Activating Circular Services in the Electric and Electronic Sector

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Deliverable 4.3. Demonstration of distribution & use phase for target products

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Authors	Arçelik, ADVA, Lexmark, Gaiker, Rina-C

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DOCUMENT CONTROL PAGE

<table>
<tr><td>Author(s)</td><td>Klaus Grobe, ADVA
Agnes Vigh, Lexmark
Patrick Carminati, Lexmark
Agnes Bartfai, Lexmark
Maxime Furkel, Lexmark
Aybüke Kaba, Arçelik
Sevgican Koç, Arçelik
Emrah Yavuz, Arçelik
Özlem Ünlüer, Arçelik
Ana Isabel Díaz, Gaiker
Sara Fozza, Rina-C</td></tr>
<tr><td>Version history</td><td><table><tr><th>#</th><th>Reviewer</th><th>Comments</th></tr><tr><td>00</td><td>Gaiker</td><td>Document revised by WP leader and TMC</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table></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 distribution and use 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 scope of this document comprises all activities developed within subtask 4.1.2, subtask 4.2.2, subtask 4.3.2 and subtask 4.4.2 of WP4: all four subtasks belonging to the distribution and use phase for each demonstration.

The objectives of the distribution and use phase are 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.

Continuing from the activities carried out during the design and production phase, the present report describes the next step in the implementation of product specific CEBMs according to the CE actions selected for each demonstration. In particular, the use phase is focused on exploring the potential to change from linear or 'classic' business models (selling + maintenance services) to circular offerings (Product Service Systems) where the manufacturer retains the ownership of the product while offering leasing, renting or pay-per-use to meet customer's needs with less environmental impacts. The CEBMs for each of the demonstration products are supported by the use of ICT tools specifically developed for logistics optimisation and secure information exchange across the value chain.

The washing machine demonstrator is led by Arçelik, where the purpose is to test the feasibility of moving towards a renting/leasing business model for washing machine oriented to corporate customers (B2B) and offer improved circular solutions for white goods electronics. For this purpose, newly eco-designed washing machine units manufactured in the first phase of the demonstration period were shipped and installed in testing facilities in Turkey, Spain and Italy in order to assess customer acceptance and compare results between countries. The outcomes from this demonstration underline the need to offer attractive quality/price combos in order to generate customer interest. While B2C consumers do not find washing machine leasing too appealing up-front, some B2B customers such as the ones selected for this demo (dormitories, residences, nursing homes, offices) may find this offer fitting for their needs. The feasibility of the leasing model from an economic perspective is positive for a 10 year period although the viability depends on increasing the number of customers.

The printer and toner cartridges demonstrator is led by Lexmark and the aim is to analyse the potential to expand the printers refurbishment business. Two main issues identified in the previous demonstration stage will be addressed in this report: cost and customer acceptance. On cost, we'll see that there is a path to get parts from recyclers and generate cost savings; on the other hand, 3D printing hasn't demonstrated financial interest for the printers. Lexmark also worked with its subcontractor to investigate efficiency gain in the refurbishment process and ultimately drive an appealing business case. For customer acceptance, Lexmark held qualitative one-to-one interviews with eight key and representative customers to better understand their expectations. While cost keeps being the major driver, the interviews highlighted interesting enablers to make refurbishment an attractive market. Lexmark also prepared and shipped to selected customers 4 refurbished printers build with various cosmetic defects to test cosmetic defect acceptance as well as functionality acceptance. Also in this demonstration period, recycled material content was successfully certified with track and trace of recycled content up to the finished good received at the distribution centre stage. Reverse logistic ICT tool was tested by demonstrator bringing interesting outcomes. Finally, demonstrator highlights actions related to lobbying and Public Relation communication toward enhancing Circular Economy in its industry.

The third demonstrator is led by ADVA and the main goal is to assess different PSS alternatives that could be applied to the ALM system and other ADVA products, considering all relevant parameters (product characteristics, maintenance, lifecycle cost etc.) and from both the company's and customer's perspective. Three PSS and two ICT products have been analysed and the results show that, from an environmental point of view, no significant differences have been found. From a financial point of view, there are significant differences related to revenues, maintenance costs and customer costs. This work has been complemented by an extensive lifetime optimisation analysis which includes the impact on the results of a potential change in emission factors, being extensible to other ICT products. At the same time, the newly developed sensors for fire detection and access control are being tested in a commercial site as a PSS and the first results are shown. Regarding ICT tools, an update is included on the testing of blockchain to exchange information and facilitate recycling operations. Finally, the update of ADVA's Ecodesign Guide has been possible based on the project findings and partners' feedback.

