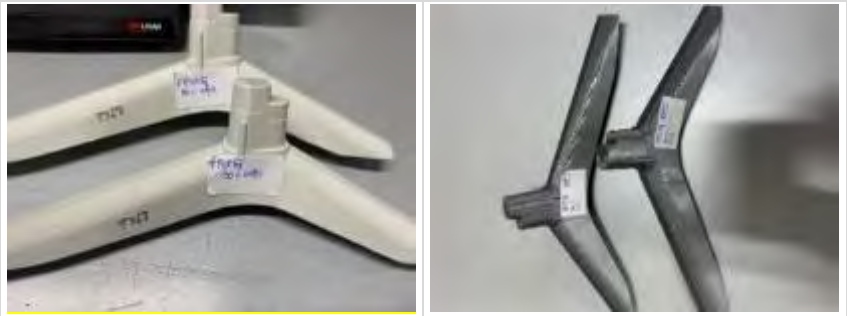


Figure 67. 1.2 FACILAN C8 material, rPETG 30 % infill density (left) and 1.3 PET G material - 20 % infill density and 0.2 layer (right)

Figure 68. 1.4 PETG material - with the infill density of 30 %, 15% and 20%.

Second set

After the failed tests in the first set, a second set of stand samples were tested including diverse material types and rates, see below.

2.1.PETG 30% infill 0.2r PETG

2.2.FACILIAN C8 30% 0.2r

2.3.PETG 30% infill 0.2r, PETG 50% infill 8 perim 0.2 refol

2.4.PETG 50% infill 8 perim 0.2r

2.5.Per 8 PETG %50 infill, PETG D - per8 50% infill

The first sample failed to pass the safety test LVD -Low Voltage Directive (product safety test standard made under IEC 62368-1), therefore the 4 samples left were not completed.

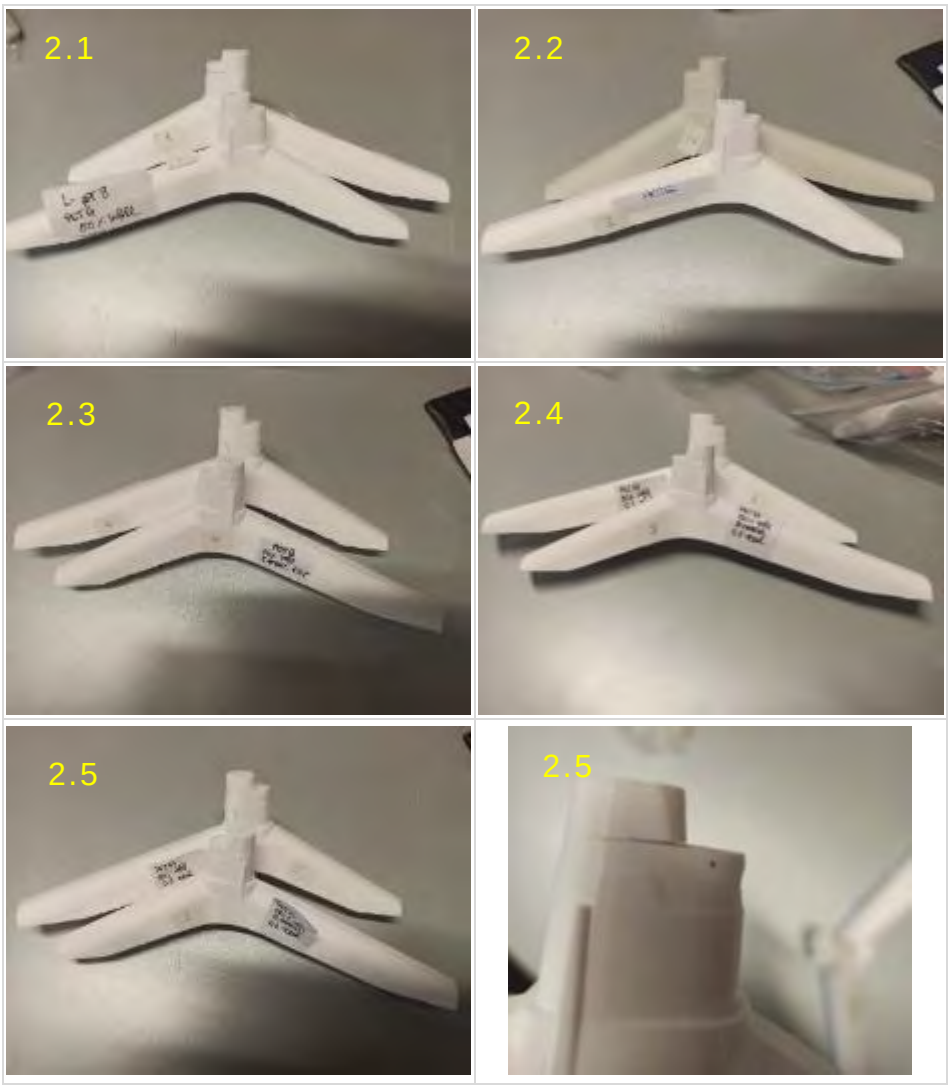


Figure 69. 3D printed TV stand samples 2.1, 2.2, 2.3, 2.4 and 2.5

Conclusions

rPET and PETG filaments are the most suitable materials for 3D printing. However, the formulation developed was too rigid and could not pass the safety tests. The TV stands are critical components in the sense that they carry the weight of the TV and thus it is important that they do not break apart. In the tests, it has been concluded that products with weight >7kg could not pass the tests.

Only the TV stands are suitable for 3D printing in the TV set, which limits the 3D printer usage for the TV plastic spare or customizable parts. With the results obtained, both in terms of cost efficiency and durability of the component, it is not feasible to use the 3D printed parts.

7.4. Improve dismantling and recycling operations

7.4.1. Technical analysis of the recycling and dismantling operations

Greentronics and Indumetal have conducted technical analysis on the dismantling operations of the demo TVs. Five TVs were sent to Greentronics and two TVs were sent to Indumetal for this analysis.

16 different components/parts were considered relevant for potential use as spare parts:

1	Power cable
2	Back cover
3	Plastic stand bracket
4	Wall mount bracket
5	Cable
6	T-con Board
7	Main Board
8	PSU (Power Supply Unit)
9	Loudspeaker
10	Wi-fi Board
11	Front plastic cover (front frame)
12	Display
13	Display plastic frame
14	Reflective plastic film
15	Led Bar
15	Remote control

Greentronics and Indumetal analysed this list of spare parts and prepared a dismantling procedure for the demo product, as included in Annex 3. The aim is to facilitate the extraction operations of non-damaged spare parts from EoL TVs and to provide expert advice on design-for-recycling or design-for-dismantling measures to Arçelik.

Greentronics

Grundig G43C 893 5A

DISMANTLING PROCEDURE

Contents

Prerequisite 2
DISMANTLING PROCEDURE 3
Removing the power cord 3
Removing the back cover 4
Removing the leg holders 5
Removing the speakers 6
Removing the Wi-Fi board 6

INDUMETAL RECYCLING

Arçelik

DISMANTLING PROCEDURE FOR TV GRUNDIG G43C 893 5A

Greentronics and Indumetal recorded the dismantling times for selected parts as shown in Table 11 and Table 12.

Table 11. Dismantling times achieved by Greentonics

Code	Part/Component	Time (sec)
1	Power cable	17
2	Back cover	145
3	Plastic stand bracket	54
4	Wall mount bracket	26
5	Cable	43
6	T-con Board	13
7	Main Board	27
8	PSU (Power Supply Unit)	22
9	Loudspeaker	8
10	Wi-fi Board	11
11	Front plastic cover (front frame)	51
12	Display	50
13	Display plastic frame	83
14	Reflective plastic film	25
15	Led Bar	44
15	Remote control	10
TOTAL		**629**

Table 12. Dismantling times achieved by Indumetal

Code	Part/Component	Time (sec)
1	Power cable	13
2	Back cover	251
3	Hoparlor	26
4	Main board	67
5	PSU	39
6	T-con Board	25
7	Wi-fi/Bluetooth board	25
8	IR LED board	104
9	Front cover	138
10	Display	2
11	Mid frame	67
12	Plastic films	3
13	LED bar	20
14	Metallic housing	0
15	Remote control	0
16	Battery	0
18	Fasteners (time already included in each component)	0
TOTAL		**780**

A TV was disassembled before the exercise to establish the logical disassembly order of the indicated components and identify them in conjunction with the disassembly manuals.

On average, it took 10,5 minutes and 13 minutes to Greentonics and Indumetal respectively to disassemble the full list of components.

Both recyclers provided their comments on the experience related to the dismantling of the TV (see Annex 3). Some examples are shown below:

[GREENTRONICS] Removing the LCD panel was challenging and required 2 people and patience. In the LCD panel removal process, the wide cables that connect the panel to the thin electronic board are critical and should be dealt diligently so that they are not damaged. Damaging the wide cables damages the whole panel and renders the panel useless. Thus, it needs to be handled very delicately.

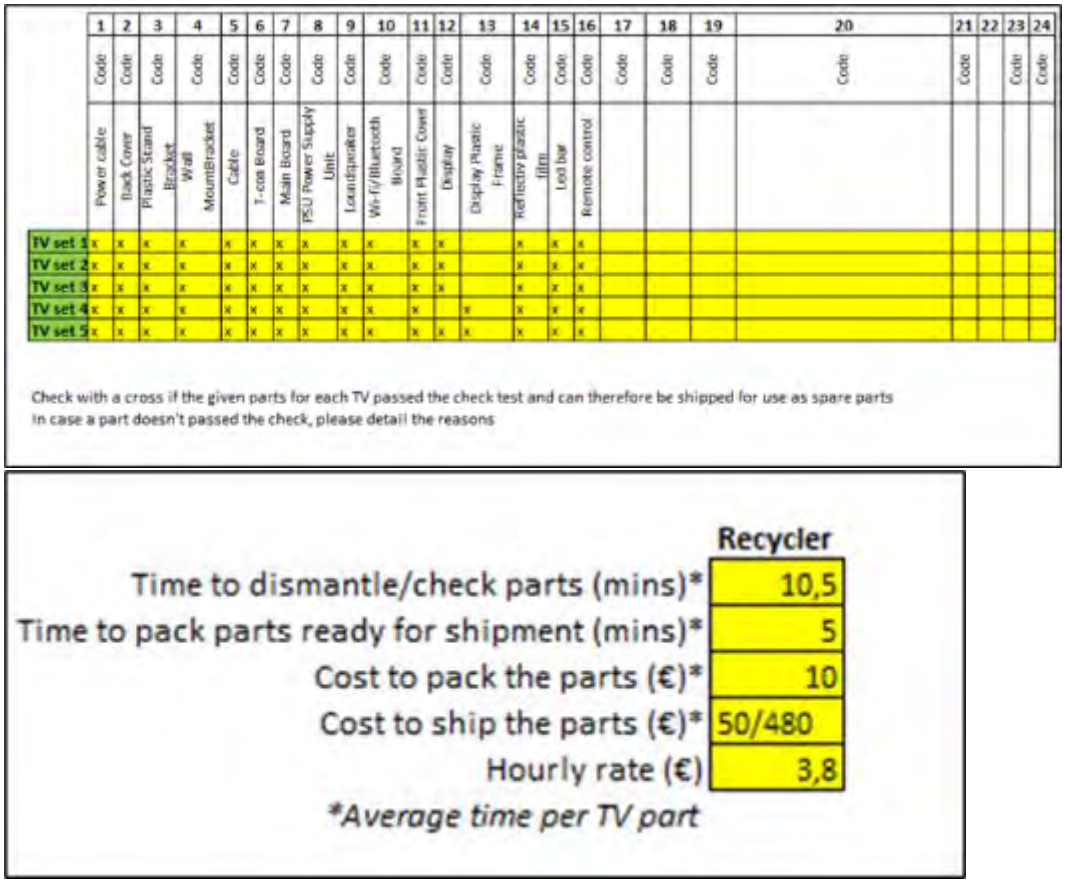
[INDUMETAL] In all dismantled TVs, the mid-frame is recovered in a broken state and two persons are required to do it.

Considering that the panel is the component that is most damaged in the TVs, it can be concluded that the recovery of second-hand panels requires a rather meticulous process.

In the business-as-usual scenario, recyclers do not receive WEEE in good conditions. This reduces the potential to recover spare parts. Therefore, from a circularity and recovery of components perspective, it makes more sense for repair companies to have special operations to work on the recovery of components before the product becomes waste.

7.4.2. Cost and price analysis of the recycling and dismantling operations

A dismantling template was used to analyse the cost of recovering pre-selected TV parts/components based on time/human labour/shipment costs. The template was completed by both recyclers, and it is detailed in Figure 70 and Figure 71.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code		Code	Code
	Power cable	Back Cover	Plastic Stand Bracket	Wall MountBracket	Cable	T-con Board	Main Board	PSU Power Supply Unit	Loundspeaker	Wi-fi/Bluetooth Board	Front Plastic Cover	Display	Display Plastic Frame	Reflectiv plastic film	Led bar	Remote control								
TV set 1	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x								
TV set 2	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x								
TV set 3	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x								
TV set 4	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x								
TV set 5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								

Check with a cross if the given parts for each TV passed the check test and can therefore be shipped for use as spare parts
In case a part doesn't passed the check, please detail the reasons

	Recycler
Time to dismantle/check parts (mins)*	10,5
Time to pack parts ready for shipment (mins)*	5
Cost to pack the parts (€)*	10
Cost to ship the parts (€)*	50/480
Hourly rate (€)	3,8

Average time per TV part

Figure 70. Dismantling template completed by Greentronics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code		Code	Code
	Open Cell	Back Cover	Front Cover	Touch Kit	Mid Frame	Led Bar	Main Board	Led Driver	Bracket	Wi-fi/Bluetooth Board	IR Led Board	Card Board	Ferrit	Hoparlor	On/off switch	OPS	Remote Control	Fasteners (Screw, etc.)	**PSU** (Power Supply Unit)	**Other plastics** (Isolator, Lens Plastic, AC-out Cover, Wall Mount Set, Stand, Stand Bracket, Side AV Bracket, Side AV Label, Source Board Cover, silicon, Tape, Label)	Other Metals	Battery	T-con Board	Cable
TV set 1	NA	X	X		X, broken	X	X			X	X		X	X			X	X	X	X			X	X
TV set 2	NA	X	X		X, broken	X	X			X	X		X	X			X	X	X	X			X	X

DATA FOR 1 TV	INDUMETAL
Time to dismantle/check parts (mins)*	13
Time to pack parts ready for shipment (mins)*	21
Cost to pack the parts (€)*	4
Cost to ship the parts (€)*	200
Hourly rate (€)	30

Figure 71. Dismantling template completed by Indumetal

Considering these templates, a comparison (see Table 13) has been done with data provided by Greentronics and Indumetal.

Table 13. Dismantling times achieved by recyclers for the TV set

TV Component Recovery Costs	Greentronics	Indumetal
Time to dismantle/check parts (mins)	10,5	13
Time to pack parts ready for shipment (mins)	5	21
Cost to pack the parts (€)	10	4
Cost to ship the parts (€)	480	200
Hourly rate (€)	3,8	30

Results from this analysis show that:

- the average time to recover a spare TV part is 11.45 minutes, although experience is a relevant parameter in this operation
- significant differences are found for packaging times of the components between both recyclers, probably due to lack of specific instructions on packaging requirements
- the average cost for part packaging is EUR 7
- shipping costs vary significantly, in the Greentronics case considering two destinations: Arçelik's subsidiary Arctic Plant in Romania or Arçelik facilities in Istanbul. Since Arçelik does not have a TV facility in Romania, it does not make business sense for Arçelik to use the recovered components as spare parts in Romania
- taking into account the hourly rate, the difference between both countries is very relevant and therefore this is a critical issue that would require further analysis

As it can be seen in the table above, the two recyclers had very different figures provided with respect to the cost of shipment of components to Turkey and the hourly rates as well as the time to pack parts ready for shipment and the cost to pack the parts.

Conclusions

- The feasibility of using recovered components as spare parts or as parts in refurbished products can change based on logistics costs, labour costs, packaging costs.
- Due to the regulations, manufacturers of EEE products are not allowed to use refurbished parts in a brand-new product. From Arçelik's perspective, the recovered products can only be used as spare parts to be sold to customers with declaration provided to customers that these parts are reused parts.
- Due to the above considerations, from Arçelik's perspective it does not make sense to ship the parts to Arçelik TV factory in Turkey because Arçelik already has its own refurbishment centre in Turkey and the costs are very competitive compared to the ones indicated by either Greentronics or Indumetal.

- Arçelik does not have TV sales in Romania, but it has TV sales in Spain. Therefore, if Arçelik and Emaus could invest together in the recovery of TVs, this can promise to be a value added future business line.
- It might make sense for organizations like Emaús to use the recovered components during refurbishment of the products but it all depends on the feasibility of comparing the cost of using a brand new component vs buying a recovered component. In this regard, the logistics cost matters the most, followed by labour cost. It seems highly likely that in order to increase the recovery rate of the products and the reuse rate of the products, an infrastructure should be developed with potential incentives from governments so that the recyclers can establish new business lines focusing on the recovery of the components and cooperate with repair companies like Emaús for the use of such recovered components. It makes business sense that such establishments are located in close proximity for the sake of cost reduction.

7.5. Improve material circularity of the TV sets

Within the TV set demo Arçelik has performed a case study on the potential to use recycled plastics from EoL devices outside Turkey. The main objective of the study was to analyse the technical feasibility of reusing ABS or PC-ABS from end-of-life TV sets and incorporate the recycled plastic material into new TV parts. With this case study, Arçelik intends to explore the potential to increase circularity in its business model.

Therefore, the aim of this exercise is to evaluate the technical feasibility of using recycled resins from end-of-life flat TV panels collected by a European partner (in this case Indumetal) as secondary raw material to be incorporated in new Arçelik product parts.

At the beginning of the study, two plastic material streams from end-of-life TV sets were identified as potential candidates for recovery and reuse: ABS and PC-ABS.

Flat TV panels from end-of-life TV sets were collected by Indumetal at their facilities. Since Indumetal receives all kind of brands together and sorting them is an added difficulty, it was decided to use a mix from the flat TV panels in the WEEE stream.

In a first step, Indumetal sorted the flat TV panels selecting only ABS and PC-ABS back covers and frames, separated into different streams for processing. The two batches, ABS and PC-ABS (around 35 kg each) were sent to Gaiker to be processed.

Figure 72. Selection of TV parts at Indumetal for recovery of recycled plastics

In Gaiker, all parts were checked to ensure only ABS and PC-ABS was processed. The process steps were the following:

- Manual sorting: removing stickers, remaining metal pieces, screws etc.
- Shredding: size reduction to about 15 mm.
- Metal separation: elimination of remaining ferrous and non-ferrous particles or inserts using eddy current + magnetic overband.
- Grinding: size reduction to about 8 mm.
- Fines removal: elimination of dust and fine particles by air sifting.
- End-processing: washing, drying, melting, compounding.

The flakes obtained from TV parts were a mixture of black and grey colours.

Figure 73. PC-ABS flakes (left) and testing specimens (right)

The plastic flakes were also analysed for any content of restricted substances with X-ray fluorescence (XRF) analysis. This analysis showed that the PC-ABS material did comply with the relevant applicable regulations. However, for the ABS material the analysis showed some flakes seemed to have high Bromine content. Although this could be due to just a few processed TV parts containing high Br, it rendered the recycled material unsuitable for utilisation. Thus, the ABS batch was not further processed.

Gaiker then carried out a characterisation of the PC-ABS batch to compare the properties of recycled PC-ABS material obtained from EoL TVs with the properties of virgin PC-ABS used for the Arçelik TVs.

The following tests were performed:

- DSC (Differential Scanning Calorimeter)
- MFI (Melt Flow Index)
- Tensile strength at yield
- Elongation at yield
- Young modulus
- Izod impact strength
- Vicat Softening Temperature, /B
- Heat Deflection Temperature, HDT/A

The results are shown in the table below.

Table 14. Characterisation of recycled PC_ABS from EoL TV flat panels.

	STANDARD	ACCEPTANCE LIMITS PC/ABS/V0	RESULTS OF RECYCLED PC/ABS
PHYSICAL PROPERTIES			
Density, g/cm^3	ISO 1183	1,2	1,20
Melt Flow Rate, g/10'	ISO 1133	15 - 27	16
THERMAL PROPERTIES			
Vicat Softening Temperature, /B	ISO 306 /50N	87	94
Heat Deflection Temperature, HDT/A	ISO 75 /1,8MPa	70	80
MECHANICAL PROPERTIES			
Flexural Modulus, MPa	ISO 178	2500	2580
Tensile Strength at yield, MPa	ISO 527	55	47,7
Young Modulus, MPa	ISO 527	2300	3010
Elongation at yield, %	ISO 527	3,5	3

The tests provided positive results and are compliant with Arçelik specs except for mechanical properties such as tensile strength and elongation at yield. These properties can be improved to meet Arçelik's standards by including virgin materials and reformulating.

This study has shown a potential for Arçelik to use recycled PC ABS from recovered TV back covers. Arçelik's TV plant is located in Turkey and Turkey restricts the import of recycled raw materials. Therefore, although using the recycled raw materials recovered by Indumetal would prove to be a very viable option if Arçelik would be able to import recycled raw materials, in practice, this is not possible due to the regulation in Turkey. On the other hand, Arçelik has its own WEEE recycling plants in Turkey and the products collected from the market regardless of their brand are manually dismantled in these facilities. The PC_ABS raw material coming from Arçelik's own WEEE plants in Turkey can be recycled and recovered to be used in TV back covers. There is only one issue to be

careful of, which is the TV eco design regulations restricting halogens in plastic parts. Because the TV plastics need to be flame retardant, some producers might use halogens although the use is restricted. Arçelik will need to apply chemical tests to check that the parts recovered does not include halogens. This is a costly process and increases the costs of using the material.

7.6. Use ICTs to enhance TV set's circularity during the end-of-life phase

7.6.1. Smart questioning demo

The demonstration of the Circularise Smart Question Technology was conducted in a similar fashion for the washing machine and the TV demonstrator of Arcelik. With this demonstrator, Circularise aims to provide data about the materials, sustainability parameters and production process of any product. This supply chain transparency is crucial in order to:

a) mitigate supply chain risks and make supply chains more resilient and European manufacturers more independent from externally imported raw materials

b) enable customers and political decision makers to understand more about the sustainability of products in order to make decisions for sustainable products

c) conduct circular economy by knowing how to repair, refurbish and recycle the product and material

d) assess the safety and quality of products

The system allows doing so by decentralising the responsibility of providing reliable, up to date data about each step of the supply chain. This is done by distributing the responsibility of reporting about materials and production processes along the supply chain and connecting this information via a trusted system which keeps supplier identity and concrete subcomponent recipes protected.

The use of composition data

Circularise and Arcelik identified the five components of the TV as PC, Back Cover, Reflector, Open Cell and Back Panel. The suppliers for each of the components was then either onboarded on the Circularise system or represented by an account manager from Arcelik knowledgable about the component and its exact composition. The suppliers or representatives then each created a smart pledge containing the exact chemical composition of the component on the Circularise system. This smart pledge was then transformed into an encrypted link to the original composition data. This reflects the chemical composition to be safely communicated.