The TV set demonstrator is led by Arçelik, where the purpose is to test the feasibility of moving towards a renting/leasing business model for TVs oriented to corporate customers (B2B) and offer improved circular solutions for consumer electronics. For this purpose, newly eco-designed TV sets manufactured in the first phase of the demonstration period were shipped and installed in testing facilities both in Turkey and Spain. As with the washing machines, testing at demonstration facilities has enabled gathering customer feedback in both countries. The outcomes indicate that TVs are more suited to B2B customers than washing machines, and the acceptance depends on the service offered, which should be made more attractive by including other consumer electronics in the package as well as streaming services.

The fact that all models examined at this point have positive NPV is encouraging for Arçelik and this analysis will be taken a step further and studied internally by different groups within the company to decide about a final implementation.

Content

2. Acronyms and abbreviations

ABS	Acrylonitrile butadiene styrene
ASIC	Application-specific integrated circuit
B2B	Business to business
CAGR	Compound annual growth rate
CapEx	Capital expenditures
CAS	Chemicals Abstract Service
CCS	Carbon capture and storage
CE	Circular economy
CMOS	Complementary metal-oxide semiconductor
COGS	Cost of goods sold
CPU	Central processing unit
CX	Customer experience
DCN	Data communications network
DfX	Design for X (X = disassembly, reuse, maintainability, recycling etc.)
DoW	Description of work
EBIT	Earnings before interest and taxes
EEE	Electrical and electronic equipment
EF	Emission factor [$kgCO_2e/kWh$]
EoL	End of life
FMD	Full material declaration
GWP	Global warming potential [$kgCO_2e$]
HW	Hardware
ICT	Information and communication technology
IFRS	International Financial Reporting Standard
LCA	Lifecycle assessment
LCC	Lifecycle costing
LCCP	Lexmark Cartridges Collection Program
LECP	Lexmark Equipment Collection Program
NOC	Network operations centre
NPV	Net present value
OpEx	Operational expenditures
OSI	Open system Interconnection
PaaS	Product as a service
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
REACh	Registration, evaluation and authorization of chemicals
RoI	Return on invest
SVHC	Substances of very high concern
SW	Software
TCO	Total cost of ownership
TEER	Telecommunications energy-efficiency rating
UPR_{10}	10-years use/production ratio (GWP)
WACC	Weighted average cost of capital
WDM	Wavelength-domain multiplexing
WEEE	Waste electrical and electronic equipment

3. Introduction

This document reports the outcomes of the distribution and use 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.

This is the third 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. 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.

Continuing from the activities carried out during the design and production phase, the present report describes the next step in the implementation of product specific CEBMs according to the CE actions selected for each demonstration. In particular, the use phase is focused on exploring the potential for change from linear or 'classic' business models (selling + maintenance services) to circular offerings (Product Service Systems) where the manufacturer retains the ownership of the product while offering leasing, renting or pay-per-use options to meet customer's needs with less environmental impacts, all of them supported by ICT tools.

The actions selected for implementation in the use 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)	Life-cycle stage	Circular economy action	Action description
Washing machines (ARÇELIK) 	Use	Develop a renting/eco-leasing model for B2B market	• Demonstration with focus on corporate customers. Demo sites: nursing home in Spain, student dorms in Turkey, partner company in Italy
Printer products, including laser printers and toner cartridges (LEXMARK) 	Use/ End of Life	Assessment of opportunities to enhance circularity of current Printer PSS	• Recover printer parts for refurbishment operations • Explore competitiveness of 3D printing for spare plastic parts
		Reverse logistic in the supply chain	• Extending LCCP to printers – merging with LECP • ICT tools for improvement in logistics
		Assessment of the potential to increase material circularity	• Recover secondary materials from EoL printers and cartridges • ICT tools to certificate recycled content
Telecom equipment (ADVA) 	Use	Explore feasibility of renting/leasing/PSS	• Assessment of different PSS models, extension to other ICT products • Lifetime optimisation of ICT products • Demonstration of leasing/renting with selected stakeholder
TV sets (ARÇELIK) 	Use	Develop a renting/eco-leasing model for B2B market	• Demonstration with focus on corporate customers. Demo sites: nursing home in Spain, student dorms in Turkey