Total weight of the product: 5.9kg

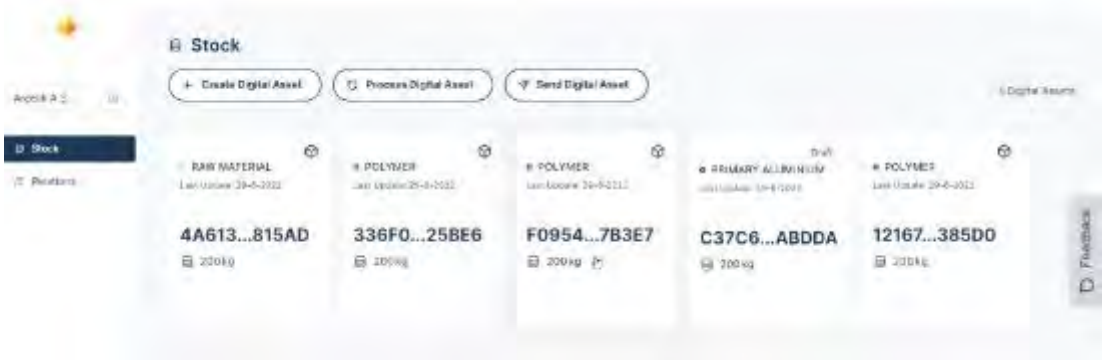
Part	Weight	Raw material	CAS Number
PC	2kg	ABS	9003-56-9
Back Cover	2kg	Plastic, Polyethylene	9002-88-4
Reflector	0.1	Plastic, Polyethylene	9002-88-4
Open cell	2kg	Silica Glass	60676-86-0
Back Panel	2kg	Metal, Aluminum Alloy	91728-14-2

Part	Raw material	CAS Number
PC	ABS	100-41-4 108-95-2 108-90-7 107-13-1 100-42-5 106-99-0 100-40-3 98-54-4 115-86-6 24936-68-3 9003-56-9 181028-79-5 9003-56-9 9003-54-7 68928-70-1 103598-77-2 25971-63-5 5945-33-5 65997-17-3
Back Cover	Plastic, Polyethylene	100-41-4 108-95-2 108-90-7 107-13-1 100-42-5 106-99-0 100-40-3 98-54-4 115-86-6 24936-68-3 9003-56-9 181028-79-5 9003-56-9 9003-54-7 68928-70-1 103598-77-2 25971-63-5 5945-33-5 65997-17-3

Reflector	Plastic, Polyethylene	100-41-4 108-95-2 108-90-7 107-13-1 100-42-5 106-99-0 100-40-3 98-54-4 115-86-6 24936-68-3 9003-56-9 181028-79-5 9003-56-9 9003-54-7 68928-70-1 103598-77-2 25971-63-5 5945-33-5 65997-17-3
Open cell	Silica Glass	60676-86-0
Back Panel	Metal, Aluminum Alloy	91728-14-2

The public dashboard

The encryption of the material data alone was only the first step of the demonstration. The second requirement that had to be fulfilled was the quantification of the material created. The chemical composition of the material had to be linked to actual physical material that is being supplied to Arcelik in the quantity that it is actually being produced and supplied. In order to do so, each supplier created an amount of material on the system, called digital asset. This digital asset represents the batch of a normal production process of the supplier. The digital asset functions as a digital twin of the physical material. The digital assets created were the five components PC, Back Cover, Reflector, Open Cel, and Back Panel.



The amount of the material that is sold to Arcelik is then transferred to Arcelik with the encrypted fingerprint of composition data added to it. Arcelik received the components and added them with the ratio of the material amounts in the final product to their production process.

The production process of the final assembly was then logged on the Circularise system to create the digital asset of the final product in the exact quantity of production.

The query of data

As a result the data of the product is accessible to anyone who receives the material or product as part of their role along the supply chain. When selling or sending the final product, Arcelik sends the digital asset in the ration of sold TVs to the customer. The customer, refurbisher, repairer or recycler can then access the data of the product via the smart question technology to find out what materials are prevalent in the product and how the material flow of the whole supply chain is constituted. This allows stakeholders to take decisions based on reliable material data and ad-hoc answered questions by suppliers of the supply chain anonymously. The suppliers remain the owners

of the data with the opportunity to fine-tune how much data is shared with whom. The smart questioning technology enables the sharing of specific answers to pressing questions in the repair or recycling process without sharing the full material information.

7.6.2. Information exchange platform

The information is accessible to all approved accounts connected to Arçelik's account and it makes possible to share information related to dismantling and repair operations with organisations such as Emáus, or recyclers such as Greentronics. This facilitates communication in a secure environment and can also connect to the Rina-C tool for logistics operations when shipping of materials or parts is required, and to the Circularise tool to request information on the bill of materials, recycled content of the washing machine parts, etc.

Due to the Ecodesign regulations in Europe, Arçelik uploads similar documents on their website. For countries outside of Europe, using the Soltel platform can be a quick and practical solution.

In order for this application to be successful, companies in the TV value chain (recyclers, reusers…) should use the documents uploaded by Arçelik. Arçelik can answer incoming questions and this, in turn, can guide Arçelik's new design studies. In this way, modularity can be the focus for new designs. Useful and guiding comments can be given to designers as a target while designing.

8. Conclusions

The final stage of the C-SERVEES demonstrations in WP4 has been focused on the implementation of specific short-term circular economy actions for the end-of-life phase in each of the four product-specific CEBMs developed in WP2, which were presented as D2.2, D2.3, D2.4 and D2.5. Also included was the testing of the ICT platform integrating the different ICT tools developed in the project, in Particular the testing of the Smart Questioning functionality, the information exchange functionality and the logistics optimisation functionality, all of them supporting the product specific CEBMs at the end-of-life phase to facilitate repair, refurbishment and disassembly operations, optimise logistics for spare parts, enabling secure information exchange across the supply chain and enhance WEEE management.

The main conclusions of this work are listed below:

Washing machine and TV set demonstrations

- A new business opportunity has been created under the scope of the CEBM to prolong the useful lifetime of Arçelik's products outside Turkey, following circular and social economy principles. That opportunity is related to a household appliances eco-leasing model complemented by end-of-use collection, preparation for repair and refurbishment, and reselling to low-income customers. The collaboration agreement would include specific training for workers performing the refurbishment operations, establishing a collection scheme for end-of-use devices, promotion of the refurbished products and consumer education campaigns.
- Results from the livings labs have shown that end users look positively on circular economy and eco-design principles applied to the home appliances and are interested in acquiring refurbished products, with the proposed prices being acceptable, even though doubts are expressed about the durability and lifetime expectancy, in particular for the washing machines.
- Using the 3D printing technology to produce spare parts for refurbishment o repair operations was successful in producing several prototypes according to the design specifications, however the validation tests did not yield positive results, as the prototypes failed under testing conditions.
- A potential line to recovery spare parts from end-of-life devices was explored in collaboration with recyclers, although the economic feasibility is limited by i) the collection scheme for end-of-life EEE, which currently does not support reuse operations, ii) the logistics costs to ship recovered parts or components and iii) the availability of reassessment (preparation for reuse) centres in the vicinity of the recyclers' facilities.

Printer and toner cartridge demonstration

- The outcomes of the demonstration support the technical and economic feasibility of reusing of printer parts from end-of-life printers at the recycler's locations provided the recyclers can adapt to the business case requirements and that they receive suitable printers (according to Lexmark's standards) in their WEEE streams, which may pose a major challenge. ICT tool functionalities have been shown to

provide support for this business case by granting access to essential documentation and facilitating information and feedback exchange.

- Extending the LCCP online platform to printers is an effective way of improving reverse logistics, which is one major factor contributing towards the cost-effectiveness of the refurbishment operations. Enlarging the returned printer flows will enable Lexmark circular economy objectives in Europe to be fulfilled, accelerating the implementation of the proposed CEBM.
- Using recycled ABS from end-of-life printers is shown to be challenging due to the various impurities found in the secondary material after processing. Ensuring the absence of brominated plastic and metal, rubber and ceramic impurities is essential for this path to be successfully implemented in Lexmark's CEBM. Regarding the recovery of ABS from toner cartridges, for now the best circular option continues to be remanufacturing the cartrigdes to maintain their value in the market as long as possible.
- Performance of the printer is the main concern of customers when acquiring a refurbished product, cost being a key element in decision making. Cosmetic issues are generally accepted, a finding which may affect Lexmark refurbishment operation activities.

ALM products demonstration

- The characterization factor developed earlier in the demonstration period, UPR_{10}, has been validated as an indicator of optimum lifetime and replacement times for different EEE, including the other three demo products. UPR_{10} is the ratio of 10 years use-phase GWP (global warming potential) and the production GWP according to LCA. GWP was selected as the most relevant sustainability indicator in the LCA studies performed. Thresholds have been established to determine when a product should be replaced for energy-efficiency and related GWP reasons or should be given long or even extended lifetime, using this indicator.
- Usage of UPR_{10} is relatively simple, compared to conducting full lifecycle assessments since only the production-phase GWP and the use-phase GWP need to be known. This could have relevance for future regulations, establishing different quota for reuse, lifetime extension etc. for different product classes
- UPR_{10} may have an influence on the choice of the most-suitable product-service system (PSS) as the supporting CE business model. In particular, PSS that aim at substantially improving product utilization, e.g., by better sharing, may also lead to substantially increased lifetime energy consumption, thus increasing UPR_{10}.

A summary of the main results obtained in the final stage of the demonstrations is shown in the table below:

Table 15. Main aspects explored and classified according to the potential for future exploitation

Washing machine demo	Printer and toner cartridge demo	ALM system demo	TV set demo
Business line for used WMs outside Turkey	Printer parts recovery and reuse with ICT tool support for data sharing	Lifetime optimisation for ICT products	Business line for used TVs outside Turkey
	Use of secondary plastic materials from end-of-life printers and toner cartridges	Extension of lifetime optimisation + PSS: DSS for EEE products	
3D printing of spare parts	3D printing of non-functional parts		3D printing of spare parts
Use of ICT tools to facilitate EoL activities	Cosmetic issues acceptance	Disassembly guidelines for ICT products	Use of ICT tools to facilitate EoL activities
	Use of ICT tools for logistics optimisation		

COLOR CODING

- ++ Good results
- + Potentially good results
- +/- Unconclusive results
- - Negative results

Annex 1 (ARÇELIK – Washing machine demonstration)

4.1 Improve repair and refurbishment operations

Manuals developed for Emaús 'Preparation for reuse' operations

Technical information:	Version: r1	Date: 26.10.2020

Type:	Refurbishment procedure	
Operation:	BELT REPLACEMENT	
Code	7150341600 DNM C-SERVEES	
Comments:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products.	
	8. Makinenin arka kapak/duvar vidaları çıkartılır. Rear wall (rear panel)'s screws (x5) are removed.	
	9. Makinenin arka kapağı/duvarı açılır. Rear wall is removed.	

	10. Kayış çıkartılır. Poly-V belt is removed.	
	11. Yeni kayış takılır (Adım-1). First, the belt is placed in the groove of the motor pulley (indicate with lower yellow arrow). Then the belt is placed on the half surface of the pulley to the right of the main pulley (indicate with upper yellow arrow). The belt is kept tight so that it does not slip off the main pulley surface.	
	12. Yeni kayış takılır (Adım-2). The belt is assembled by turning the main pulley counter clockwise half a turn.	

	13. Yeni kayış takılmış şekilde ürün görseli Picture of new belt.	
	14. Kayış yenisi ile değiştirilir. Kayış için özel bir temizleme prosedürü yoktur. The belt is replaced with new one. There is no cleaning procedure for belt.	

Technical information:	Version: r1	Date: 26.10.2020

Type:	Refurbishment procedure	
Operation:	DETERGENT BOX GROUP REPLACEMENT	
Code:	7150341600 DNM C-SERVEES	
Comments:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products.	
	15. Üst tabla 2 adet vida ile gövdeye grupludur. Top plate has 2 screws (indicated with red circles).	
	16. 2 vida sökülerek üst tabla açılır. Top plate screws are removed (indicate with red circles).	

	17. Üst tabla açılır. Top plate is removed.	
	18. Yumuşatıcı gözündeki sifonun işaretli noktasına bastırarak, deterjan çekmecesini kendinize doğru çekip çıkarın. Press the dotted point on the siphon in the softener compartment and pull towards you until the compartment is removed from the machine (indicated with yellow arrow).	
	19. Sağ ve solda bulunan pano bağlantı vidaları sökülür. Cabinet - panel connection screws on the right and left are removed (indicated with red circle).	
	20. Deterjan kutusu - pano bağlantı vidası sökülür. Detergent box - panel connection screw is removed (indicated with red circle).	
	21. Pano braket - pano bağlantısı sökülür. Bracket - panel connection is removed (indicated with red circle).	

	22. Pano sökümünden sonraki pano resmi. Front panel picture of after panel dismantling process.	
	23. Panodaki 3 adet soket sökülür. Sockets are removed (indicated with red circle).	
	24. Pano braket ve deterjan kutusunu bağlayan vida sökülür. Bracket – detergent box connection screw is removed (indicated with red circle).	
	25. Gövde ve deterjan kutusunu bağlayan vida sökülür. Cabinet – detergent box connection screw is removed (indicated with red circle).	
	26. 2818440200 stoklu kazan su giriş hortumu sökülür. 2818440200 - tub inlet hose is removed removed (indicated with red circle).	

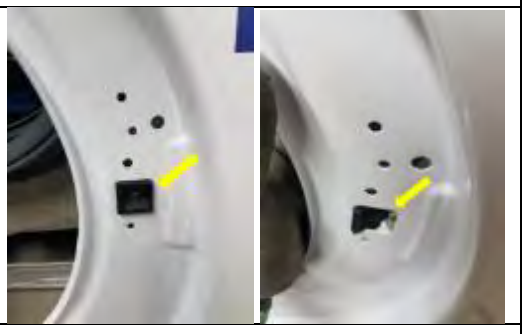
	27. Vana soketleri sökülür. Valve's sockets are removed (indicated with red circle).	
	28. Vanayı gövdeye bağlayan vida sökülür (Adım-1) Valve – cabinet connection's screw is removed (indicated with red circle) (Step-1).	
	29. Vanayı gövdeye bağlayan vida sökülür (Adım-2) Valve – cabinet connection's screw is removed (indicated with red circle) (Step-2).	
	30. Deterjan çekmecesinin temizliğinin nasıl yapılması gerektiği çamaşır makinesi temizleme prosedüründe detaylı olarak tariflenmiştir. Cleaning the detergent drawer details were explained in washing machine cleaning procedure. Please follow this steps.	

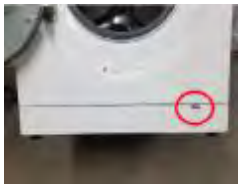
Technical Information:	Version: r1	Date: 26.10.2020

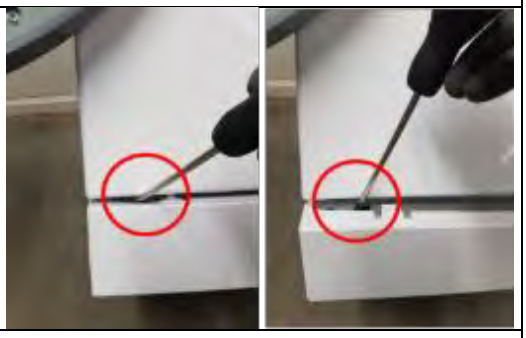
Type:	Refurbishment procedure	
Operation:	DOOR LOCK REPLACEMENT	
Code:	7150341600 DNM C-SERVEES	
Comments:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products.	
	31. Üst tabla 2 adet vida ile gövdeye grupludur. Top plate have 2 screws (indicate with red color circle).	
	32. 2 vida sökülerek üst tabla açılır. Top plate screws are removed (indicate with red color circle).	
	33. Üst tabla açılır. Top plate is removed.	
	34. Yumuşatıcı gözündeki sifonun işaretli noktasına bastırarak, deterjan çekmecesini kendinize doğru çekip çıkarın. Press the dotted point on the siphon in the softener compartment and pull towards you until the compartment is removed from the machine (indicated with yellow arrow).	

	35. Sağ ve solda bulunan pano bağlantı vidaları sökülür. Cabinet - panel connection screws on the right and left are removed (indicated with red circle).	
	36. Deterjan kutusu - pano bağlantı vidası sökülür. Detergent box - panel connection screw is removed (indicated with red circle).	
	37. Pano braket - pano bağlantısı sökülür. Bracket - panel connection is removed (indicated with red circle).	
	38. Pano sökümünden sonraki pano resmi. Front panel picture of after panel dismantling process.	
	39. Panodaki 3 adet soket sökülür. Sockets are removed (indicated with red circle).	

	40. Ön kapak açılır. Front door is opened.	
	41. Emniyet anahtarı vidaları sökülür Door lock's screws are removed (indicated with yellow arrow).	
	42. Körük yayı özel bir aparat ile çıkartılır. Gasket clamp is removed with a special tool (indicated with red circle).	
	43. Körük yayı özel bir aparat ile çıkartıldıktan sonra körük el yardımı ile ön duvardan sökülür (Adım-1). Gasket clamp is removed with a special tool (indicated with red circle). After the gasket clamp is removed with a special tool, the gasket is removed from the front wall by hand (Step-1).	

	44. Körük yayı özel bir aparat ile çıkartıldıktan sonra körük el yardımı ile ön duvardan sökülür (Adım-2). Gasket clamp is removed with a special tool (indicated with red circle). After the gasket clamp is removed with a special tool, the gasket is removed from the front wall by hand (Step-2).	
	45. Körük ön duvardan tamamıyle sökülür (Adım-3). The gasket is completely removed from the front wall (Step-3).	
	46. Ön kapak switch mili sökülür. Front door switch spindle is removed (indicated with yellow arrow).	
	47. Kapı kilidi ön duvardan el yardımıyla sökülür. Door lock is removed from front wall by hand (indicated with yellow arrow).	

	48. Kapı kilidi ön duvardan el yardımıyla sökülür (arkadan bakış). Door lock is removed from front wall by hand (back view).	
	49. Kapı kilidi sökülmüş ön duvar görseli Front wall image with door lock was removed.	
	50. Ön duvarın sağ ve solunda bulunan vidalar sökülür. Screws on the right and left of the front wall are removed (indicated with red circle).	
	51. Filtre kapağını açın. Kapağın üzerindeki tırnağı aşağıya doğru bastırıp, parçayı kendinize doğru çekin. Open the filter cap. If the filter cap is composed of two pieces, press the tab on the filter cap downwards and pull the piece out towards yourself.	 

	52. Kilit açma kolu çekilir. Door opening arm is pulled (indicated with red circle).	
	53. Tornavida yardımıyla tekmelik çıkartılır (Adım-1). The kick plate is removed with the help of a screwdriver (Step-1).	
	54. Tornavida yardımıyla tekmelik çıkartılır (Adım-2). The kick plate is removed with the help of a screwdriver (Step-2).	
	55. Tornavida yardımıyla tekmelik çıkartılır (Adım-3). The kick plate is removed with the help of a screwdriver (Step-3).	

	56. Tekmelik çıkartılır (Adım-4). The kick plate is removed (Step-4).	
	57. Tekmelik çıkartıldıktan sonraki görsel (Adım-4). The picture of after the kick plate is removed (Step-4).	
	58. Pompa bağlantı vidası ve ön duvar bağlantı vidaları sökülür. Pump connection screw and front wall connection screws are removed.	
	59. Ön duvar sökülür (Adım-1). Front wall is removed (Step-1).	

	60. Ön duvar sökülür (Adım-2). Front wall is removed (Step-2).	
	61. Ön duvar sökülür (Adım-3). Front wall is removed (Step-3).	
	62. Kapı kilidi soketi sökülür. Door lock's socket is removed (indicated with yellow arrow).	
	63. Ön kapak kapı switch tutucu kapağı açılır. Front door switch holder is opened indicated with yellow arrow).	

	64. Soket çıkartılır. Socket is removed from front door switch holder (indicated with yellow arrow).	
	65. Kapı kilidi yenisi ile değiştirilir. Kayış için özel bir temizleme prosedürü yoktur. The door lock is replaced with new one. There is no cleaning procedure for door lock.	

ECO-DESIGN STUDY

PRODUCT: WASHING MACHINE

MODEL: GWN 49430

CLIENT: ARÇELIK

5 October 2021

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1. INITIAL ASSESSMENT

According to the ISO 14006 standard, eco-design is defined as the integration of environmental aspects in the design and development of the product with the aim of reducing adverse environmental impacts throughout the life cycle, in addition to this, it is understood that it must have an approach aimed at easy repair with the objective of extending its life cycle.

The importance of incorporating the environmental variable from the moment of design is key, as it is estimated that 80% of the environmental impacts of a producer's entire life cycle are determined during the design phase.

From a repair point of view, it is a design with good accessibility for the technician in terms of components, but with some flaws that are incompatible with an eco-design.

We will analyse the positive aspects and weaknesses of the model in question, from the point of view of its construction and components, it offers very good main features:

- Energy class: A+++
- Capacity: 9Kg and a centrifuging speed of 1400rpm
- Noise level in washing/centrifuging (dB): 56/78
- Automatic load control (lower water consumption), 9900 litres per year, the average for this type of appliance is around 12,200 litres, with approximately 220 washes per year.
- Annual energy consumption (kWh/year): 192, the average is around 190 kWh.
- Inverter motor system, EcoMotor with 10-year warranty
- Steam function to eliminate bacteria in the laundry, recommended for people with allergies to certain fabrics, also helps to prevent creasing and makes ironing virtually unnecessary.
- Touch Control System
- Warranty of 3 years, from the year (2022) by law the warranties will go from 2 to 3 years, at the moment Arcelik is already offering it.

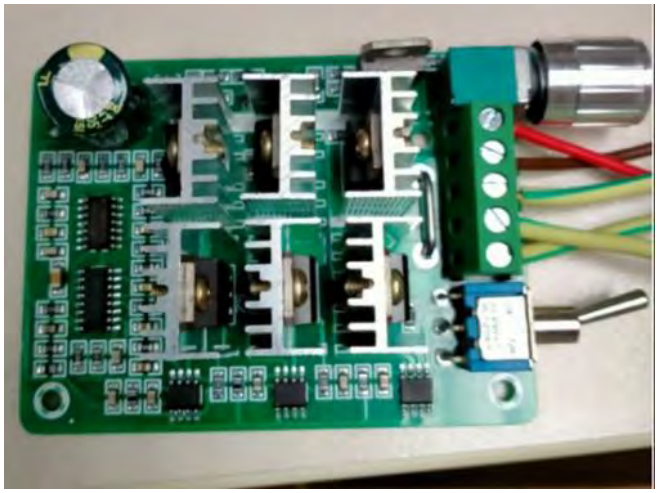
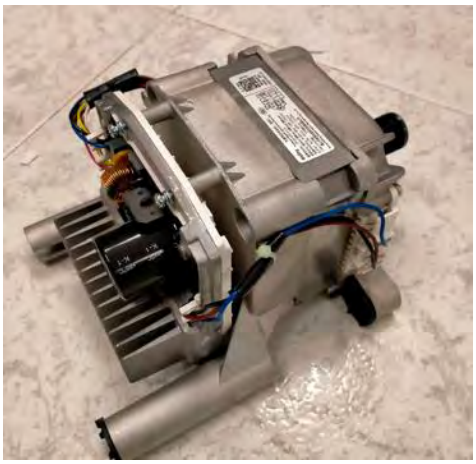
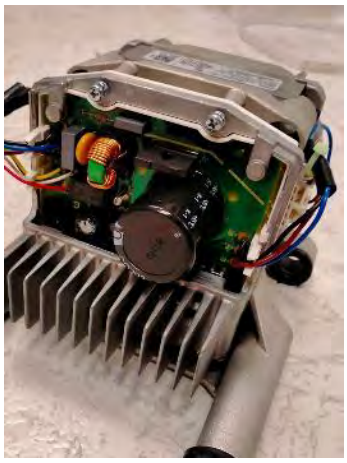
2. POSITIVE ASPECTS

2.1 MOTOR INVERTER:

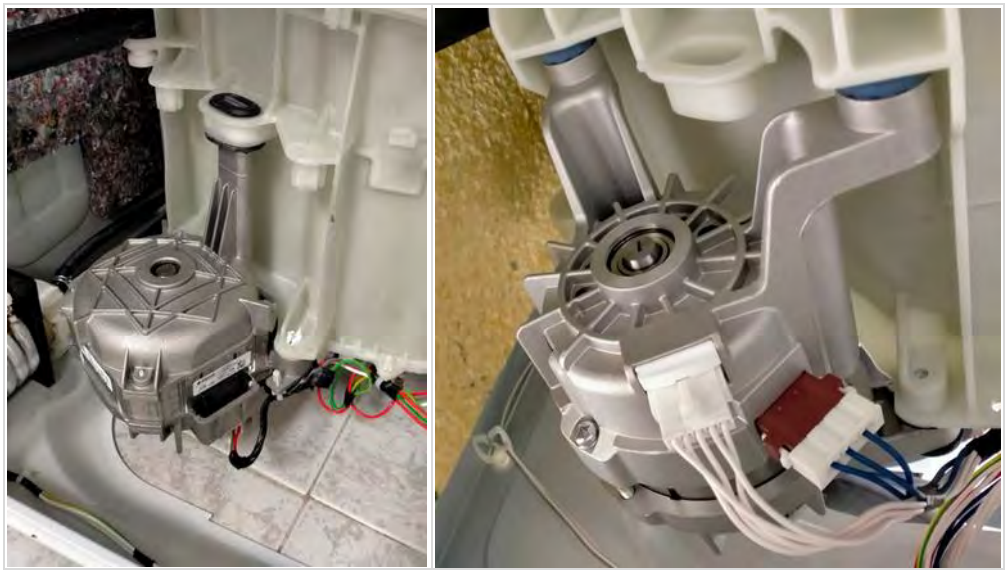
It is a brushless motor, where the noise emitted can be reduced by up to 60% compared to traditional washing machines, it can reach a maximum speed of 13,000rpm, and it is class F, which indicates that it uses more modern materials that withstand higher temperatures (155ºC).

The mechanical part and the friction are reduced, so the durability is longer and the amount of energy consumed is lower as no start-up peaks are generated when the ignition is switched on.

In this design it should be noted that the electronics that governs the speed is not integrated in the motor, so it can be considered almost an "indestructible" motor, in other types of designs the electronics is integrated, so when it has to be replaced, it generates a greater amount of waste and higher cost.

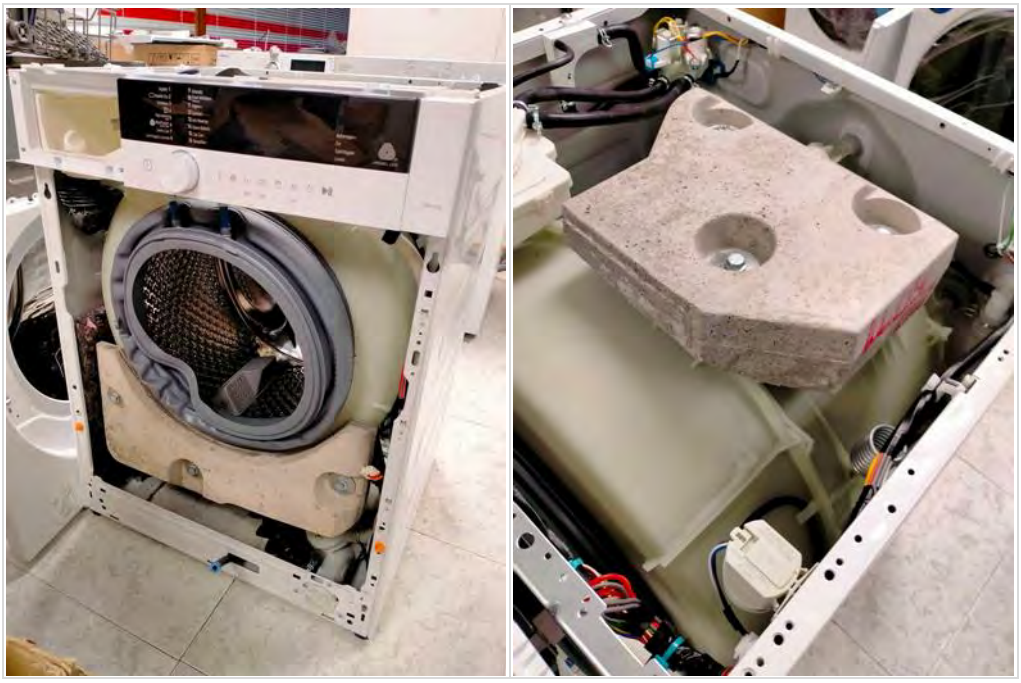





The design of the anchoring of the motor to the tank makes its replacement easy and quick, simply anchored with 2 screws and a hub from the tank, while in other similar motors it is anchored to the tank with the 2 legs (more material, see pictures below).



2.2 FRONT PANEL AND TOP:

Easy to disassemble and access to the components, the drain pump and the guard can be removed without problems, good design with good working space, the anchors with plastic parts come from materials with a % recycling, the bowl holder and the bowl is made of PP with 40% talc, which is considered the ecological plastic.



2.3 ELECTRONICS:

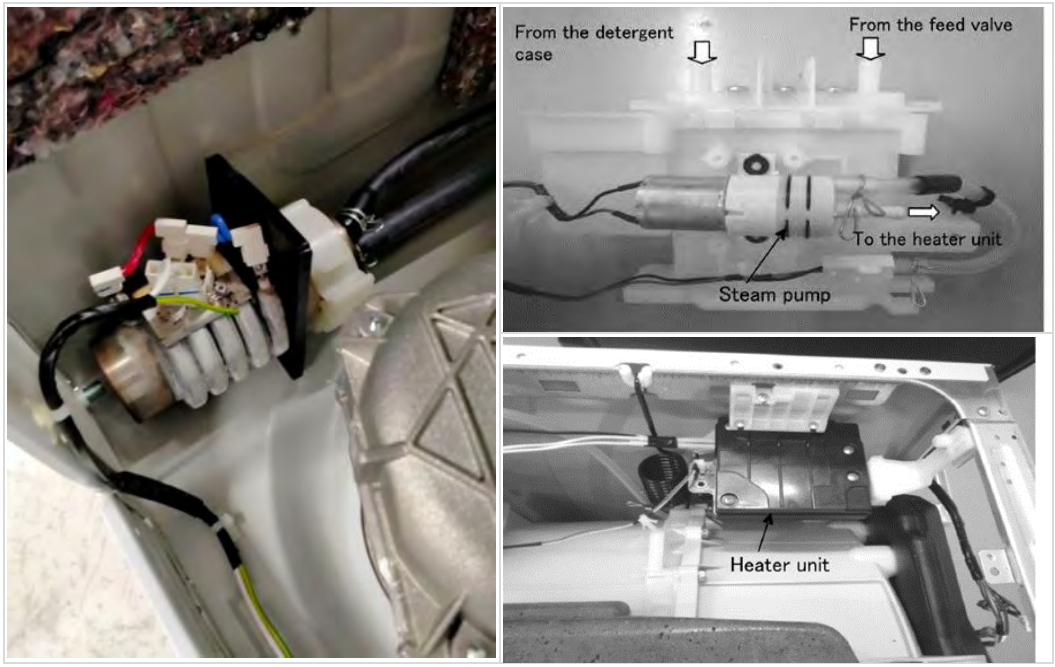
It consists of 2 main circuits, the power circuit located in the control panel area (photo on the left) and the inverter circuit housed on the side. This design allows the circuit to

be less expensive, so that in the event of an out-of-warranty intervention, the user will probably opt to repair rather than buy a new one.

2.4 FUNCTION STEAM:

It incorporates a simple system where a solenoid valve drives water to the heating unit and returns to the inside of the tank, the systems I know have more development and more components, in this design the resistance goes to the air and is not protected by any plastic, in the same way the impulsion pump disappears, less materials to apparently do the same function as in other designs.

Arcelik design vs other brands design (with booster pump)



2.5 SHOCK ABSORBERS:

It is advisable to use 3 dampers in washing machines with loads above 9Kg, the harmonic force that introduces the unbalance in our system is due to the irregularities in the distribution of the rotating mass, the arrangement of 3 units helps to avoid the unbalance and the impact of the floating assembly against the furniture.

2.6 BEATERS:

The beaters are fundamental parts to obtain an optimal result in the cleaning of clothes, they are usually components subject to impacts, mainly due to misuse by the user where he/she introduces objects that can cause breakages such as slippers, rivets, rivets of the garments...

The beater is fastened to the tank by means of a clip. In 2010, Arcelik decided to change the design and introduced screws to fasten it, although it can also be simply clipped, but they come from the factory with screws. The manufacturer assures us that it is a robust design and that it does not have a high breakage rate.

2.7 SW UPDATES:

Arcelik washing machines have the development in their electronic design phase of being able to configure the software, an indisputable advantage for its rapid implementation in the market. This helps reduce consumption and environmental impact in a fast and sustainable way.

3. NEGATIVE ASPECTS

3.1 DOOR LOCKERS

Its design does not allow the hatch to be opened in the event of door lock failure or any other anomaly, causing the hatch to break and potentially damaging part of the front panel, which would require the replacement of more parts.

Designs with mechanical unlocking have a brightly coloured strip to allow the user to unlock it when the time comes.

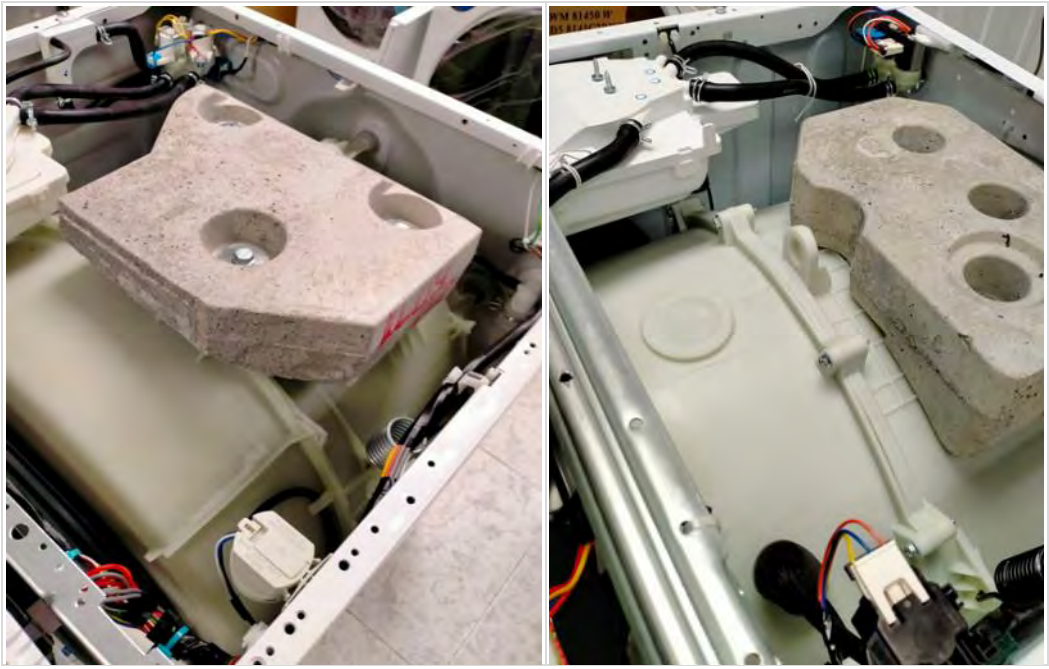
The photo on the left is from the Arcelik design, the photo on the right is a typical view of the manual opening system.

3.2 FLOATING SET

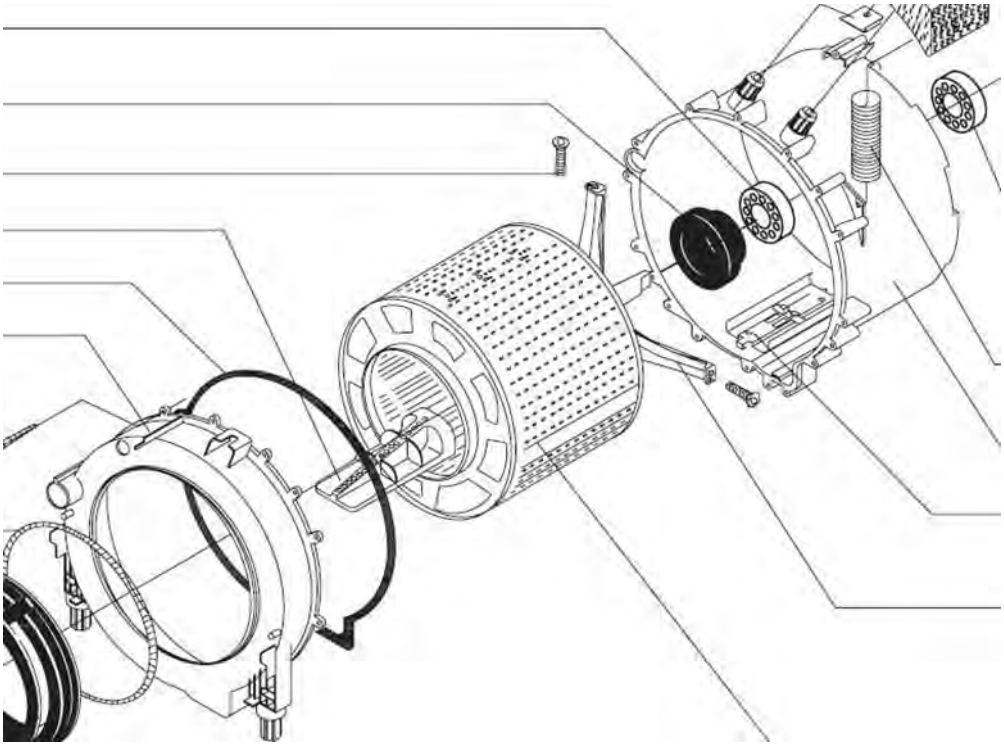
Perhaps the most negative part of the whole design, it does not respect the principles of repairability and is not environmentally sustainable, the design of the floating assembly is compact, the front and rear half tanks are sealed, which makes it impossible to repair economically, not knowing its RRP the assessment is negative because it is considered to be an uneconomical piece for the user.

Throughout the life of the appliance it is common that the star of the drum support breaks due to the attack of chemical agents, limescale remains and low temperatures that do not dissolve the detergents well and therefore accumulate in that area causing the breakage of the same, or it may happen that the seal is worn and water reaches the bearings causing noise, in this case it would not be possible to make a repair only of that part, they are usually typical failures in all washing machines.

In the photo on the left you can see that there are no fastening screws between the half-shells, in the photo on the right you can see this design, and different materials can be used for their recovery.

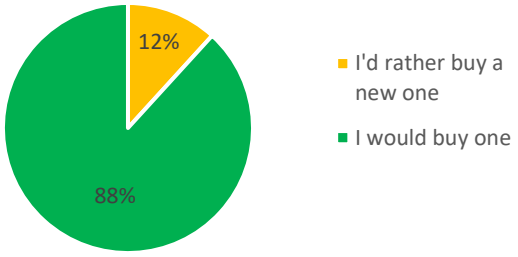


An example of eco-design applied to the floating assembly would be as described in the explosion where it can be seen how the bearings, the oil seal, the beaters and the drum support have their own references to be able to carry out the intervention.

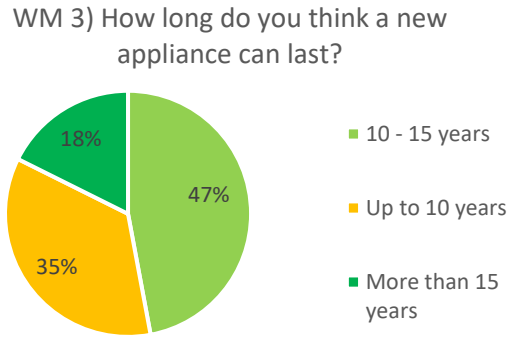


4.2 Collect customers' feedback (living labs)

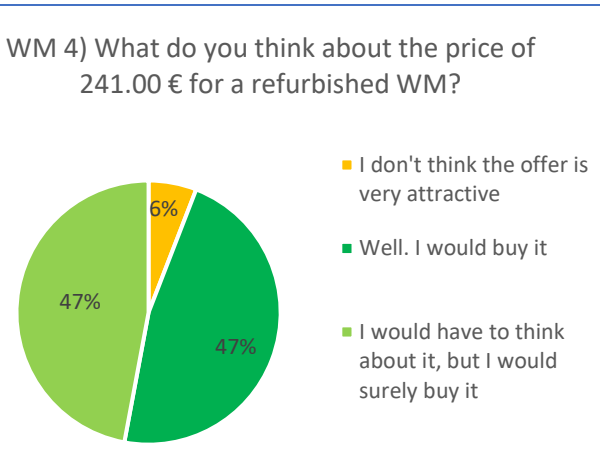
WASHING MACHINE LIVING LAB QUESTIONNAIRE EVALUATION OF RESPONSES



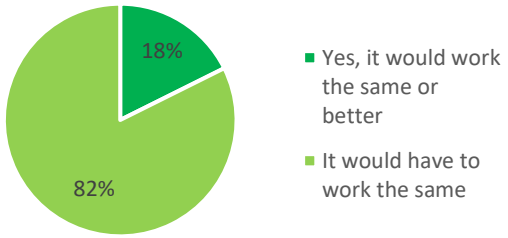
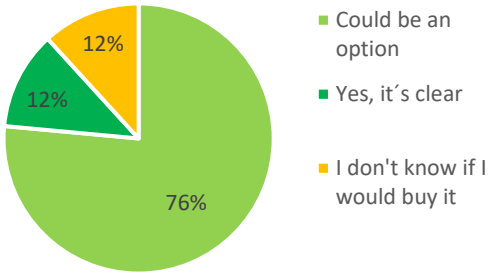
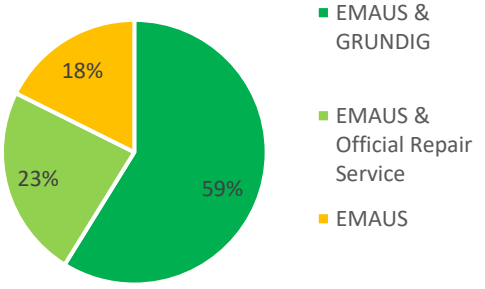
In the case of the washing machine, not all participants think that it is interesting to buy reconditioned appliances, 12% say that they would prefer to buy a new washing machine rather than a reconditioned one.

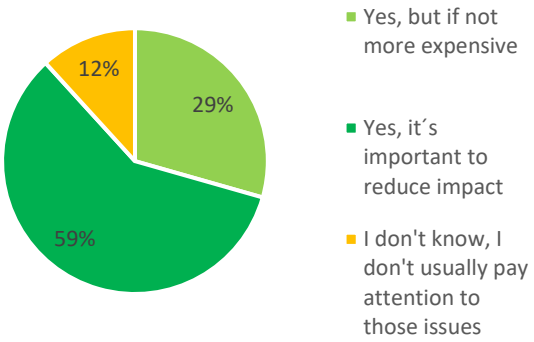
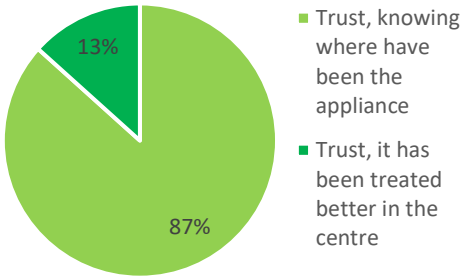
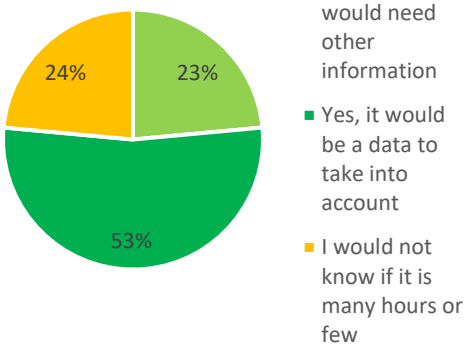


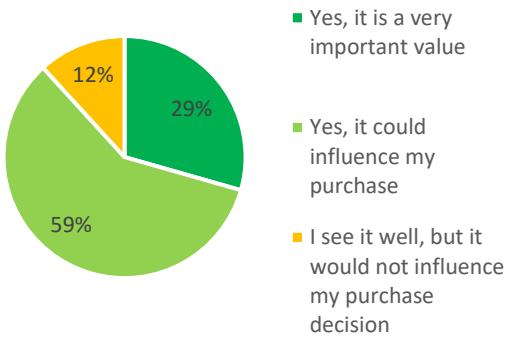
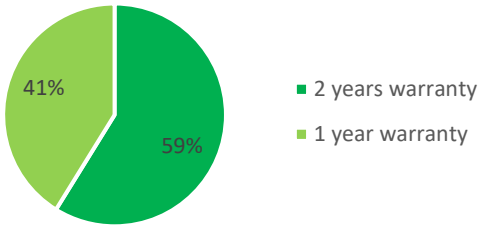
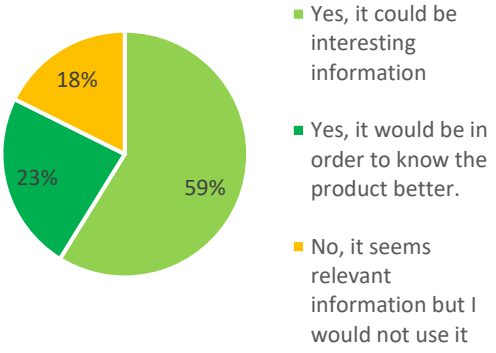
Regarding how long they think the product can last, they are of the opinion that the durability should be longer. Most users estimate the lifetime of a washing machine to be between 10-15 years. Even so, a significant proportion believe that a washing machine can last less than 10 years.



Among the people that would consider buying a refurbished WM, most find the prices proposed acceptable, except for 6% who do not find the price of a reconditioned washing machine attractive.

WM 5) Do you think checking, cleaning and changing the critical parts of a WM, its durability is ensured? 	When asked the question of how they think the product would perform after refurbishment, 82% of people think it should perform in the same way.
WM 6) If the project goes ahead, GRUNDIG would enter into an agreement with EMAÚS to refurbish and sell WMs. Would you buy it? 	However, the willingness to buy a reconditioned appliance is lower. When asked whether they would buy the washing machine from EMAÚS, this could be an option for 76% of the respondents, a very representative figure, and 12% do not even know whether they would consider buying the washing machine.
WM 7) How do you think the guarantee of the refurbishing product sold in EMAÚS should be accredited? 	In terms of warranty, 59% of the respondents prefer EMAÚS and GRUNDIG to be responsible for the warranty of the washing machine. The second option in terms of preference would be EMAÚS with the collaboration of the official repair service, although the support is reduced to practically less than half. 18% of people trust EMAÚS to be responsible for the warranty.

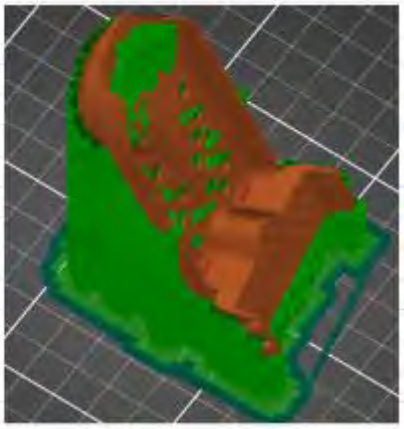
WM 8) Would you buy a refurbished appliance because it generates less impact on the environment? 	Participants in the session believe that the purchase of reconditioned appliances is important to reduce the environmental impact. In the case of the washing machine, 59% believe it is an important factor in the decision process. 29% find it important but would not buy it if it was more expensive. 12% of people does not pay attention to the environmental impact when deciding whether to buy a washing machine.
WM 9) The product has been in a renting model in a centre for elderly people for 3 years. Does it generate trust or mistrust in you? 	Renting is interesting insofar as the provenance of the product is known, 87% of respondents are confident when knowing where the washing machine has been previously, but this is not related to the fact that the appliances have received better treatment and that the included maintenance service increases the life cycle of the product.
WM 10) Could knowing the hours of use of the product help you in the decision? 	Participants find it interesting to know the hours of use of the product, 53% of people believe that it is a piece of information to take into account when making the decision to buy a washing machine, although a significant percentage, 24%, responded that they would not need this information because they would not know how to interpret it.