For the washing machines and TV sets, Arçelik has studied the viability of introducing a renting/eco-leasing model for their corporate customers, offering the product as well as maintenance services and taking care of the products once the client decides to terminate the contract or requests a substitution or upgrade. The demonstrations are intended to provide Arçelik with customer feedback and to simulate the new business case with potential customers both in Spain and in Turkey. Arçelik is working towards this goal together with Emaus, who is in charge of the repair/preparation for reuse operations and would take over the products once the renting period is over.

In the case of the printer and toner cartridges, the PSS is already the standard business model for Lexmark, being called MPS or Managed Print Services and offering customised printing solutions to their customers including maintenance and replacement for their laser printers and free collection of used cartridges through the LCCP (Lexmark Cartridge Collection Program). Lexmark is looking to expand their MPS with more circular options by promoting the refurbishment and reuse of selected printer models and working on raising customer awareness and acceptance of this option. In this way, Lexmark continues the activities already started in the design phase, in collaboration with the recycler partners, to implement design for reuse/design for refurbishment in their products, establish the basis for a business case on recovered printer parts, and incorporate more recycled content in their product portfolio.

In the ALM demonstration, ADVA has carried out an in-depth analysis of potential PSSs considering not only the ALM system but a second product of the same category with different use phase conditions, identifying the most suitable PSS model for each case. The analysis takes into account both commercial and environmental aspects, considering the company's view and the customer's view, and is complemented by complete lifetime optimisation. It is also complemented with findings from previous PSS analysis by ADVA.

The ALM demonstration includes as well the demonstrator testing at B2B facilities (new passive sensors developed), testing of ICT functionalities for the ALM system and the update of ADVA's Ecodesign Guide based on the findings of the design and production phase (D4.2) and further inputs obtained during the project.

The results shown in this report were achieved in the period from October 2020 up to September 2021, and due to the different nature of the demonstrators in the C-SERVEES project the activities carried out do no follow an identical scheme, since they are adapted to the idiosyncrasy of each EEE product. The objectives however remain the same, which is to examine, test and adopt circular strategies for the use phase of the selected EEE products that can be extended and adopted throughout the corresponding product categories.

4. Washing machines demonstrator

The activities conducted in the distribution and use 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 distribution and use 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 distribution and use phase.

WASH-CIRCMODE Canvas Sub-Component	WASH-CIRCMODE validated short-term Circular Economy Actions
WASH_C1.1 Diversify circular activities	WASH_A1.1.4 Develop renting model for B2B customers
WASH_C3.3 Address partnerships' cultural issues that would encourage circular economy business models to be widely adopted	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_A4.1.2 Develop new corporate B2B sales channels in Europe for renting washing machines
WASH_C7.2 Introduce and/or enhance offerings of leased, rented or shared product options	WASH_A7.2.1 Develop a WM rental business model
WASH_C8.2 Adapt financial administration to enable economy business models such as leasing and renting options for both the B2B and B2C customer segments	WASH_A8.2.1 Assess the feasibility of WM leasing/renting options

CE actions WM_A1.1.4, WM_A4.1.2, WM_A7.2.1 and WM_A8.2.1 are all related to the exploration and testing of new renting/leasing models for the washing machine and are covered in sections 4.1 and 4.2. CE action WM_A3.3.2 is addressed together with TV_A3.3.2 and covered in sections 7.3.

Arçelik produced 106 eco-designed washing machines to be used as demo products at the beginning of April 2020. Product SKU is 7170341600 and product serial numbers are 2004400002 – 2004400108. The product SKU was created for the C-SERVEES Project and includes innovative aspects applied for the first time on the target device, such as increased recycled content, new label, new panel, QR code, etc. This is covered in D4.2.