WM 11) EMAÚS reintegrates people into the workplace, does it affect your decision? 	The reinsertion of EMAÚS into the labour market is viewed favourably by the survey participants, and it can be deduced that it is a factor that favours purchasing.
WM 12) How many years of warranty would you need to buy a refurbished appliance? 	On the question of the years of guarantee they see as appropriate for the products offered in the project, 59% see 2 years of guarantee as a good option. The rest see 1 year warranty for washing machines as a good option.
WM 13) Would you need to know more detailed information about the origin of the materials and their environmental impact? 	Respondents find it interesting to know more detailed information on the provenance of materials and their impact, with the majority expressing that this could be a type of information they would access at some point. However, 18% of respondents feel that this type of data is relevant to them but would not use it. Respondents express concern about the environment and the impact of product development on the environment.

4.3.2 Results from 3D printing tests

Deterjan Sifonu Yeni CL2 final 3D printing properties of the FDM 3D printed prototype

DETERJAN SIFONU_YENI_CL2	
layer hight	0,1 mm
perimeters	6
solid layers top	9
solid layers bottom	5
fill density	50%
Fill pattern	rectilinear
nozzle	235 °C
bed	90°C
Full support	100°%
Filament	PETG

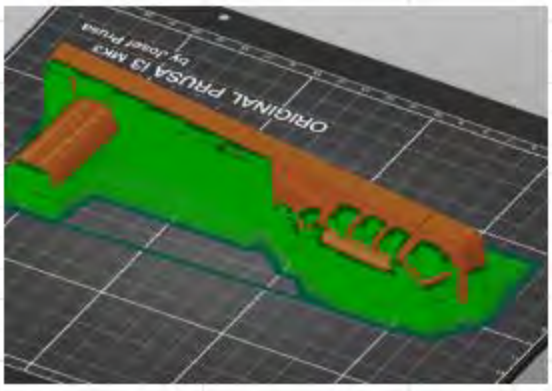


Sivi Deterjan Kabi Yeni C2L final 3D printing properties of the FDM 3D printed prototype

SIVI DETERJAN KABI_YENI_CL2	
layer hight	0,1 mm
perimeters	10
solid layers top	9
solid layers bottom	5
fill density	50%
Fill pattern	rectilinear
nozzle	235 °C
bed	90°C
Full support	100°%
Filament	PETG

SIFON KABI Yeni C2L final 3D printing properties of the FDM 3D printed prototype

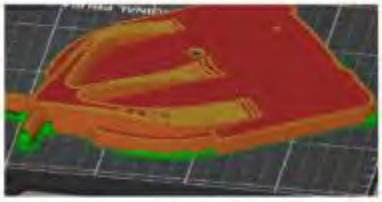
SIFON KABI_YENI_C2L	
layer hight	0,1 mm
perimeters	10
solid layers top	9
solid layers bottom	5
fill density	50%
Fill pattern	rectilinear
nozzle	235 °C
bed	90°C
Full support	100°%
Filament	PETG

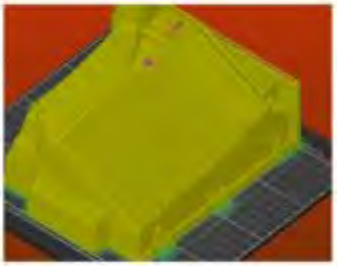


Large washing machine part/1 and part/2

MODEL 1 and 3 WASHING MACHINE

layer hight	0,24 mm
perimeters	3
solid layers top	5
solid layers bottom	4
fill density	50%
Fill pattern	rectilinear
nozzle	215 °C
bed	60°C
Full support	100°%
Filament	STRONGMAN PLA





Deterjan Sifonu Yeni CL2 final 3D printing properties of the FDM 3D printed prototype

Material:		**PETG**	
Model:		**DETERJAN_SIFONU_YENI_C2L**	
LAYER		**INFILL**	
LAYER HEIGHT	0,1	fill density	50%
1ª LAYER HEIGHT	0.2	Pattern	rectilinear
		Top/Botton Pattern	monotonic
PERIMETERS			
Nº	6	**REDUCING PRINTING TIME**	
Spiral Base	x	Combine infill every	1
		Only infill where needed	x
HORIZONTAL SHELLS			
Top solid	9		
Botton solid	5	**ADVANCED**	
		Solid infill every	0
QUALITY		Fill angle	45
Extra perimeters	✓	Solid infill threshold area	70
Ensure vertical shell thickness	✓	Only retract when crossing perim	x
Detect thin walls	✓	Infill before perimeters	x
Detect bridging perimeters	✓		
		SKIRT	
ADVANCED		Loops minimum	4
Seam position	nearest	Distance from object	0
External perimeters first	x	Skirt height	4
		Minimun extrusion length	4
SPEED			
Perimeters	45	**BRIM**	
Small perimeters	25	Brim width	3
External perimeters	25		
Infill	80	**SUPPORT MATERIAL**	
Solid Infill	80	Generate support material	✓
Top solid infill	40	Autogenerated support	✓
Support material	50	Overhead treshold	90
Support material interface	80%	Enforce support for the first	70
Bridges	30	**RAFT**	
Gap fill	40	Raft Layer	0
Travel	100	**OPTION FOR SUPPORT MATERIAL AND RAFT**	
		Contact Z distance	0.2 (detachable)
First layer speed	20	Pattern	rectilinear
		Pattern spacing	2
FILAMENT		Pattern layer	0
Diameter	1,75	Interface layers	2
Extrusion multiplier	1	Interface pattern spacing	0.2 mm
Density	1,27	XY separation between object and its support	80%
EXTRUDER TEMPERATURE		Don't support bridges	✓
Nozzle	235 °C		
Bed	90°C	Printer:	PRUSA i3 MK3
		Software:	PrucaSlicer
RETRACTION		Print time:	13 h 13 min
Length	5		
Lift Z	0		
Speed	40		
Extra length on restart	0		
Minimun travel after retraction	3		
Retraction layer change	x		
Wipe while retracting			
Remarks:		Glass bed with MAGIGO 3D PRINTING ADHESIVE	
		full support	
		60 % speed	

Sivi Deterjan Kabi Yeni C2L final 3D printing properties of the FDM 3D printed prototype

Material:		**PETG**	
Model:		**SIVI DETERJAN_KABI_YENI_C2L**	

LAYER		**INFILL**	
LAYER HEIGHT	0,1	fill density	50%
1ª LAYER HEIGHT	0.2	Pattern	rectilinear
		Top/Botton Pattern	monotonic
PERIMETERS			
Nº	10	**REDUCING PRINTING TIME**	
Spiral Base	x	Combine infill every	1
		Only infill where needed	x
HORIZONTAL SHELLS			
Top solid	9		
Botton solid	5	**ADVANCED**	
		Solid infill every	0
QUALITY		Fill angle	45
Extra perimeters	✓	Solid infill threshold area	70
Ensure vertical shell thickness	✓	Only retract when crossing perim	x
Detect thin walls	✓	Infill before perimeters	x
Detect bridging perimeters	✓		
		SKIRT	
ADVANCED		Loops minimum	4
Seam position	nearest	Distance from object	0
External perimeters first	x	Skirt height	4
		Minimun extrusion length	4
SPEED			
Perimeters	45	**BRIM**	
Small perimeters	25	Brim width	3
External perimeters	25		
Infill	80	**SUPPORT MATERIAL**	
Solid Infill	80	Generate support material	✓
Top solid infill	40	Autogenerated support	✓
Support material	50	Overhead treshold	90
Support material interface	80%	Enforce support for the first	70
Bridges	30	**RAFT**	
Gap fill	40	Raft Layer	0
Travel	100	**OPTION FOR SUPPORT MATERIAL AND RAFT**	
		Contact Z distance	0.2 (detachable)
First layer speed	20	Pattern	rectilinear
		Pattern spacing	2
FILAMENT		Pattern layer	0
Diameter	1,75	Interface layers	2
Extrusion multiplier	1	Interface pattern spacing	0.2 mm
Density	1,27	XY separation between object and its support	80%
EXTRUDER TEMPERATURE		Don't support bridges	✓
Nozzle	235 °C		
Bed	90°C	Printer:	PRUSA i3 MK3
		Software:	PrucaSlicer
RETRACTION		Print time:	*14 h 02 min

* with speed reduction during the printing period up to 20 h of printing

Length	5	
Lift Z	0	
Speed	40	
Extra length on restart	0	
Minimun travel after retraction	3	
Retraction layer change	x	
Wipe while retracting		

Remarks:		Glass bed with MAGIGO 3D PRINTING ADHESIVE and KORES glue
		full support
		68 % speed manualy adjusting during the print

SIFON KABI Yeni C2L final 3D printing properties of the FDM 3D printed prototype

Material:	**PETG**
Model:	**SIFON_KABI_YENI_C2L**

LAYER	
LAYER HEIGHT	0,1
1ª LAYER HEIGHT	0.2
PERIMETERS	
Nº	10
Spiral Base	x
HORIZONTAL SHELLS	
Top solid	9
Botton solid	5
QUALITY	
Extra perimeters	✓
Ensure vertical shell thickness	✓
Detect thin walls	✓
Detect bridging perimeters	✓
ADVANCED	
Seam position	nearest
External perimeters first	x

SPEED	
Perimeters	45
Small perimeters	25
External perimeters	25
Infill	80
Solid Infill	80
Top solid infill	40
Support material	50
Support material interface	80%
Bridges	30
Gap fill	40
Travel	100
First layer speed	20

FILAMENT	
Diameter	1,75
Extrusion multiplier	1
Density	1,27
EXTRUDER TEMPERATURE	
Nozzle	235 °C
Bed	90°C
RETRACTION	
Length	5
Lift Z	0
Speed	40
Extra length on restart	0
Minimun travel after retraction	3
Retraction layer change	x
Wipe while retracting	

INFILL	
fill density	50%
Pattern	rectilinear
Top/Botton Pattern	monotonic
REDUCING PRINTING TIME	
Combine infill every	1
Only infill where needed	x
ADVANCED	
Solid infill every	0
Fill angle	45
Solid infill threshold area	70
Only retract when crossing perim	x
Infill before perimeters	x
SKIRT	
Loops minimum	4
Distance from object	0
Skirt height	4
Minimun extrusion length	4
BRIM	
Brim width	3
SUPPORT MATERIAL	
Generate support material	✓
Autogenerated support	✓
Overhead treshold	80
Enforce support for the first	60
RAFT	
Raft Layer	0
OPTION FOR SUPPORT MATERIAL AND RAFT	
Contact Z distance	0.2 (detachable)
Pattern	rectilinear
Pattern spacing	2
Pattern layer	0
Interface layers	2
Interface pattern spacing	0.2 mm
XY separation between object and its support	80%
Don't support bridges	✓

Printer:	PRUSA i3 MK3
Software:	PrucaSlicer
Print time:	*11 h 55 min

* with speed reduction during the printing period up to 18 h of printing

Remarks:	Glass bed with MAGIGO 3D PRINTING ADHESIVE and KORES glue
	full support
	65 % speed manualy adjusting during the print

Large washing machine part/1 and part/2

Material:		**STRONGMAN PLA AZUREFILM FILAMENT**	
Model:		**MODELS 1 AND 3 WASHING MACHINE PARTS**	

LAYER		**INFILL**	
LAYER HEIGHT	0,24	fill density	20%
1ª LAYER HEIGHT	0.2	Pattern	rectilinear
		Top/Botton Pattern	monotonic
PERIMETERS			
Nº	3	**REDUCING PRINTING TIME**	
Spiral Vase	x	Combine infill every	1
		Only infill where needed	x
HORIZONTAL SHELLS			
Top solid	5		
Botton solid	4	**ADVANCED**	
		Solid infill every	0
QUALITY		Fill angle	45
Extra perimeters		Solid infill threshold area	0
Ensure vertical shell thickness	✓	Only retract when crossing perim	x
Detect thin walls	✓	Infill before perimeters	x
Detect bridging perimeters	✓		
		SKIRT	
ADVANCED		Loops minimum	4
Seam position	nearest	Distance from object	0
External perimeters first	x	Skirt height	4
		Minimun extrusion length	4
SPEED			
Perimeters	40	**BRIM**	
Small perimeters	25	Brim width	3
External perimeters	40		
Infill	40	**SUPPORT MATERIAL**	
Solid Infill	40	Generate support material	✓
Top solid infill	40	Autogenerated support	✓
Support material	30	Overhead treshold	40
Support material interface	30	Enforce support for the first	0
Bridges	30	**RAFT**	
Gap fill	40	Raft Layer	0
Travel	110	**OPTION FOR SUPPORT MATERIAL AND RAFT**	
		Contact Z distance	0.15 (detachable)
First layer speed	10	Pattern	rectilinear
		Pattern spacing	5
FILAMENT		Pattern angle	90
Diameter	1,75	Interface layers	2
Extrusion multiplier	0,95	Interface pattern spacing	0.2 mm
Density	1,3	XY separation between object and its support	1%
EXTRUDER TEMPERATURE		Support on build plate only	✓
Nozzle	215 °C	**EXTRUSION WIDTH**	
Bed	60°C	First layer	0,52
		Support material	0,43
RETRACTION		**FAN SETTINGS**	
Length	0,9	Fan speed min/max	98/99
Lift Z	0	Bridges fan speed	98
Speed	40	Disable fan for the first	2
Extra length on restart	0		
Minimun travel after retraction	3	Support on build plate only	✓
Retraction layer change	x	Software:	PrucaSlicer
Wipe while retracting		Print time:	*3d h 3h 29 min

* with speed reduction during the printing period up to 18 h of printing

Remarks:		Glass bed with MAGIGO 3D PRINTING ADHESIVE full support

Technical data sheet PETG (1,75mm)

PHYSICAL	CONDITIONS	TEST METHOD	TYPICAL VALUE
Density		ASTM D792	1.29 g/cm3
Bulk Density			0.73 g/cm3
Intrinsic Viscosity		ISO 1628-5	0.80 dl/g
Water Absorption		ASTM D570	0.12 %
Color	b*	ASTM D6290	≤ 1
	L*	ASTM D6290	≥ 64
MECHANICAL			
Tensile modulus		ISO 527-2	3000 Mpa
Tensile Yield stress		ISO 527-2	53 Mpa
Elongnation at Yield		ISO 527-2	4%
Tensile Strenght		ISO 527-2	53 MPa
Elongation at Strenght		ISO 527-2	4%
Stress at Break		ISO 527-2	19 Mpa
Nominal enlongation at Break		ISO 527-2	31%
Flexural Modulus		ISO 178	2040 Mpa
Flexural Stress		ISO 178	171 Mpa
Deflection at Flexural Strenght		ISO 178	8.6 mm
IMPACT			
Notched Izod Impact Strenght	23°C, 50 % RH	ISO 180	4.5 kJ/m2
Unnotched Izod Impact Strenght	23°C, 50 % RH	ISO 180	No Break
HARDNESS			
Shore Hardness		ASTM D2240	70
THERMAL			
Heat Deflection Temperature			
	0.45 Mpa	ISO 75-2	68°C
	1.8 Mpa	ISO 75-2	62°C
Vicat Softening Temeprature		ISO 306	78°C
Glass Transistion Temperature		ASTM D3418	80°C
PRINT RECOMMENDATIONS			
Nozzle Temperature	210 - 235°C		
Bed Temperature	50-80 °5 C		
Print Speed	35-17 mm/s		
Bed Adhesion	PEI shEET, Buildtak, Adhesion spray		

4.4.1 Improve dismantling and recycling operations

GRUNDIG Washing Machine

DISMANTLING PROCEDURE

Table of Contents

Prerequisite

DISMANTLING PROCEDURE

- Removing the back metal panel
- Removing the top metal panel
- Removing the detergent box
- Removing the control panel
- Removing the front door
- Removing the front metal panel
- Removing the gasket
- Removing the Upper & Lower counterweight
- Removing the drain pump
- Removing the belt
- Removing the pulley
- Removing the motor
- Removing the spring
- Removing the Welded tube group (tub & drum)
- Removing the heater
- Removing the cable group

COMMENTS

Prerequisites

For the dismantling procedure we will need the following tools:

1. 13 mm socket wrench

2. Philip screwdriver

3. Pair of gloves

4. Pliers

5. Plastic pry tool

DISMANTLING PROCEDURE

1. Removing the back metal panel

The back metal panel is held in place by 5 screws.

Remove the screws and the back panel will come off.

2. Removing the top metal panel

In order to remove the top panel, we need to unscrew the 2 screws that hold it in place. The screws are located on the back side.

After removing the screws, lift the panel from the back side, and slide to the front.

3. Removing the detergent box

To remove the detergent box:

1. Pull the detergent box all the way out.

2. Press on the blue plastic clip.

3. While pressing the blue plastic clip slide the box out

4. Removing the control panel

The control panel is held in place by 3 screws and 3 plastic clips. Also, connectors on the right of the panel have to be unplugged.

1. Remove the 3 screws.

2. Use the plastic pry tool to unclip the panel

3. Unplug the connectors

5. Removing the front door

The front door is held in place by 2 screws. Unscrew them and pull up on the door to release it.

6. Removing the front metal panel

In order to remove the front panel, first you need to remove the gasket around it. For this use the plastic pry tool.

The second step is to remove the plastic cap that is situated in the lower part of the front panel. Use the plastic pry tool for this.

With the plastic cap removed you will gain access to all the screws you need to unscrew in order to remove the front panel.

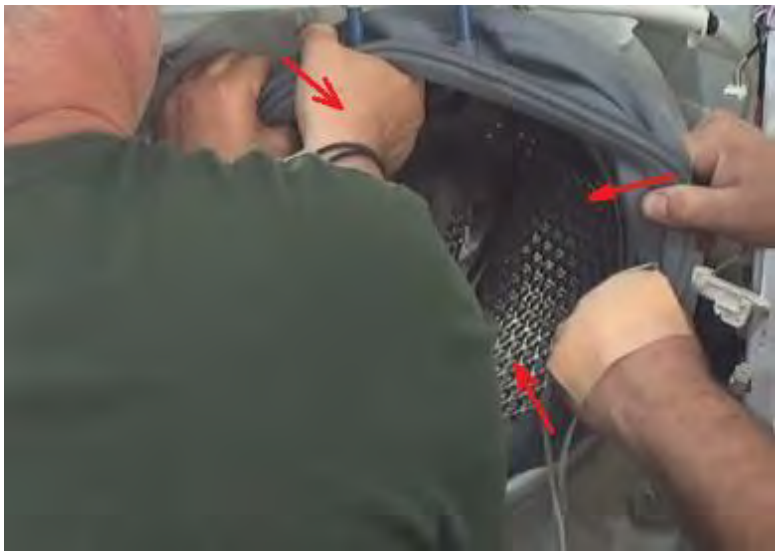
7. Removing the gasket

1. Use a pliers to remove the metal safety that holds the hose.

2. Disconnect the hose.
3. Using the plastic pry tool pull out the safety cable that secures the gasket

4. Pull out the safety cable

5. Press down on the edges to remove the gasket.



8. Removing the Upper & Lower counterweight

In order to remove the 2 cement blocks that balance the vat 6 screws must be unscrewed.

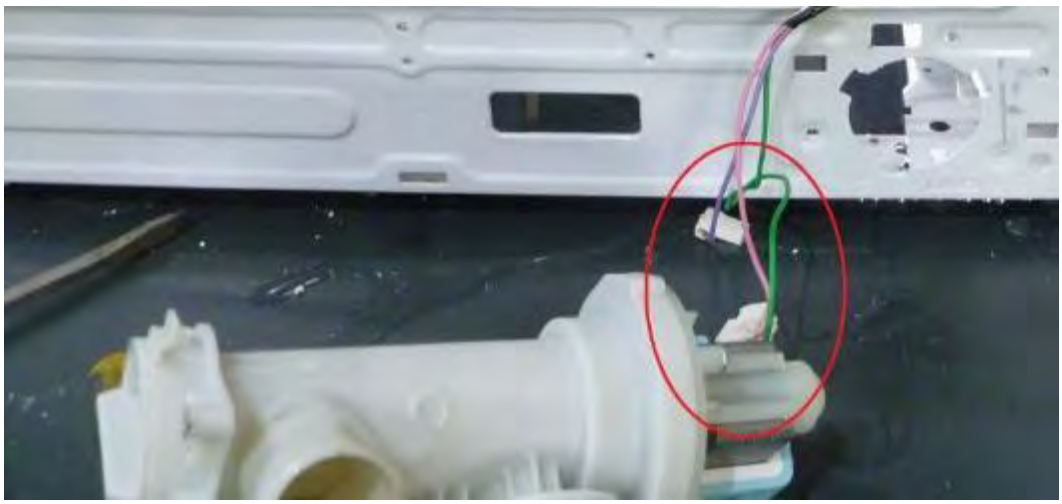
9. Removing the drain pump

1. Remove the filter by turning counter clockwise and the remove the 3 screws that hold the drain pump.

2. Use the pliers to remove the safety rings that hold the 3 hoses.

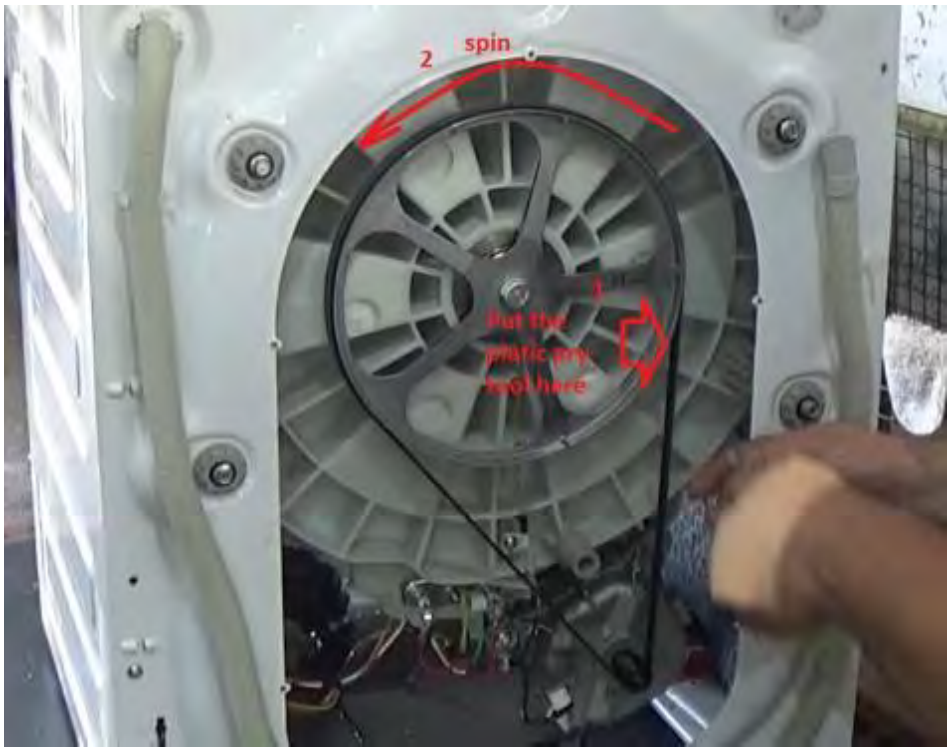
3. Unplug the 3 hoses.
4. Remove the 3 screws that hold the pump.

5. Remove the power cables and remove the pump.



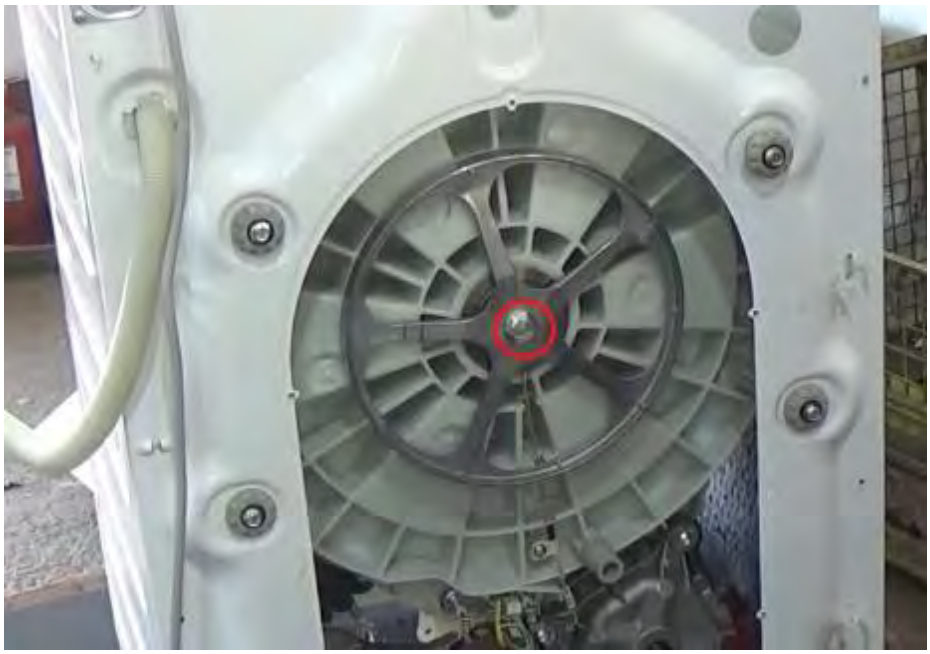
10. Removing the belt

In order to remove the belt put the plastic pry tool between the belt and the big metal wheel. Spin the big metal wheel counter clockwise until the belt comes off.



11. Removing the pulley

The pulley is held in place by a nut.

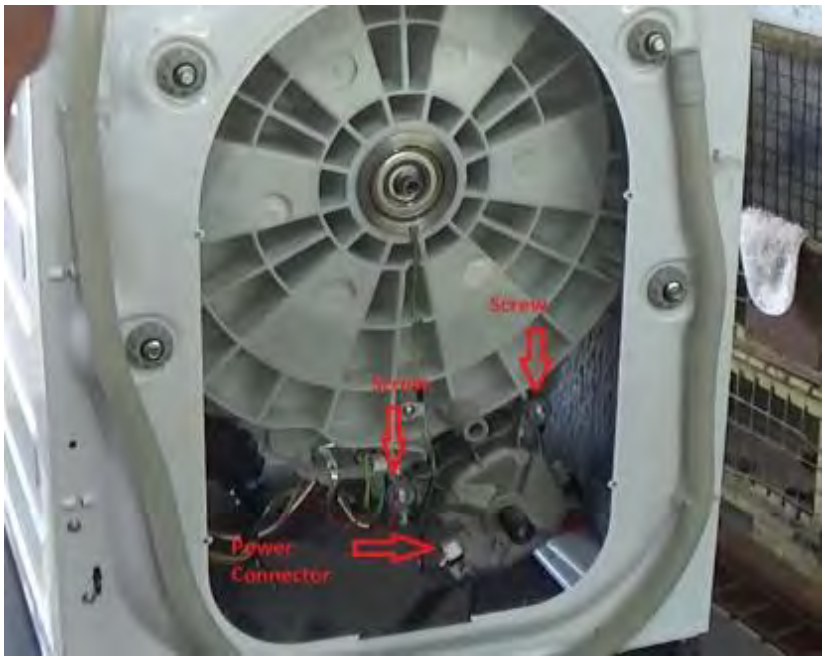


In order to remove the pulley, secure it so it doesn't spin. Then use a pliers to unlock the nut by turning counterclockwise.

12. Removing the motor

The motor is held in place using 2 screws. Also you must disconnect the motor power connector.

1. Disconnect the power connector.
2. Unscrew the screws.
3. Pull out the motor.



13. Removing the spring

The spring is located in the upper part of the washing machine. It connects the metal frame to the drum.

Release the tension in the spring by pulling the drum up and then use a screwdriver to press on the spring's end.

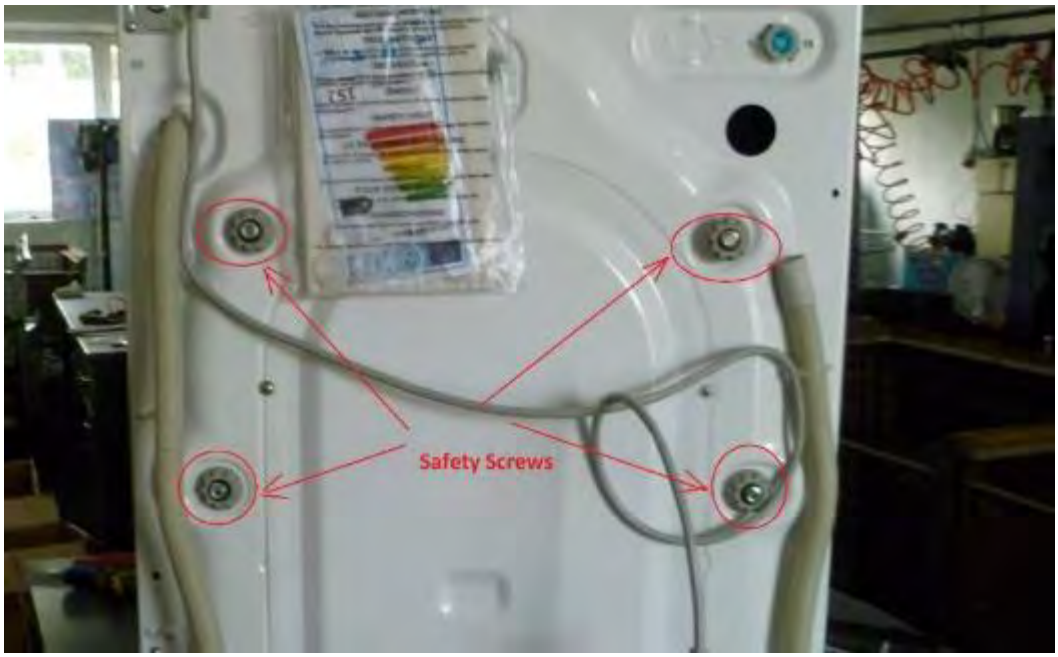
14. Removing the Welded tube group (tub & drum)

In order to remove the Welded tub group (tub & drum) first you must unlock the 3 shock absorbers.

Each shock absorber has 1 plastic pin that keeps each end in place. Simply remove the plastic pins and take out the shock absorber.

Disconnect the black hose that is connected to the drum.

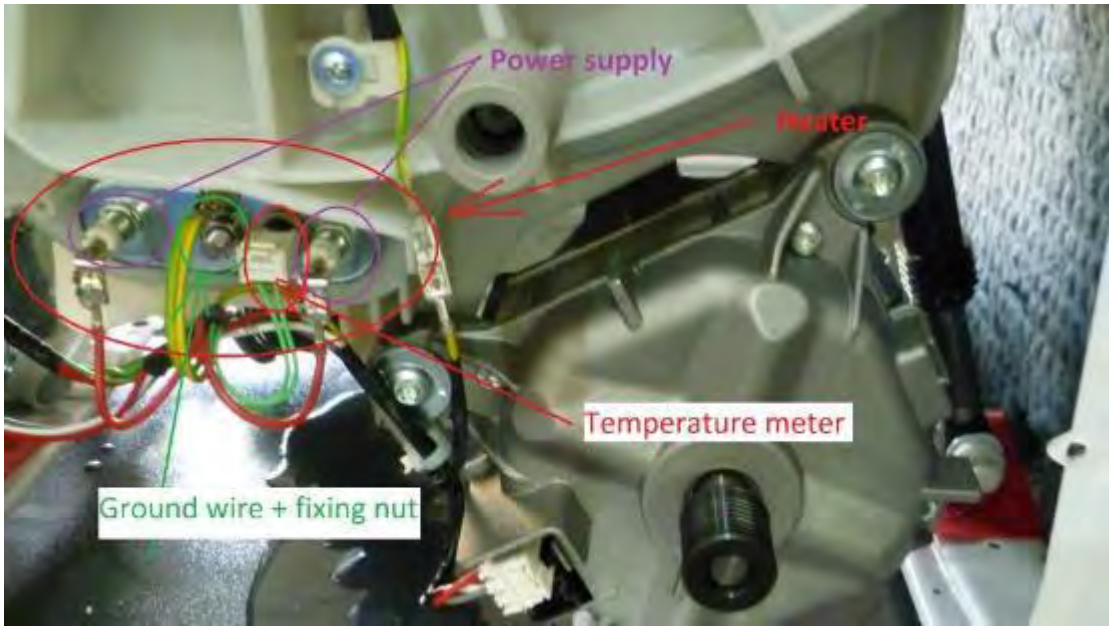
Remove the drum safety screws



Take out the drum by the front panel.

15. Removing the heater

The ceramic heater is located in the back of the washing machine on the lower part of the vat.



1. Remove the back metal panel as shown before
2. Remove all the connectors
3. Remove the fixing nut
4. Pull out the heater

16. Removing the cable group

The cable group is situated in the lower right in the back of the washing machine. It has all the cables connected to it.

Before taking it out remove all the connectors.

Cut off all the ties that hold the wires in place all around the frame.

Remove the screws and pull out the controller

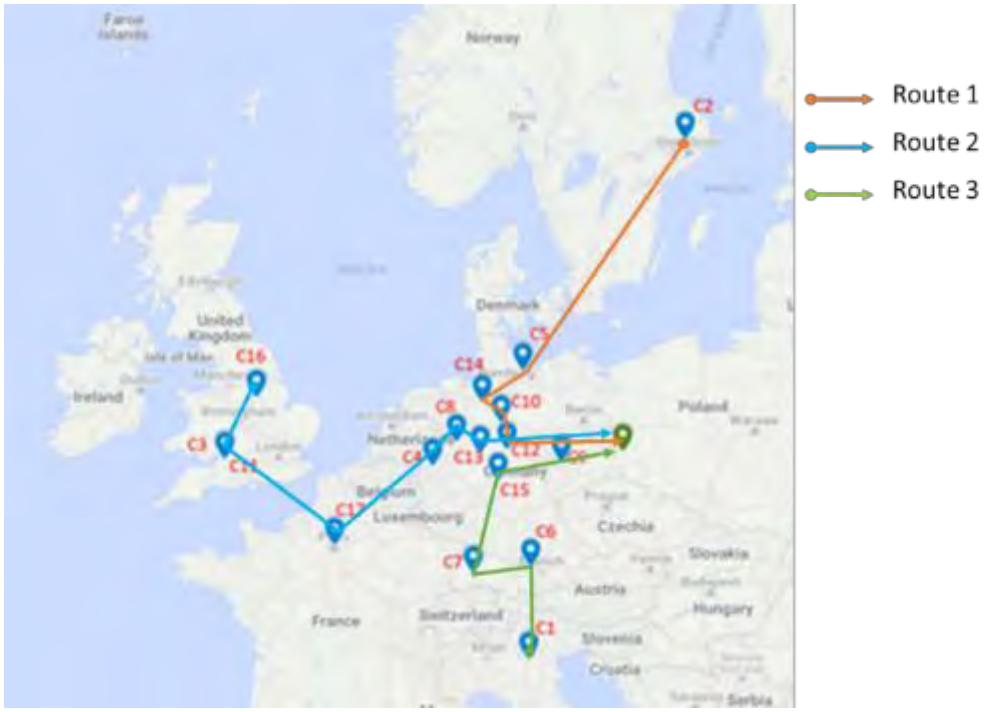
COMMENTS

- Special attention should be taken when removing the gasket. Do not use sharp tools to remove the safety cable as it may damage the gasket.
- Use protective gear for your legs when manipulating the 2 cement blocks as they are quite heavy.
- Use gloves when disconnecting the cables as capacitors could still hold electric charge.

Annex 2 (LEXMARK – Printers and toner cartridges demonstration)

5.7.3 Reverse logistics ICT platform

The platform calculated the best routes with the less CO2 emission. One route has the collections points of Company 2-5-14-10-12, the second route has Company 16-11-3-17-4-8-13, and the third route has Company 1-6-7-15-9. Results are reported in the following figures:



Route 1: Company 2-5-14-10-12

C2 – C5						
C5 -C14						
C14 – C10						
C10 – C12						
C12 - DEST						

Time window for delivery: 18 – 23 May

Route 2: Company 16-11-3-17-4-8-13

C16 – C11						
C11 -C3						
C3 – C17						
C17 – C4						
C4 – C8						
C8 – C13						
C13 - DEST						

Time window for delivery: 27 – 31 May

Route 3: Company 1-6-7-15-9

C1 – C6						
C6 -C7						
C7 – C15						
C15 – C9						
C9 – DEST						

Time window for delivery: 30 May

The tool has also calculated the best routes according to the availability of printers. Based on the product availability the companies have been categories into 3 groups. In Group1 there are available products at Company C 2-5-14-10 and C 11-17-1. For the transportation 2 trucks would be needed. In Group 2 there is Company 4-13-15-12-9 + 6, for this solution also 2 trucks are needed. In Group 3 only 1 truck is enough to collect products from Company 16-3-8-7. Results are reported below:

1° Group: Availability of products 13-19 May

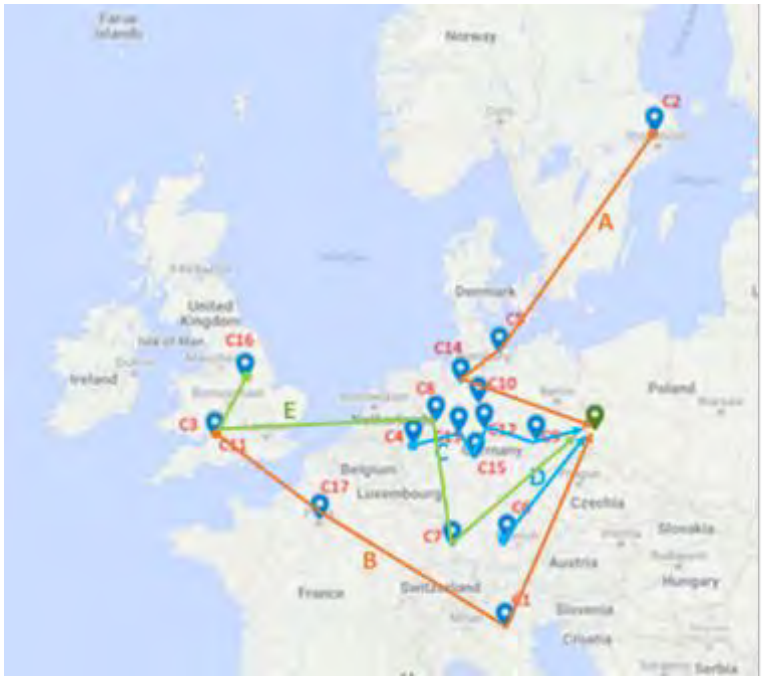
Supplier name	Preferred pick-up date	City	Country
Company 5	13/05/2022	Lübeck	Germany
Company 10	16/05/2022	Langenhagen	Germany
Company 1	17/05/2022	VERONA	Italy
Company 11	17/05/2022	BRISTOL	UK
Company 17	17/05/2022	SAINT DENIS	France
Company2	18/05/2022	Arlandastad	Sweden
Company 14	19/05/2022	Weyhe	Germany

2° Group: Availability of products 23-25 May

Supplier name	Preferred pick-up date	City	Country
Company 4	23/05/2022	Neuss	Germany
Company 6	23/05/2022	Ried	Germany
Company 12	23/05/2022	Northeim	Germany
Company 9	24/05/2022	Leipzig	Germany
Company 13	25/05/2022	Lichtenau-Atteln	Germany
Company 15	25/05/2022	Niederaula	Germany

3° Group: Availability of products: 26-31 May

Supplier name	Preferred pick-up date	City	Country
Company 3	26/05/2022	BRISTOL	UK
Company 16	27/05/2022	Mansfield	UK
Company 7	30/05/2022	Villingen-Schwenningen	Germany
Company 8	31/05/2022	Münster	Germany



1° Group: Truck A: Company 2 – 5 - 14 -10

Truck B: Company 11 – 17 - 1

C2 – C5							
C5 -C14							
C14 – C10							
C10 – DEST							
C11 – C17							
C17 – C1							
C1 - DEST							

Time window for delivery: 18 – 19 May

2° Group: **Truck C: Company 4 – 13 – 15 – 12 - 9**

Truck D: Company 6

	Path	Total CO2 (kg)	Total Nox (kg)	Total PM10 (kg)	Total distance (km)	Truck	Delivery Time
	→ Neuss Rhein-Kreis Neuss-Deutschland; Lichtenau-Kreis Paderborn-Deutschland; Alsfeld-Vogelsbergkreis-Deutschland; Northeim-Landkreis Northeim-Deutschland; Leipzig-Deutschland; Mering-Landkreis Aichach-Friedberg-Deutschland; Zary-powiat zarski-Polska]	1.275.32	1.93	0.21	1.834.11	2	17:47:59
C4 – C13	Neuss-Rhein-Kreis Neuss-Deutschland → Lichtenau-Kreis Paderborn-Deutschland	111.04	0.43	0.03	152.84	Truck 1	2:0.41
C13 -C15	Lichtenau-Kreis Paderborn-Deutschland → Alsfeld-Vogelsbergkreis-Deutschland	115.53	0.35	0.02	149.51	Truck 1	1:33:2
C15 – C12	Alsfeld-Vogelsbergkreis-Deutschland → Northeim-Landkreis Northeim-Deutschland	116.28	0.36	0.02	156.83	Truck 1	1:36:42
C12 – C9	Northeim-Landkreis Northeim-Deutschland → Leipzig-Deutschland	158.62	0.51	0.03	218.70	Truck 1	2:17:53
C9 – DEST	Leipzig-Deutschland → Zary powiat zarski Polska	238.05	0.72	0.04	258.38	Truck 1	2:15:21
C6 – DEST	Mering-Landkreis Aichach-Friedberg-Deutschland → Zary powiat zarski-Polska	503.73	1.54	0.08	655.34	Truck 2	8:49:12

Time window for delivery: 23 – 25 May

3° Group: **Truck E: Company 16 – 3 – 8 – 7**

	Path	[illegible]	[illegible]	[illegible]	[illegible]	Truck	[illegible]
	→ [illegible]	1.789.18	[illegible]	0.11	2.451.[illegible]	[illegible]	Day 1 2:20:[illegible]
C16 – C3	Sheffield? [illegible] → Bristol City of Bristol-United Kingdom	[illegible]	[illegible]	[illegible]	[illegible]	Truck 1	[illegible]
C3 -C8	Bristol-City of Bristol-United Kingdom → Münster-Deutschland	447.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C8 – C7	Münster-Deutschland → Villingen-Schwenningen-Schwarzwald-Baar-Kreis-Deutschland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C7 – DEST	Villingen-Schwenningen-Sch. → Zary powiat zarski Polska	412.41	[illegible]	[illegible]	[illegible]	Truck 1	[illegible]

Time window for delivery: 27 – 31 May

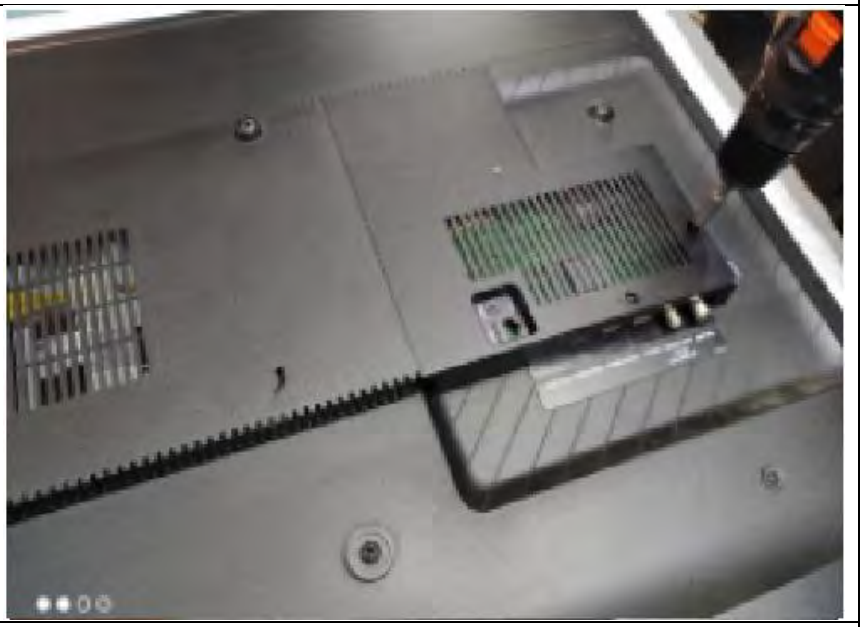
Annex 3 (ARÇELIK – TV set demonstration)

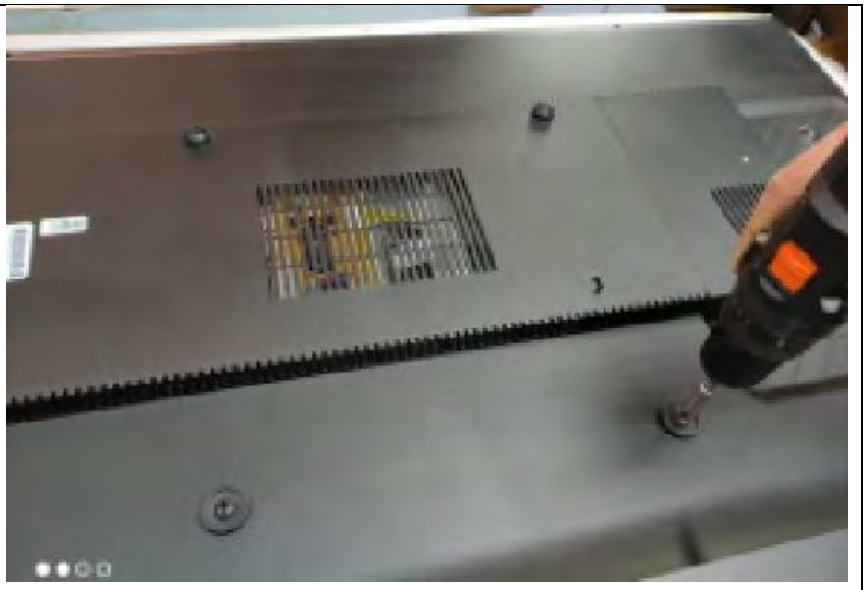
7.1.1 Preparation for refurbishment experience

Manuals developed for Emaús 'Preparation for reuse' operations

Rework Process: RP_C_SERVEES_2012_001	Versión / Release: r2	Fecha / Date: 22/02/2021

Tipo / Type:	Rework Process TV		
Asunto / Subject:	C-SERVEES PROJECT		
Propietario / Owner:	**Javier Garcia**	email:	javier.garcia@beko.com
Estado / Status: ONGOING Dec. 2020	G43C 893 5A GRUNDIG (UGE000) POWERMAX NX		
Introducción / Introduction:	Cambio de LEDs / LED replacement		
Explicación / Explanation:	Los LEDs son uno de los componentes con mayor desgaste. La sustitución de este componente alargaría la vida útil del aparato de forma significativa. LED is one of the components with higher component wear. By replacing the LED bars, the lifetime of the unit could be increased significantly.		
Herramientas necesarias / Needed tools:	- Juego destornilladores - Guantes - Espátula de plástico - Barra de LED's (WCH60602-AB)	- Screwdrivers - Gloves - Plastic spatula - LED bars (WCH60602-AB)	
			

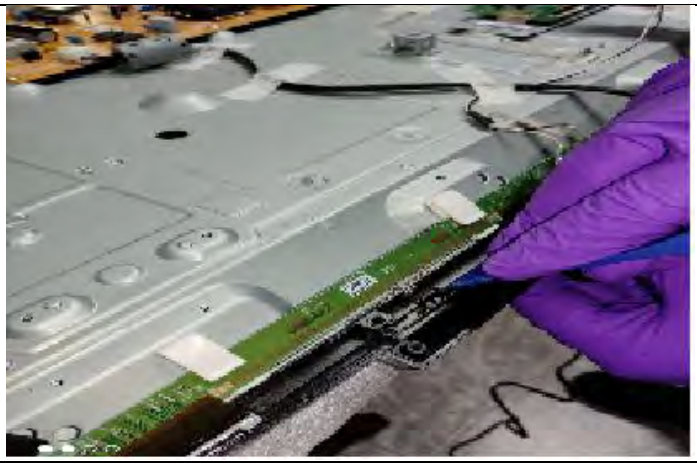
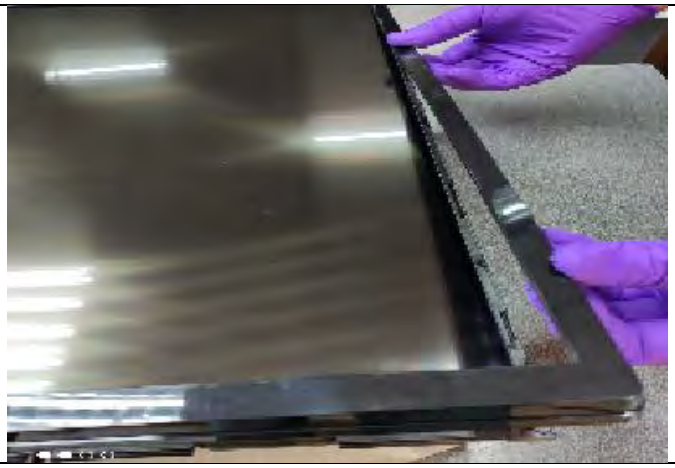
Procedimiento / Procedure:	
IMPORTANTE: Para este procedimiento es especialmente importante trabajar en un lugar perfectamente limpio y utilizar guantes. IMPORTANT: For this procedure is especially important to work in a very clean space and protect the hands with gloves.	
1. Colocar el TV con la pantalla abajo sobre una superficie plana y protegida para evitar daños en la superficie. Desatornillar la tapa trasera. 1. The TV will be placed in a flat and protected surface to avoid damages on the surface. Unscrew back cover.	
2. Continuar desatornillando los tornillos de la PCB main. 2. Continue unscrewing the screws of the Main PCB cover.	