Figure 1. Washing machine units for the C-SERVEES demonstration

The demo product brand is Grundig and it has 9 kg capacity, maximum spin speed of 1200 rpm, energy efficiency class A+++ and it includes connectivity features. It was manufactured in Çayırova, Turkey and is currently sold in Turkey, Spain, and Italy.

The main objective of this phase was to examine the feasibility of new eco-leasing models for Arçelik's washing machines and use the target circular products, eco-designed and manufactured specifically for the demonstration, to test the new model in real sites and gather customer feedback.

For the washing machines and TV sets, Arçelik has studied the viability of introducing a renting/eco-leasing model for their corporate customers, offering the product as well as maintenance services and taking care of the products once the client decides to terminate the contract or requests a substitution or upgrade. The washing machines would then be examined to determine the need for repair or refurbishment and given a second life whenever possible, in accordance with circular economy principles.

The demonstrations are intended to provide Arçelik with customer feedback and to simulate the new business case with potential customers both in Spain and in Turkey. Arçelik is working towards this goal together with Emaus, who is in charge of the repair/preparation for reuse operations and would take over the products once the renting period is over.

To carry out the eco-leasing demonstration, washing machine demo products were sent to selected locations within the scope of the project. In order to obtain feedback in different countries, an agreement was reached between Arçelik and the demo sites both in Turkey and Spain. In Italy, C-SERVEES partner ERION agreed to place two washing machines at their company's facilities to test intensive use of the newly eco-designed products. Finally, the distribution of the products was:

- 2 washing machines sent to Italy
- 25 washing machines sent to Spain
- 75 washing machines sent to Turkey

4.1. Assessment of new PSS for the washing machines

With the help of the C-SERVEES project, a study on the feasibility of a business model based on the renting and subsequent refurbishment and sale of second-hand products was possible for the first time in Arçelik and will greatly serve for the business decision on whether or not Arçelik should follow this business model in specific markets with selected product groups. The C-SERVEES project team has already contacted the product management team as well as the central feasibility studies team to further work on our draft feasibility to turn this into a business model go-no go decision to be presented to Arçelik's top management. Arçelik's C-SERVEES feasibility study will be considered as the basis of studies within this wider group's feasibility study.

During the demonstration period, we have analysed the rent and refurbished product sale models within a feasibility study for both B2B and B2C customers. With certain changes in assumptions, we were able to understand the economic system challenges and enablers for both target customer groups.

4.1.1. Insights about consumer preferences based on Arçelik's previous Paper per Use study

Arçelik has previously considered the pay per use models which did not turn out to be feasible due to a variety of factors. During the pay per use model studies, extensive persona studies were carried out to understand how consumers react to new business models such as pay per use or rent model. The personas subject to research included: 54% single people, 23% couples, 15% AirBnB & Dormitory professionals, 8% construction professionals. The persona included working singles, university students, young couples planning to get married, etc. These studies consider both washing machines and TV sets.

The below mentioned factors which have been outlined in Arçelik's previous studies also contributed to our mindset for coming to a conclusion on the feasibility of the model for C-SERVEES project and Arçelik's business strategy. The insights are as follows:

- Most important criteria for washing machines include short programs, spin speed, volume of the tank as well as less water and electricity consumption. The families with kids also attach greater importance to drying the garments.
- B2C consumers are generally ok with the idea of using a second hand product if the hygienic conditions are strictly improved. A refurbished product is associated

with eco-friendly and sustainable product claims. They are willing to use a refurbished product as long as the product is hygienic, clean, sterilized and smoothly working. Sterilization of the below mentioned parts are critical in the WM's and TV's: detergent compartment, the tank- where personal laundry touch, the TV display- where users touch.