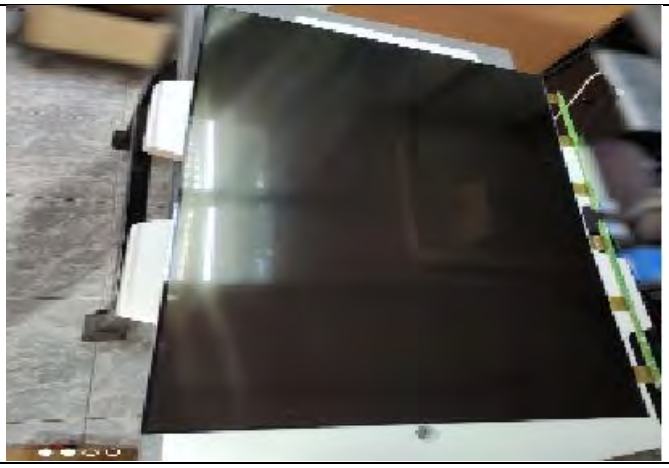
3. Seguimos con los tornillos que ocultan las roscas donde iría atornillado el soporte de pared. 3. We continue with the screws that hide the threads where a wall support would be fixed.	
4. En algunos modelos, podemos encontrar tornillos que son más difíciles de localizar como los mostrados en la imagen. 4. In some models we can find screws with difficult location as shown in the picture.	
5. Una vez se hayan desatornillados todos los tornillos, retiramos la tapa trasera. Desmontar todas las piezas necesarias para poder acceder a los leds. 5. Once all screws are unscrewed, back cover should be removed. All parts that are needed to be removed to access	

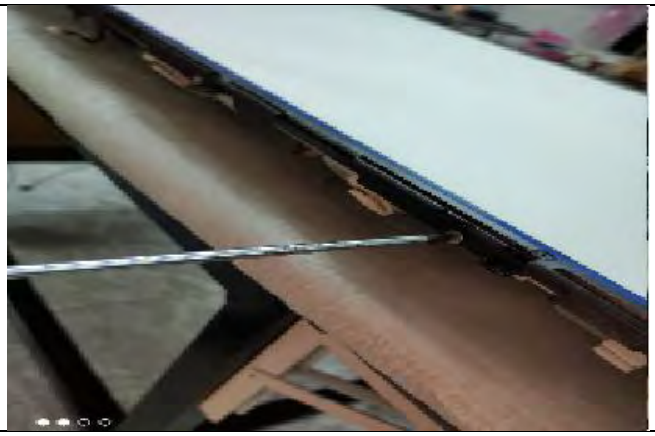
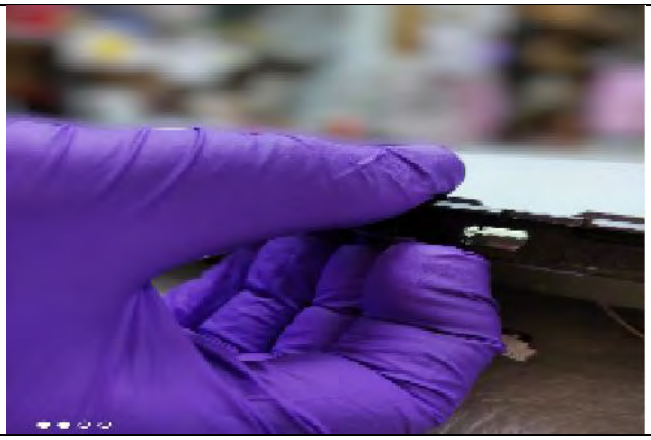
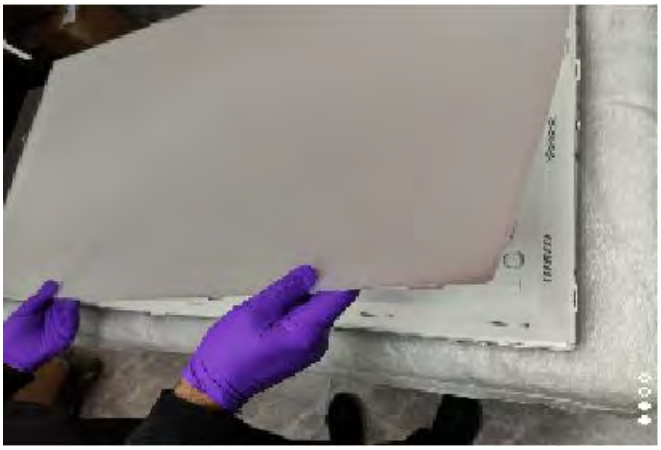
the LED bars, should be disassembled.	
6. Se desconectan y se desmontan los altavoces. . 6. Unplug and disassemble the speakers. .	
7. Se desatornilla el protector de los drivers del panel display. 7. Unscrew the drivers' protector from display panel.	

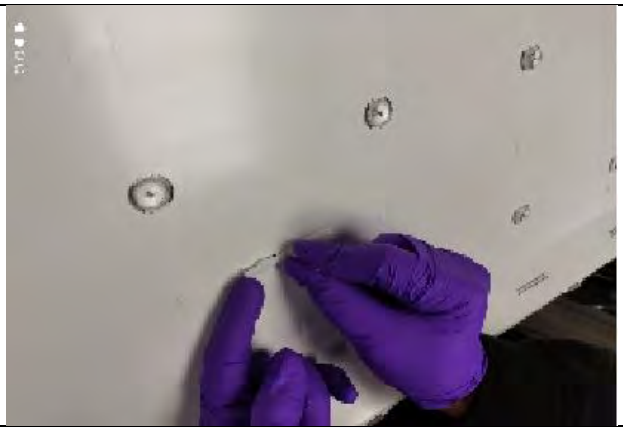
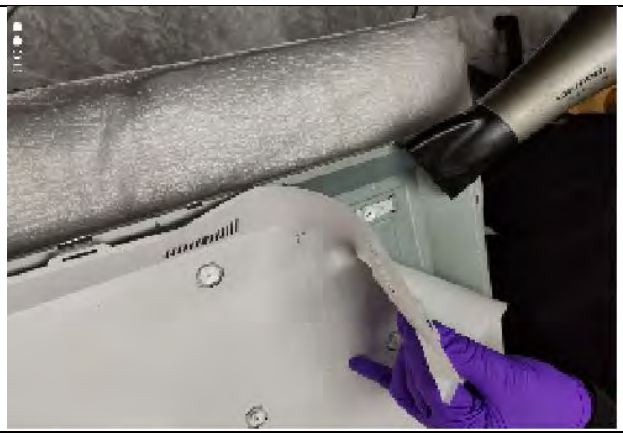
8. En algunos modelos podemos encontrar algunos tornillos que fijan el marco frontal del panel a la carcasa interior. 8. In some models, there could be some screws holding the front frame of the panel to the inner housing.	
9. Retirar el módulo WIFI de su alojamiento y desconectarlo. 9. Remove WIFI board from its place and unplug.	
10. Retirar el módulo de Infrarrojos de su alojamiento y desconectarlo. 10. Remove IR board from its place and unplug.	

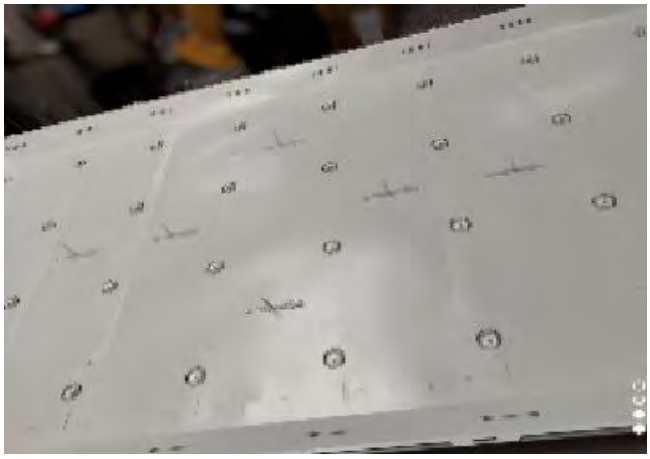
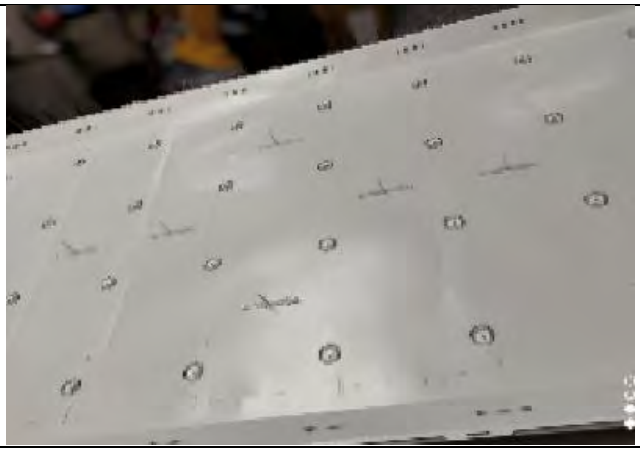
11. Desconectar el módulo T-COM / SCALER. 11. Unplug T-com /Scaler pcb.	
12. Retiramos el protector de los drivers del panel. 12. Remove protector from the panel divers.	
13. Despegamos las tomas de masa de los drivers que van pegados a la carcasa interior. 13. Unstick ground sockets fixed to the inner housing.	

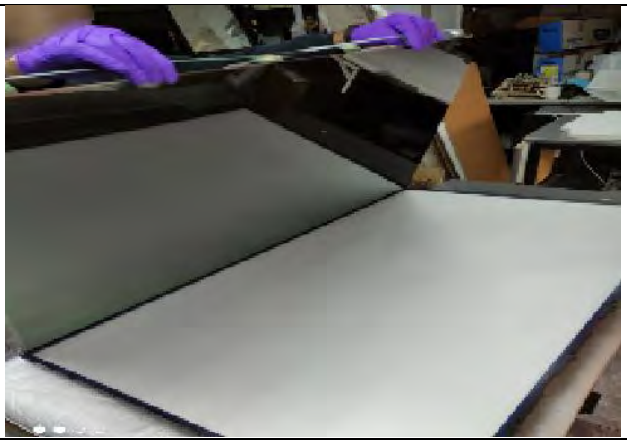
14. Con ayuda de una espátula de plástico, hacemos palanca en el interior del marco frontal, despegándolo solo un poco. 14. With help of a plastic palette, lever inside the front frame. Take out just a little bit.	
15. Con mucho cuidado tiramos y giramos los drivers del panel para que queden colgando. 15. Pull carefully and turn the display drivers down. Left them hanging.	
16. Con cuidado, damos la vuelta el TV y poco a poco, empezamos a sacar el marco, que estará sujeto solo a presión. 16. Turn the TV carefully and take out the front frame that would be fixed by pressure.	

17. Preparar otra mesa y proteger la superficie para evitar daños. 17. Prepare another table and protect the surface to avoid surface damages.	
18. Muy cuidadosamente levantamos el display y lo dejamos sobre la superficie que acabamos de preparar. 18. Lift the display very carefully and leave it Prepare another table and protect the surface to avoid surface damages.	
19. En esta mesa vamos dejando por orden de desmontaje cada una de las láminas del panel. 19. Place on this table, each panel sheets by order of disassembling.	

20. Desatornillamos el marco que sujeta las láminas del panel. En algunos casos no habrá tornillos. 20. Unscrew the frame that hold the panel sheets. In some cases, there won't be any screw.	
21. Haciendo palanca muy suavemente, se van abriendo las pestañas que sujetan el marco. 21. Open the tabs that hold the frame by levering them very softly.	
22. Después de levantar todas las pestañas, se retira el marco y a continuación se dejan todas las láminas que quedan sueltas en la otra mesa. 22. After lifting all the tabs, remove the frame and take all remaining sheets all together leaving them on the other table.	

23. Solo quedará la última lámina, que es la que cubre las tiras de leds. 23. There is just one remaining sheet. This is that covers the LED bars.	
24. Retiramos las piezas que sujetan esta lámina levantándolas de un extremo y deslizándolas hacia un lado. 24. Pieces that fix the sheet could be removed by lifting one end and sliding to the side.	
25. Con un secador de pelo vamos calentando y retirando poco a poco la lámina final. 25. Last sheet should be carefully removed, heating the sheet by using a hair dryer.	

26. En este punto, quedarán a la vista todas las tiras de LED, que dependiendo del modelo, pueden estár atornilladas, pegadas o encajadas. 26. At this point, LED bars will be accessible. They could be screwed, stuck or fitted.	
27. Una vez cambiadas las tiras de LED's procedemos al montaje de la TV siguiendo todos los pasos descritos hasta ahora en orden inverso. 27. Once the DED bars have been replaced, we would assemble the TV following all previous steps in the opposite order.	
28. Es muy importante encajar cada una de las láminas en el lugar correcto. 28. It's very important to assemble each sheet fitting them in the correct place.	

29. Después se encajan el resto de las láminas, agrupándolas y encajándolas correctamente. 29. Then, rest of the sheets should be assembled grouping them and fitting correctly .	
30. El display se coloca en último lugar con mucho cuidado. 30. Very carefully, the display should be placed.	
31. Es muy importante que el display quede encajado en el lugar correcto, prestando atención a las esquinas. 31. It's extremely important that display is well fitted in his correct position by checking the corners.	
32. Antes de dar la vuelta al TV, colocar en su sitio los drivers del panel y montar el mueble frontal que va a presion. 32. Before turning the TV, fix the panel drivers in their place and assemble the front cover by press fit.	

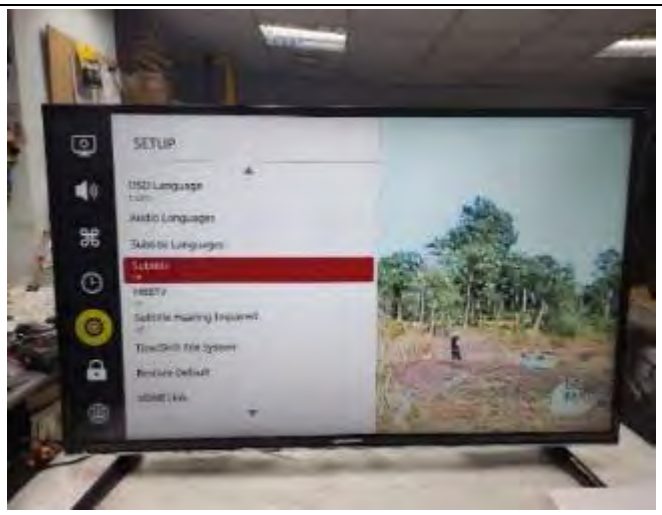
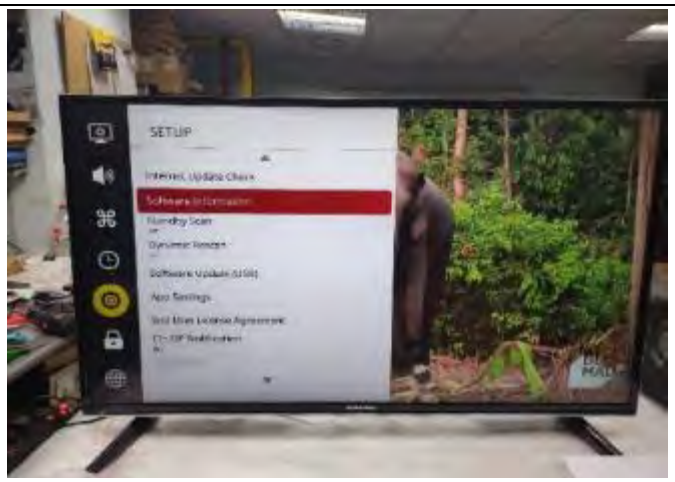
33. Seguimos los pasos en orden inverso al explicado anteriormente hasta colocar la tapa trasera y atornillarla. 33. Follow all steps in opposite order as explained before until placing the rear cover and screw it.	

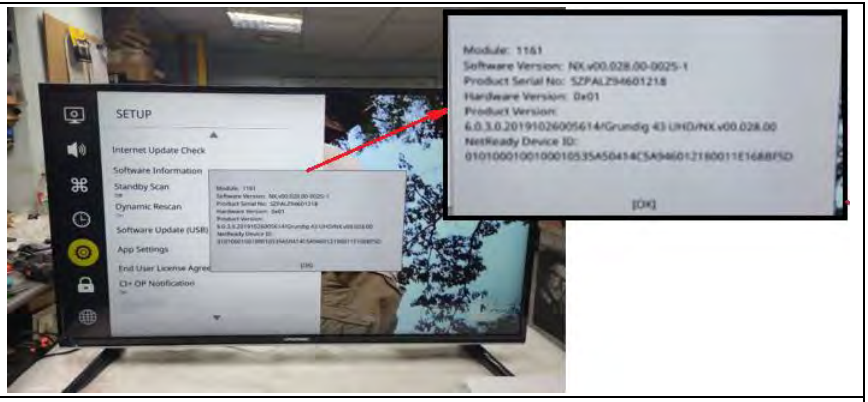
Rework Process: RP_C_SERVEES_2101_001	Versión / Release: r1	Fecha / Date: 04/01/2021

Tipo / Type:	Rework Process TV		
Asunto / Subject:	C-SERVEES PROJECT		
Propietario / Owner:	**Javier Garcia**	email:	javier.garcia@beko.com
Estado / Status: ONGOING Jan. 2021	G43C 893 5A GRUNDIG (UGE000) POWERMAX NX		
Introducción / Introduction:	Verificación y actualización del Software / Software update		
Explicación / Explanation:	El SW de un TV puede actualizarse durante la vida útil del mismo. De uno a otro se van corrigiendo y mejorando el funcionamiento del aparato. Es necesario comprobar y en su caso actualizar el SW a la nueva versión tras la readecuación de un aparato. Según los modelos hay varias opciones de actualización de SW: automática y manual. En este documento se explicarán los dos procedimientos. SW could change during the lifetime of the TV set. Detected errors are corrected and new features could be added with new versions. In case of any rework operation it is need to update the SW with the last version available. Depending on the model, there are different options to update the SW (automatic or manual). Both procedures will be explained in this document.		
Herramientas necesarias / Needed tools:	- Mando a distancia - Nueva versión del software	- Remote control - New software version	

Procedimiento / Procedure:
A) Verificación de la versión de SW / SW version verification

34. Pulsamos la tecla **"MENU"** del mando a distancia. 34. Press button "MENU" on the Remote control.	
35. Aparecerá en la pantalla la interfaz de **Ajustes**. 35. **Settings** screen will be shown.	

36. Bajamos con los botones del cursor del mando hasta la opción **“SET UP”.** 36. Move to the “SET UP” option using the cursor buttons on the R/C.		
37. Seleccionar la opción pulsando **”OK”** para entrar en el submenú. 37. Select the option by pressing “OK” and entering the submenu.		
38. Desplazar hacia abajo hasta llegar a la opción **“SOFTWARE INFORMATION”**. 38. Scroll down to “SOFTWARE INFORMATION” option.		

39. Pulsamos **"OK"** y aparece en pantalla la versión del software del televisor. 39. Pressing "OK", the SW version will be displayed.	
B) Actualización del SW vía internet / Online SW update	

Rework Process: RP_C_SERVEES_2102_001	**Versión / Release:** r1	**Fecha / Date:** 17/02/2021

Tipo / Type:	Rework Process TV		
Asunto / Subject:	C-SERVEES PROJECT		
Propietario / Owner:	**Javier Garcia**	email:	javier.garcia@beko.com
Estado / Status:	G43C 893 5A GRUNDIG (UGE000) POWERMAX NX		
Introducción / Introduction:	Verificación de conectores / Conectors check		
Explicación / Explanation:	Con el uso del aparato, la continua manipulación de los conectores puede dar lugar a problemas de conexión por deterioro de las soldaduras o desgaste mecánico de los propios conectores. Es necesario comprobar el buen funcionamiento de cada uno de ellos. Because of the handling of the connectors, the proper functioning of the connectors could be affected. It is needed to check all of them.		
Herramientas necesarias / Needed tools:	- Aparato con conexión HDMI - Auriculares - Conexión y cable de antena - Soldador - PCB main (052T43LG7C) - Connectores (HDMI, Antena auriculares)	- HDMI appliance - Headphones - Antenna connection and cable - Welding gun - Main PCB (052T43LG7C) - Connectors	

Procedimiento / Procedure:

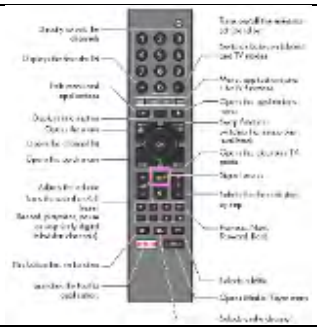
C) Verificación de los puertos HDMI / HDMI port check

1. Conectar un cable con dos conectores HDMI a un aparato con salida HDMI.

1. Plug an HDMI cable to the HDMI port of a device provided with this connection.

2. Conectar el otro extremo del cable HDMI al puerto HDMI 1 del TV y encender el TV.

2. Plug the HDMI cable to the HDMI 1 port on the TV and switch the TV on.

3. Pulsar la tecla **"Selección de Fuente"** del mando a distancia. 3. Push the "**Signal source**" button on the R/C.		
4. En la pantalla aparecerán las distintas opciones de Fuente de señal. 4. On the screen, several Signal source options will be shown.		
5. Con el cursor derecho/izquierdo seleccionar la opción **HDMI1** y pulsar **OK**. 5. By using left/right cursor buttons, select **HDMI1** option and click **OK**.		
6. Si aparece en pantalla la señal que emite el aparato conectado y confirmamos que la imagen y sonido son correctos, podemos dar por verificado con funcionamiento correcto el **HDMI1**. 6. If the image and sound of the device connected to HDMI1 is displayed correctly, we could confirm that HDMI1 is verified and working properly.		
7. Seguir los mismos pasos para verificar el resto de las conexiones HDMI. 7. Proceed in the same way to check and verify the rest of HDMI ports.		
D) Verificación de la toma de antena / Antenna connection check		

8. Es necesario disponer de una toma de antena con buena señal para una verificación correcta del sintonizador.

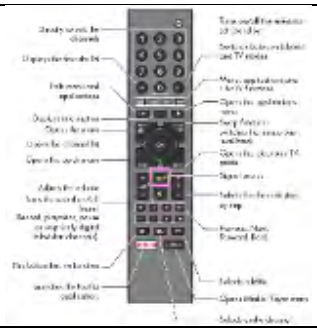
8. A good antenna signal is required to verify the tuner.

9. Conectar el cable correspondiente a la toma de antena del TV y encender el TV.

9. Plug the antenna cable to the **antenna connector** on the TV and switch the TV on.

10. Pulsar la tecla **"Selección de Fuente"** del mando a distancia.

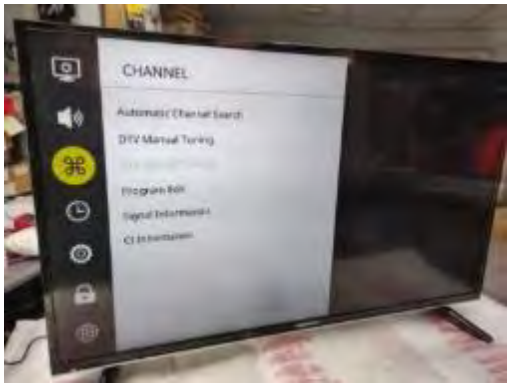
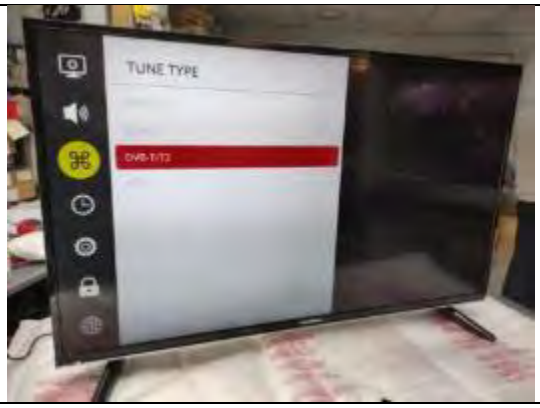
10. Push the "**Signal source**" button on the R/C.



11. En la pantalla aparecerán las distintas opciones de Fuente de señal.

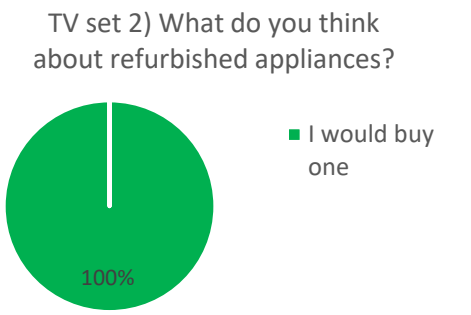
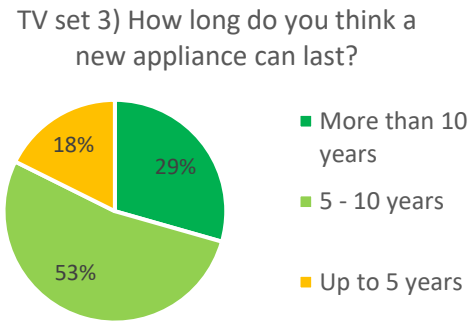
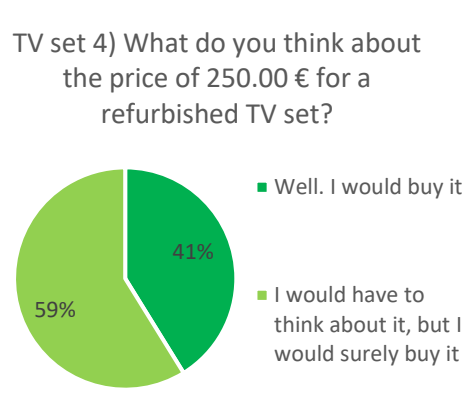
11. On the screen, several Signal source options will be shown.

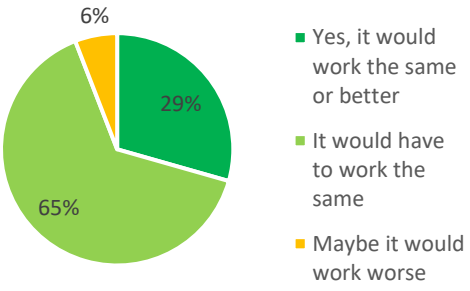
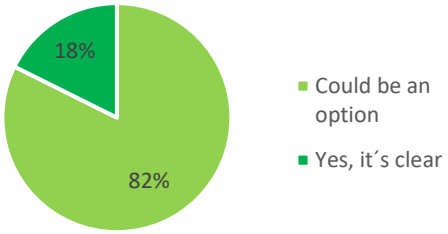
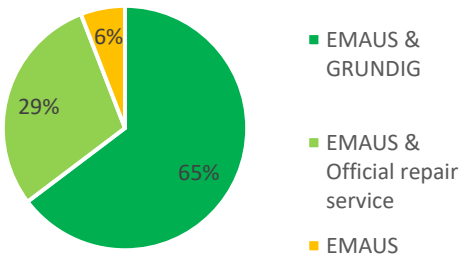
12. Con el cursor derecho/izquierdo seleccionar la opción DVB-T/T2 y pulsar OK. 12. By using left/right cursor buttons, select DVB-T/T2 option and click OK.		
13. Si en la pantalla no se visualiza ningún canal, procederemos a sintonizar el TV para hacer una nueva búsqueda de canales. 13. If any channel can't be seen, the TV tuning of the TV should be started to search all available channels.		
14. Para sintonizar el TV, pulsar el botón "MENU". 14. To search channels, press "MENU" button to on the R/C.		
15. Aparece en pantalla la interfaz de ajustes. 15. Settings interface is displayed.		

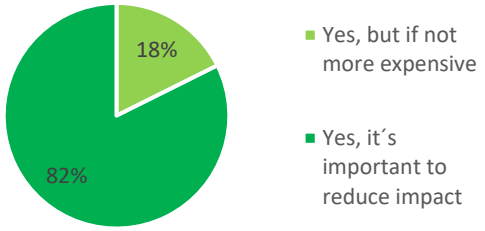
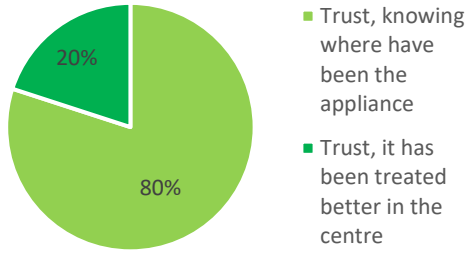
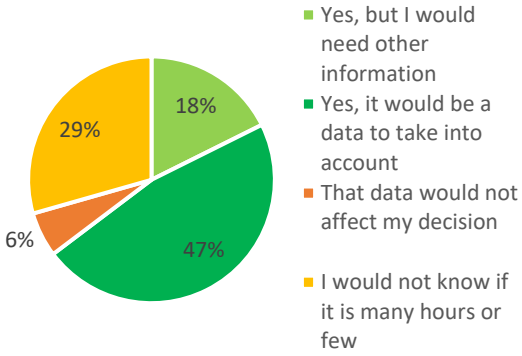
16. Bajar con los botones del cursor del mando hasta la opción **“CHANNEL”** y seleccionar pulsando **“OK”** para entrar en el submenú. 16. Move to the “CHANNEL” option using the cursor buttons on the R/C and press **“OK”** to access the submenu.		
17. Desplazar hacia abajo hasta la opción **“AUTOMATIC CHANNEL SEARCH”**. 17. Scroll down to “AUTOMATIC CHANNEL SEARCH” option.		
18. Desplazar hacia abajo hasta la opción **“AUTOMATIC CHANNEL SEARCH”** y pulsar “OK” para seleccionar. 18. Scroll down to “AUTOMATIC CHANNEL SEARCH” option and select pressing **“OK”**.		
19. Seleccionar la opción **“DVT2/T2”** y pulsar **“OK”** para confirmar. 19. Select option **“DVT2/T2”** and press **“OK”** to confirm.		

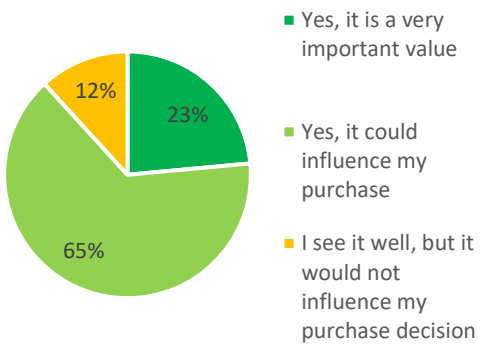
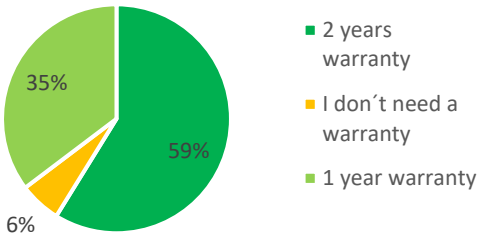
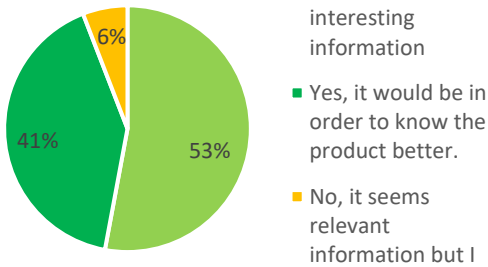
20. La búsqueda de canales se inicia automáticamente. 20. Channel search will start automatically.	
21. Al final de la búsqueda, aparecerá en pantalla el primer canal encontrado. Si el número de canales encontrados se considera aceptable según la señal de antena y la calidad, podemos dar por verificado con funcionamiento correcto el Conector de Antena. 21. Once the search process is finished, the fist channel found will be displayed automatically. If the number of found channel is considered correct, we could confirm that Antenna connector is verified and working properly.	
E) Verificación del conector de los auriculares / Headphones connection check	

7.2 Collect customers' feedback (living labs)

<table>
<tr><td>  </td><td>TV SET LIVING LAB QUESTIONNAIRE
EVALUATION OF RESPONSES</td></tr>
<tr><td> 
</td><td>All participants consider the purchase of refurbished TV sets to be of interest in the case of televisions.</td></tr>
<tr><td> 
</td><td>Most users estimate the life of a TV to be 5-10 years, so when purchasing this product, they have these expectations of use. Even so, a significant proportion believe that a TV should last more than 10 years.</td></tr>
<tr><td> 
</td><td>When asked about prices, 41% of people would be willing to pay 250 euros for a refurbished TV. The rest of the participants would have to think about it, although there is a possibility that they would buy it.</td></tr>
</table>

TV set 5) Do you think checking, cleaning and changing the critical parts of a TV set, its durability is ensured? 	When it comes to the question of how they think the product would perform after refurbishment, in the case of the television, a minority think that the product could perform worse after refurbishment, namely 6% of the respondents. However, the majority believe that it should work the same.
TV set 6) If the project goes ahead, GRUNDIG would enter into an agreement with EMAÚS to refurbish and sell TV sets. Would you buy it? 	Despite having less confidence in the reconditioning of the television than in that of the washing machine, the willingness to buy is higher for the television. When asked whether they would buy the TV from EMAUS, the result is that it could be an option for 82% of the respondents, a very representative figure, none of them refused.
TV set 7) How do you think the guarantee of the refurbishing product sold in EMAÚS should be accredited? 	Users prefer the option in which EMAUS and GRUNDIG are responsible for the warranty of the television, specifically, 65% of the total number of respondents support this option. The second option in level of preference would be EMAUS with the collaboration of the Official Repair Service, although for this option the support is reduced to practically less than half.

TV set 8) Would you buy a refurbished appliance because it generates less impact on the environment? 	Participants in the session believe that buying refurbished appliances is important to reduce environmental impact. In the case of television, 82% believe it is an important value, but the rest would not buy a television if it were more expensive.
TV set 9) The product has been in a renting model in a centre for elderly people for 3 years. Does it generate trust or mistrust in you? 	About renting, it is considered positive to know the origin of the product; 80% of the people surveyed feel confident about knowing where the television has been previously, but this is not related to the idea that the appliances have received better treatment. Nor is the included maintenance service considered to increase the life cycle of the product.
TV set 10) Could knowing the hours of use of the product help you in the decision? 	The participants find it interesting to know the hours of use of the product, 47% of people believe that this is a data to be considered when making a purchase decision, although a considerable percentage (29%) answered that they would not need this data because they would not know how to interpret it. It could be interesting for the project to think about how to transmit this information in a way that is accessible to most consumers.

TV set 11) EMAÚS reintegrates people into the workplace, does it affect your decision? 	The fact that EMAUS is a Labor Reinsertion project is positively valued by most respondents, around 90% see this aspect in a positive way and it would improve the perception of the product.
TV set 12) How many years of warranty would you need to buy a refurbished appliance? 	In terms of product warranty, 59% see a 2-year warranty as a good option. 35% see a 1-year warranty for televisions as good enough.
TV set 13) Would you need to know more detailed information about the origin of the materials and their environmental impact? 	Respondents find it interesting to know more detailed information on the provenance of materials and their impact, with the majority expressing that this could be a type of information they would access at some point. Six percent of respondents feel that this type of data is relevant to them but would not use it. Respondents express concern about the environment and the impact of product development on the environment.

GRUNDIG TV - G43C 893 5A

DISMANTLING PROCEDURE

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Removing the leg holders

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Removing the mainboard

Removing the Power Supply Board

Removing the LCD front cover

Removing the LCD screen

Removing the LCD backlight led bars

COMMENTS

Prerequisite

For dismantling the Grundig G43C 893 5A the following tools are needed:

1. A Philips screwdriver

2. A plastic pry tool

3. A pair of antistatic gloves

DISMANTLING PROCEDURE

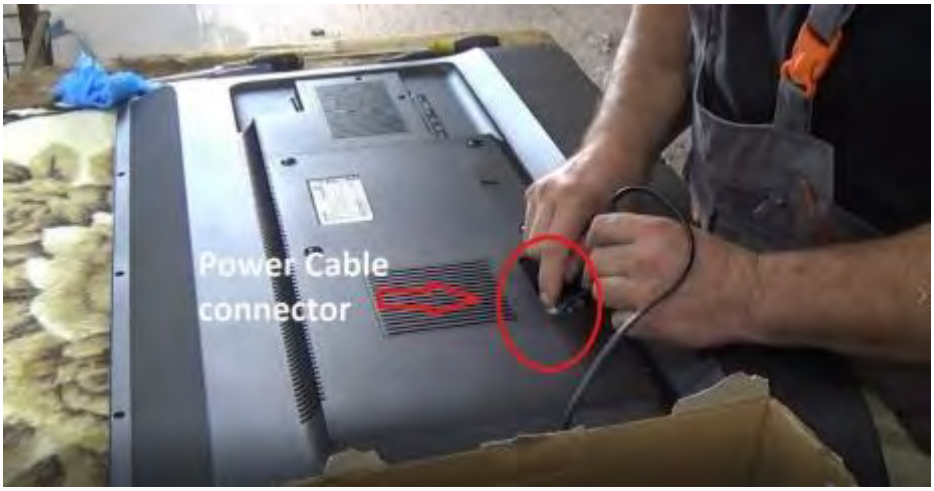
We will start the disassembly procedure by placing the TV on a clean surface, with the screen down and the back cover up.

1. Removing the power cord

The first thing we must remove is the power cord.

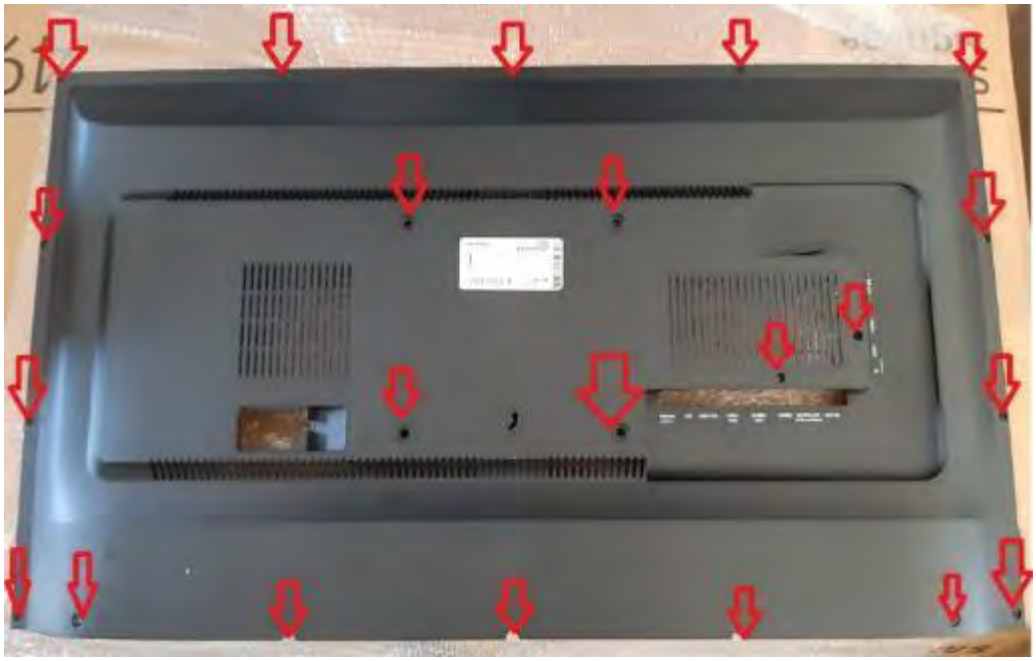
1. Remove the screw that hold the power cord cover

2. Once the cover is removed, you will have access to the power cord connector. Remove the power cord connector by pressing the connector clip



2. Removing the back cover

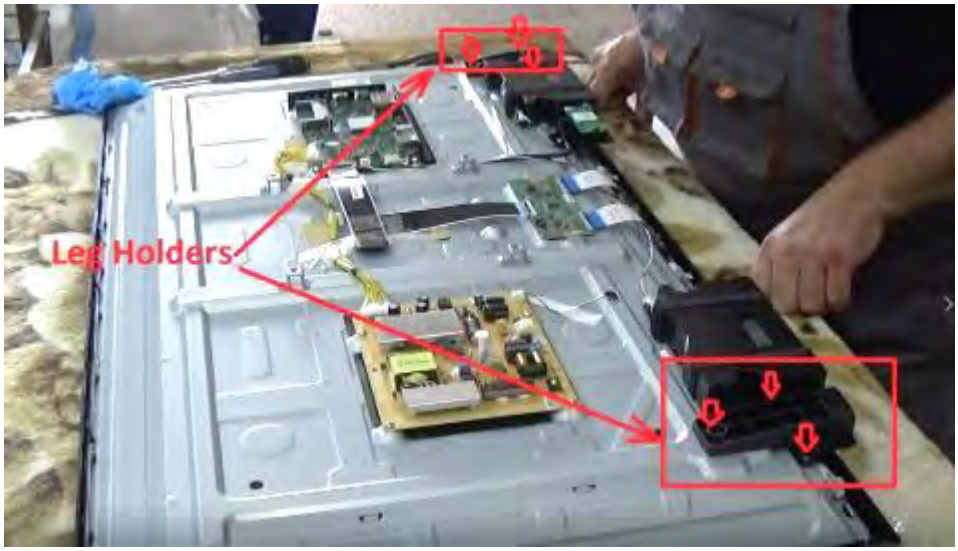
The back cover of the TV is held in place by 21 screws.



Unscrew all screws and lift the back cover from the back of the TV. The cover should come off easily, but if not, use the plastic lever tool to release the cover from the corners.

3. Removing the leg holders

There are 2 leg holders placed at each end of the bottom of the tv. Each one is held in place by 3 screws.

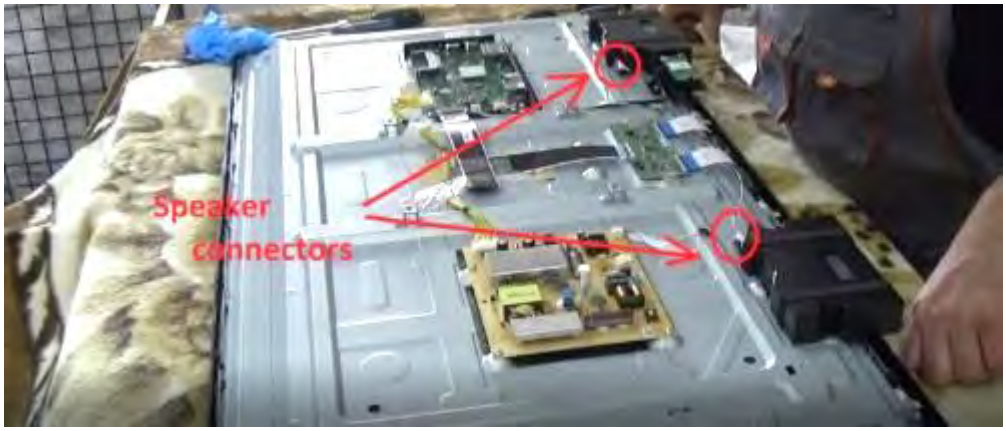


Remove all the screws and the leg holders will came off.

4. Removing the speakers

There are 2 speakers placed on the bottom of the tv.

Before removing the speakers, you must first disconnect the white connector from each of the speakers.



After removing the connector, pull out the speaker and it will come off.

5. Removing the Wi-Fi board

The Wi-Fi module is placed on a plastic holder that is held in place by one screw. It's also connected by a cable to the mainboard.

1. Remove the screw that holds the module
2. Unclip the module from the holder
3. Remove the cable that connects the Wi-Fi module

6. Removing the T-CON board

TCON is the small green board placed at the bottom of the TV, placed between the 2 speakers

It has 3 wide connectors and is held in place by 2 screws

1. Unplug the cables from the connector.

   To disconnect the cable from the connector, you must first lift the safety clip (the wide black plastic on the connector), then lift the cable slightly and it will come loose.

2. Unscrew the 2 screws holding the board in place.
3. Remove the board

7. Removing the mainboard

The main board is held in place by 4 screws placed on each corner of the board.

Also, there are 4 connectors that connect the cables coming from the other modules.

1. Unplug the power cable by pressing on the connector's clamp and pulling on the cable
2. Disconnect the display cable by first lifting the safety clip of the connector. Lift and then pull the cable to unplug it.
3. Remove the 4 screws and the board will came off.

8. Removing the Power Supply Board

The power supply board has 4 screws holding it to the chassis and 3 connectors.