- For B2B customers such as dormitory or AirBnB owners, as long as the appearance of the appliance is good, it does not matter if the product is second hand.
- Washing machine is considered to be the most crucial appliance in a B2C rent or pay per use scenario. Pay per use is not preferred if there is the option to pay a fixed monthly rent.
- Both B2B-B2C consumers see an advantage in being able to afford to upgrade a new model within a few years with the rent model.
- Not owning a product provides consumers the ability to be free and decreases the hurdle with carrying the home appliances when moving to a new home but at the same time, some users express their dislike for paying money for a product they will not own at the end. This raises the probability that after a prolonged rent period, the customer can be offered the product with a discounted price.
- Majority of the persona in the interviews indicated white goods purchase is a burden to the budget, especially when setting up a new home.
- For B2B purposes, the rent model provides flexibility to the business owners such as dormitory or hotel owners in terms of the decreased investment cost.
- Dormitory owners express further interest for such systems if the same rent package offers several appliances and not just one appliance.
- In a B2B scenario, having connected appliances and a centralized ICT payment tool might not be as necessary as it is in the B2C scenario. In the B2C scenario, the application from which the users can see their monthly bills, call a service technician, see the amount of electricity spent when their WM was in use proves to be more useful and provides the appliance producer and the consumer increased interaction.
- Washing machines do not seem to be preferable as much in B2B segment because hotels or laundromattes require an industrial type of washing machine. However, as experienced by Arçelik in the C-SERVEES project, elderly care homes and dormitories do provide an opportunity for this business line.
- As for the TV's, although Arçelik's major competitor in Turkey attempted to initiate a rent TV system as a pilot where the product would be changed in 2 years including promotional offerings such as free access to entertainment platforms, the system in Turkey did not work and they do not offer this service. We do not have extensive knowledge to the reason why this attempt failed.

- Currently we have not come across rent TV offerings for the B2C segment in the market in Arçelik's competitors. The rent offerings are dominantly focused in the WM's followed by dishwashers and other major home appliances as well as other small domestic appliances.
- TV offering in the B2B segment proves to be more preferable especially in hotels and dormitories.
- In order to make it more attractive, the TV offering in the B2B- B2C needs to focus more on giving the service as a package to include the TV along with other consumer electronics such as Bluetooth speakers, headphone sets, free subscription to Netflix, Amazon Prime, etc.
- In terms of pricing, the general tendency of the consumers is to try and calculate the cost through the expected life of white goods and compare it with the price and they tend to think that given inflation is put on top of the price in the coming periods, the cost of the product considering buying vs renting does not seem to make perfect economic sense from the B2C consumers perspective.
- Students, singles and dormitory owners are much more interested in the product compared to married couples and couples with children.
- All time service guarantee is the most attractive point for the single people but it still does not justify the prices as they do not expect a high quality machine to break down in 3-4 years.
- Students expect average functionality from an appliance and do not opt for high tech options.
- Beyond functionality, no strong feelings are attached to domestic appliances or their ownership.

4.1.2. Arçelik's C-SERVEES Feasibility Study

Arçelik has reviewed the models on the market before setting up the strategy for the new rent and refurbished appliance business model. Currently, Arçelik's competitor BSH's BlueMovement strategy that promotes an annual recurring revenue system which is also environmentally friendly was benchmarked against Arçelik's potential offerings. The BlueMovement does not currently offer TV's to B2C consumers.

The feasibility study of the TV rent model for both B2B and B2C consumers in Spain and Turkey is based on the following business model in mind:

- The consumers fill in a subscription form via online or call center. Call center calls the consumers for an appointment. Transporters come together with the service technicians to assemble the appliances.

- The consumers are given the option to rent the TV/WM for a 3 year contract with monthly payments of EUR 15 which can be renewed after the term expires.
- The consumers pay a EUR 35 deposit which is returned once the contract expires. If the consumers renounce from the system before the expiry date of the contract, they are required to pay a EUR 70 cancellation fee.
- The installation, maintenance and warranty services are provided to the consumers free of charge. If the consumers want their old appliance to be picked up, the old appliance is also picked up free of charge.
- In Arçelik's current business model, contrary to Turkey, in Spain, the installation service to the customers is not free of charge and the customers pay an extra fee if they want the product to be installed to their homes. However, in order to make the rent model attractive to the customer, the installation, maintenance, technical services are considered to be provided to the consumer free of charge both in Spain and in Turkey.
- The consumers are given the option to prolong their contract after the initial term expires. They are provided with new machinery and the previous ones are collected from the consumers to be refurbished and sold as a second hand product sale with a discounted price.

Differences between the model in Turkey and Spain: Cost of labor is cheaper in Turkey and thus the installation, service, logistics and refurbishment costs are cheaper. The WACC is taken as 4,5% in Spain and 8,3% in Turkey (valuation in TR done based on EUR currency).

Differences between the feasibility model for WM and TV categories: The ex factory costs of the selected WM and TV models are almost identical. The TV is a mid segment model which is widely preferred by both the B2B and the B2C segments. The WM is a high segment product. The TV model factors in extra licensing costs such as providing Netflix or a similar entertainment program as a free of charge offering.

As a conclusion, for all four feasibility studies carried out, the results have positive NPV for the 10 year period. Turkey's NPV is slightly higher despite the increased WACC due to the fact that the labor costs are cheaper in the study compared to Spain.

The fact that all models have positive NPV is encouraging for Arçelik and as mentioned before, a much detailed feasibility analysis will be studied internally by different groups within the company.

The results and the sensitivity analysis carried out shows that the most important factor in making this study feasible is the increase in the number of customers. Samples of the sensitivity analysis are provided in the tables below.

The risks Arçelik might face if this business model is to be conducted is provided below. As we see in the market, competitors set up a different business structure and a different company and approach this business in the mindset of a start-up. After the feasibility study, despite the positive NPV, we are also of the opinion that since the circular economy business models are new models, their NPV results should not be compared directly that of a business-as-usual scenario and a start-up mindset is needed.

Items Factored into Consideration:

Revenue Items:

- Current Sales price of the TV: EUR 500
- Current Sales prices of the WM: EUR 482
- Optimum monthly rent price: EUR 15
- The prices and COGS are moved forward by inflation rates annually
- Rent duration: 3 years
- EUR 35 rent deposit and EUR 70 cancellation fees
- Number of initial customers
- Customer churn rates within a specific period
- Continuity of demand from customers following the initial contract term
- Refurbished product revenue
- Scrap revenue

OPEX Items:

- Installation costs
- Logistics costs
- Product service call rates, service and maintenance costs
- Refurbishment costs
- ICT tools to allow for maximum interaction with the customer and allow collection of monthly rental fee (Customer application costs (hardware, software))
- Marketing and sales expenses
- Miscellaneous General and Administrative expenses- including call center costs, credit card commission costs, etc.

FCF Items:

- 4,5% WACC for Spain and 8,3% WACC for Turkey (EUR based valuation)
- 10 year term
- Maintenance CAPEX
- NWC need
- Taxes

Risks for Turning This Into an Applied Business Model by Arcelik:

- In Turkey, dealers provide very long instalments without any financial obligation to the consumers and therefore they may not be interested in rent.

- In Turkey, where Arçelik's dealer network is very strong, this creates a competitive business model for dealers. In Spain, we do not foresee this risk.
- The model is very sensitive to the number of customers to use the program as well as the service and installation costs. If the churn rate of customers cannot be properly factored, this might pose risks in terms of feasibility of the model.
- The variable costs such as marketing expenses or other administrative expenses might go higher than planned.
- The refurbished products might not meet as much demand as anticipated by the model and this might be a downside for the feasibility of the second-hand refurbished sales forecasts.

Feasibility Results:

Changes in the below mentioned parameters make the feasibility results sensitive:

+/- changes in price
+/- changes in number of first contract customers
+/- changes in installation, warranty, logistics costs and other administrative expenses
+/- change in WACC

The tables below show the results from the sensitivity analyses:

Table 2.Washing Machine Leasing Feasibility in Spain

Price	% of increase in customers	NPV
-10%	-10%	-67%
-15%	-15%	-84%
-20%	-20%	-96%
-25%	-25%	Not feasible
no change	-10%	-50%
no change	-15%	-65%
no change	-20%	-77%
no change	-30%	-90%
no change	+10%	88%

Table 3.Washing Machine Leasing Feasibility in Turkey

Price	% of increase in customers	NPV
-10%	-10%	-59%
-15%	-15%	-76%
-20%	-20%	-87%

-25%	-25%	-94%
no change	-10%	-46%
no change	-15%	-61%
no change	-20%	-72%
no change	-30%	-85%
no change	+10%	80%

Customer numbers are the main factor impacting the feasibility analyses. Especially the increasing rate of new contracts as well as recurring customers are important for the model to be feasible. Thus, while the Net Present Value is positive, the actual number is not very high, which does not support the adoption of this business model as substitute for the current 'business as usual', but rather as an additional scenario.