1. Unplug all of the connectors
2. Remove the 4 screws

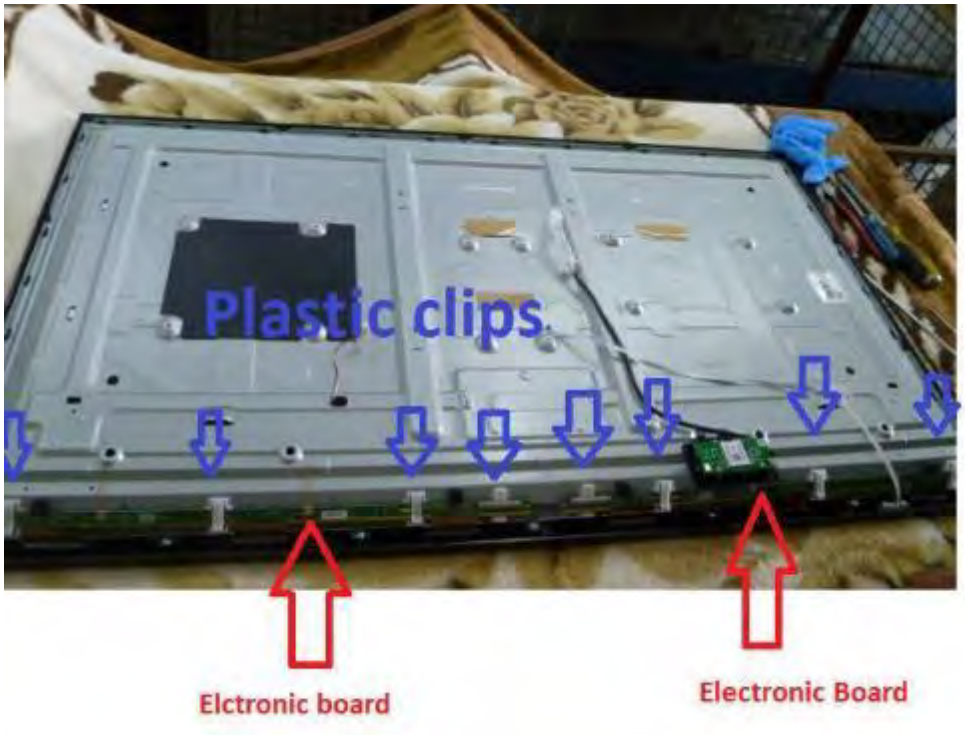
Now the board can be lifted off the chassis.

9. Removing the LCD front cover

1. Remove the cable that connects the mainboard to the IR receive

2. Remove the screws that hold the display frame

3. Carefully unclip the 2 electronic board of the LCD panel
   The electronic board is connected to the LCD panel through wide connectors that are soldered in place. These connectors cannot be removed without damaging the LCD panel.



4. Turn the TV over with the LCD screen on top.

5. Starting from the top corner easily unclip and lift the frame.

10. Removing the LCD screen

Removing the LCD panel is an operation that requires 2 people and also patience.

Start by lifting the LCD from the corners and when it starts to come off, hold it in the middle so that it does not bend.

Also keep in mind that you still have the 2 electronic boards attached to the LCD panel. **Damaging the wide cables will result in making the whole panel useless!!!**

11. Removing the LCD backlight led bars

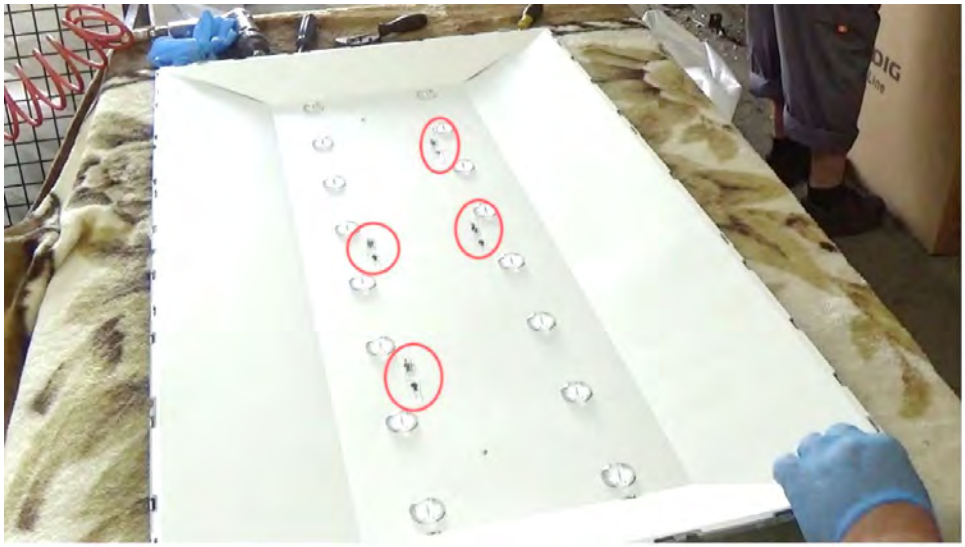
To remove the backlight led bars you will first need to remove:

a. Side frame
The plastic side frame is held around the metal chassis by clamps.
Use the plastic pry tool to unclip the frame.

b. Rest of the panel components: deflector sheets, plexiglass panel.

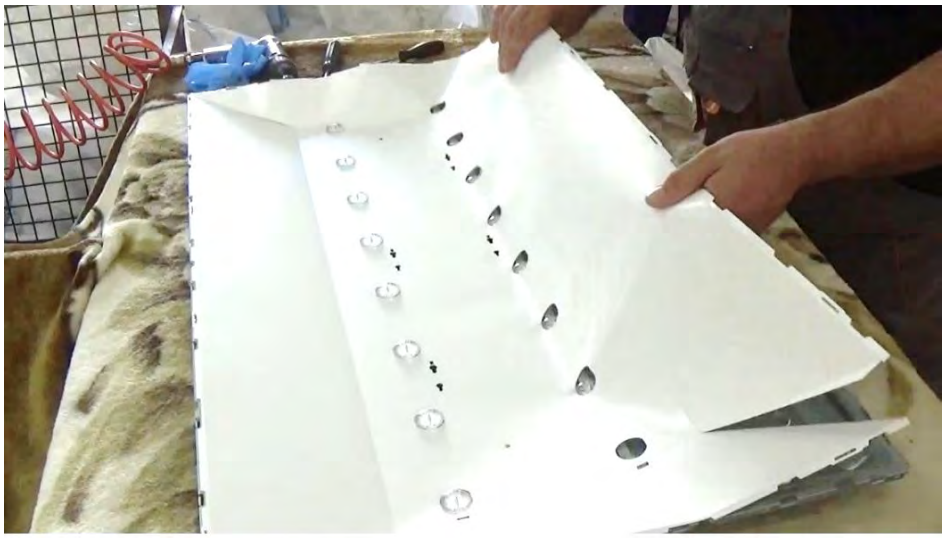
After the plastic frame is removed, simply lift the deflectors and the plexiglass panel.

c. Plastic clips holding the white paper reflector



d. White paper reflector

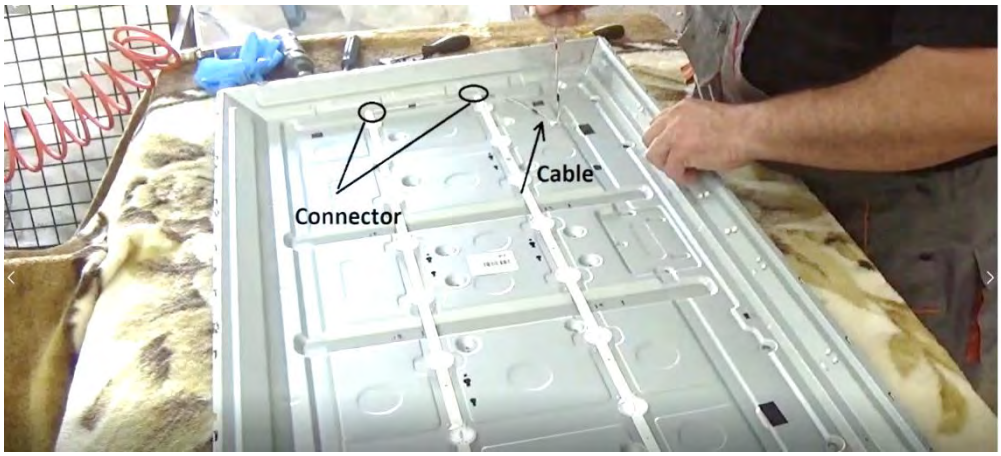
After all, four clips are removed carefully lift the white paper reflector.



After all the panel components are removed, we can proceed to removing the 2 led bars.

The LED bars have a connector at one end that needs to be removed and these are held in place by the double-sided tape.

Remove the cable that connect the led bars to the power supply.

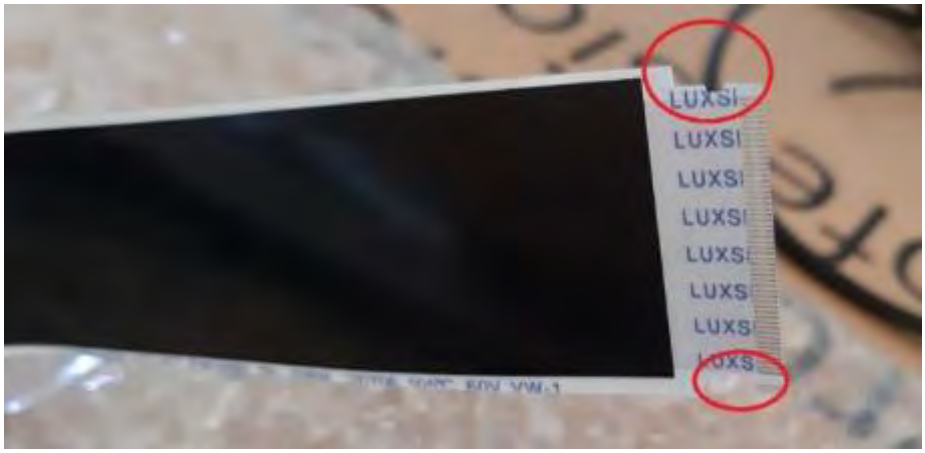


Use the pry plastic tool to carefully remove the bars from the double-sided tape.

COMMENTS

- Gloves should be worn when removing the power supply, as high voltage capacitors may be charged and there is a risk of electric shock.
- When removing electronic components, antistatic gloves should be worn as static electricity can damage sensitive electronic circuits.
- Particular care should be taken when removing the video cable that connect the TCON tot the main board and the TCON to the LCD.

These cables have fitting edges that can be easily broken if pulled without lifting first.



Also, when removing the above cables, the connector's safety clip should be carefully lifted. This are extremely sensitive connectors and special care should be taken.

When removing the LCD Panel, you should try not to damage the wide connectors that connect the panel to the thin electronic board. These connectors are solded to the boards and are extremely sensitive. Damaging their connections will result in vertical colour lines (or bands) on the display therefore making the panel useless.

Dismantling procedure developed by Indumetal for optimised dismantling of the TV set

INDUMETAL RECYCLING

Arçelik

DISMANTLING PROCEDURE FOR TV GRUNDIG G43C 893 5A

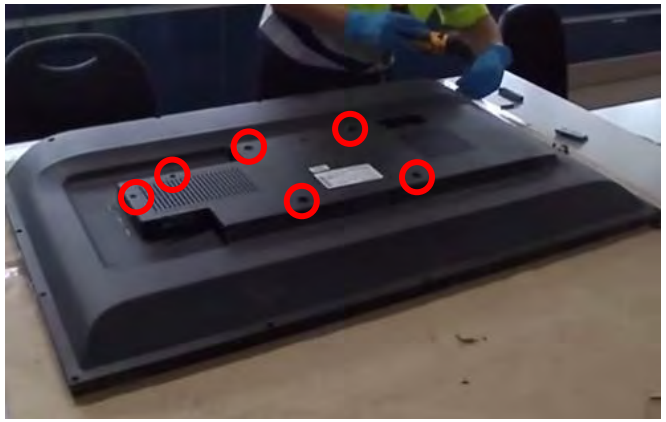
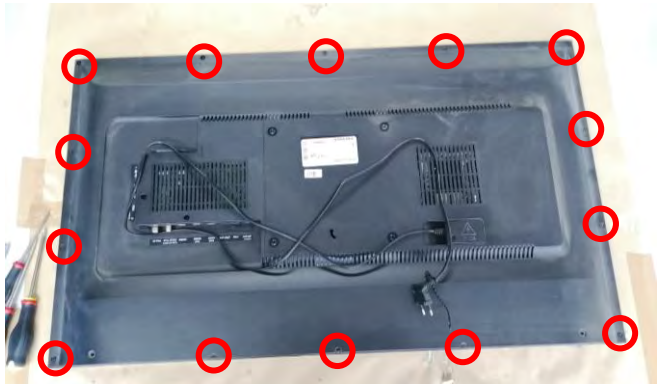
DISMANTLING PROCEDURE FOR TV GRUNDIG G43C 893 5A

We will start the dismantling with the back cover in the upper side

1. Cable

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the screw to open the cover that protects the cable **2** Remove the cover and separate the cable		1  2 

2. Back cover

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the 6 big screws of the cover 2 Change the head of the tool 3 Remove the 14 screws of the cover		1  2 

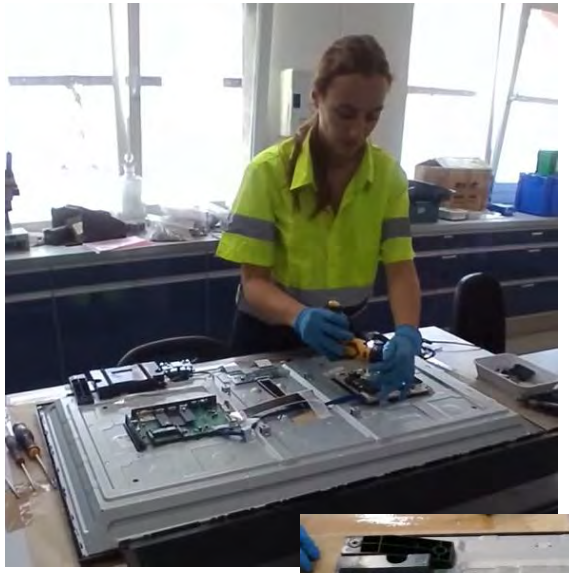
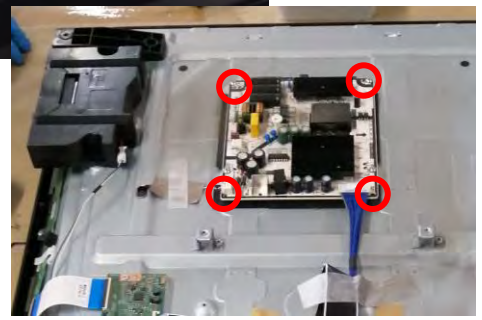
3. Hoparlor

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the 3 screws of the plastics parts close to the horparlors 2 Remove the two hoparlors just making a small force. There is not necessary unscrewing		1  2 

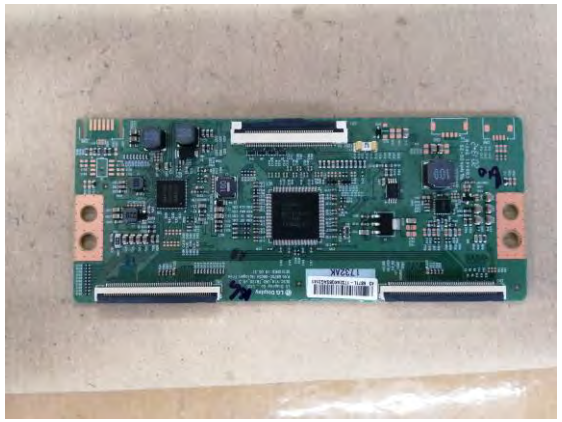
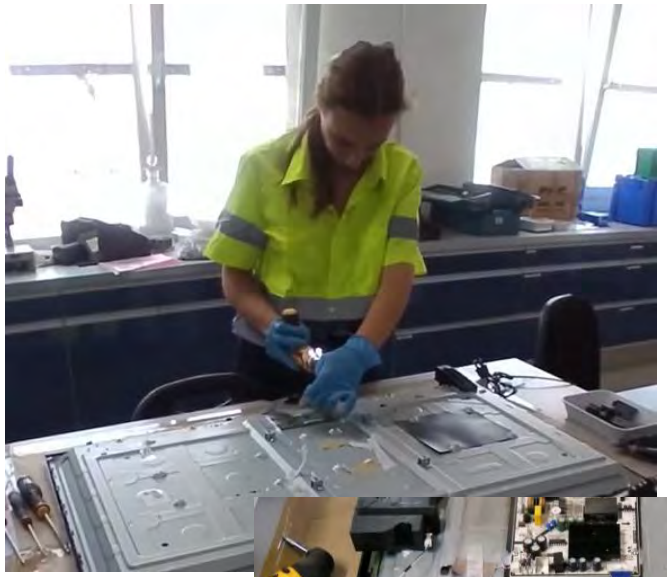
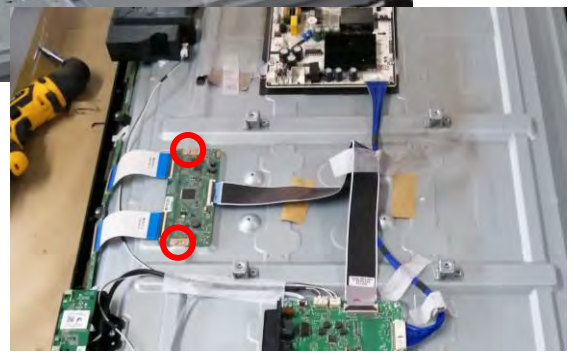
4. Main Board

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Disconnect all cables from the main board and remove the 4 screws securing the main board to the TV.		1 

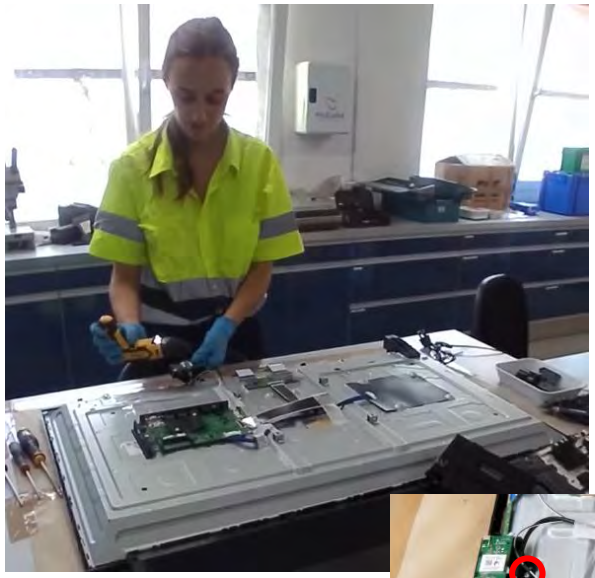
5. PSU (Power Supply Unit)

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Disconnect all cables from the PSU and remove the 4 screws securing the PSU to the TV.		1  

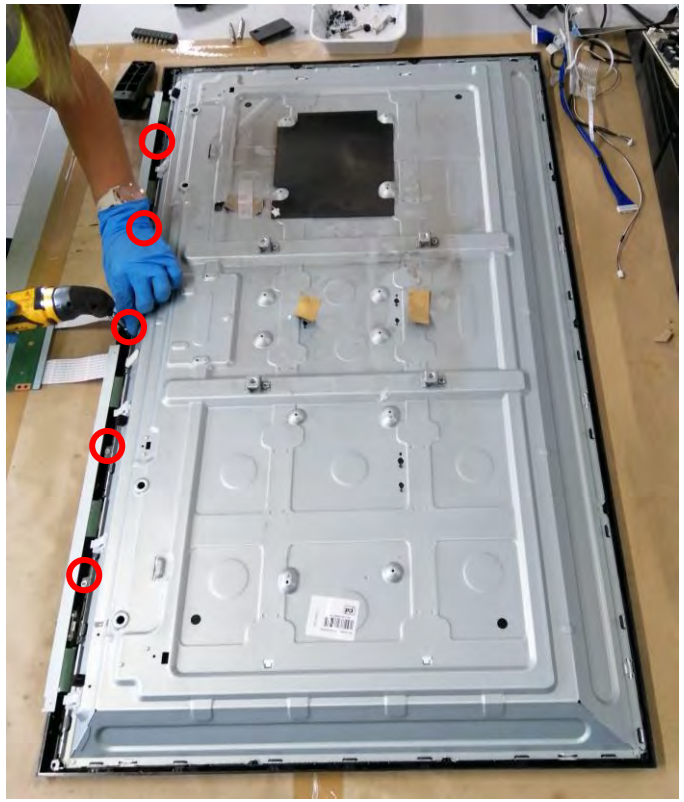
6. T-con Board

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Disconnect all cables from the T-con board and remove the 2 screws securing the board to the TV.		1  

7. Wi-fi/Bluetooth Board

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Disconnect all cables from the Wi-fi/Bluetooth board and remove 1 screw securing the board to the TV.		1  

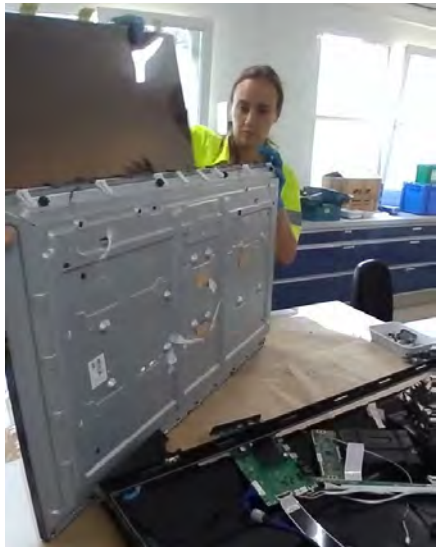
8. IR Led Board

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the 5 screws securing the board to the metallic housing.		1 

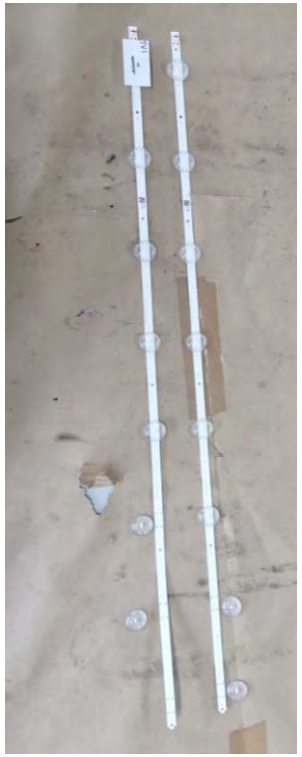
9. Front Cover

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Put in vertical the TV in order to make easier the separation of the front cover **2** Making some force, separate the frame from the rest		 1  2

10. Mid Frame

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the panel display **2** Making some force, dismantle the mid frame, releasing** the clips of the frame. ** In all dismantled TVs, the mid frame is recovered broken.		 1  2

11. LED bar

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Remove the plastic films **2** Remove the 4 plastic brackets which attach the last plastic film to the LED bar, and once removed, take off the plastic film **3** Detach carefully the LED bar		  

12. Metallic housing (Ferrit)

Dismantling procedure	Pictures of the objective	Pictures of the process
1 Once removed the LED bar, the metallic housing is free of components and is recovered		1 

13. Remote control

Dismantling procedure	Pictures of the objective	Pictures of the process
1 No need to dismantle or separate		

14. Battery

Dismantling procedure	Pictures of the objective	Pictures of the process
1 No need to dismantle or separate		

15. Other plastics

Dismantling procedure	Pictures of the objective	Pictures of the process
1 No critical components already dismantled during the sequence	 	

16. Fasteners

Dismantling procedure	Pictures of the objective	Pictures of the process
1 No critical components already dismantled during the sequence