4.2. Demonstrator testing at B2B facilities

Demo productions' location information is given below. More information on these sites is provided in section 7.2.

Fundation Matia is located in Spain.

- 25 washing machines were sent and distributed between 7 centers of Foundation Matia (elderly care center) for use of the residents and personnel.

Figure 2. Washing machine in Fundacion Matia kitchen facilities

Bolu Abant İzzet Baysal University Dormitories are located in Bolu, Turkey.

- 35 washing machines were sent to dormitories for students use

Samsun University Dormitories are located in Samsun, Turkey.

- 40 washing machines were sent to dormitories for Student use

Figure 3. Washing machine in dorm facilities

Erion is located in Milan, Italy.

- 2 washing machines sent to Erion for company workers use

A separate contract was signed with the site where each batch of devices was sent. The purpose of this contract is to receive proof that products have been shipped under the C-SERVEES Project.

University deans were informed about the project. The importance of the project and its contribution to the circular economic business model were explained to both university professors and the dean. Arçelik made a presentation about the C-SERVEES project. They were also asked to transfer the project to the students.

Emaus supported the selection of Fundation Matia, an elderly care center in Spain, for the demo study. Beko Spain supported the installation of products in 7 different Fundation Matia areas.

Erion company announced that they could accept 2 products for demonstration purposes in Italy. Beko Italy supported the installation of products in Erion facilities. The pilot performed in Italy aimed to build a case study regarding a collaborative (intense) use of the washing machines. The washing machines already installed in ERION office have been replaced with C-SERVEES washing machines. Usually, 30 employees use the washing machines in the office; on average, 3-4 washing cycles are performed daily (unfortunately, these figures have been affected by Covid restrictions, considering that the washing machines have been installed in October 2020). A customisation and upgradable washing machine study will be carried out with these products. Depending on the results from the 3D printed detergent box group parts, these washing machines will be used to try these 3D parts during intensive use.

4.3. Preparation for repair and refurbishment operations

Beko Spain, Arçelik R&D and Emaus are working together to implement standardised repair and refurbishment operations for the washing machines once the renting period is completed and/or the products need to be repaired/replaced. This part of the demonstration will take place once the testing period at the demo facilities is concluded (end of life phase), but preparation for reuse requires close collaboration between the manufacturer and the rest of the actors involved, so the analysis of washing machine most replaced spare parts and refurbishment operations, as well as repair protocols and documentation was initiated in advance. Washing machine's parts were listed and action lists prepared. Most relevant parts for refurbishment operations are listed below:

- Belt
- Detergent box group
- Door Lock
- Drain pump
- Front door
- Gasket
- Heater
- Motor
- Shock absorber

For these parts, replacement instructions and manuals were prepared by Arçelik R&D. Document languages are Turkish, English and Spanish. These documents will be used in the preparation for reuse operations to grant the used products a second life and sell them at Emaus facilities. For this reason, it is very important the technicians involved learn the procedures and follow the steps according to the manufacturer's instructions. During this period, Arçelik prepared and made these documents available and Beko Spain organized trainings for Emaus personnel. The manuals will also be accessible via the QR code on the washing machines. It was also evaluated that it could be added to the study of Rina-C.

For example, the gasket replacement manual included 35 steps. Some of these are shown below:

Información Técnica:	Versión: r1	Fecha: 26.10.2020

Tipo:	**Procedimiento readecuacion**	
Asunto:	**GASKET REPLACEMENT**	
Estado EN ESTUDIO	**7150341600 DNM C-SERVEES**	
Introduccion:	Se edita una serie de procedimientos de readecuación de una máquina tras un tiempo de uso.	
Explicación:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products.	
	1. Üst tabla 2 adet vida ile gövdeye grupludur. Top plate have 2 screws (indicate with red color circle).	
	2. 2 vida sökülerek üst tabla açılır. Top plate screws are removed (indicate with red color circle).	
	3. Üst tabla açılır. Top plate is removed.	

33. Körük çıkartılır (Adım-3). Gasket is removed (indicated with yellow arrow) (Step-3).	
34. Kazan tambur arası nemli bezle silinir. Yeni körük veya temizlenen körük makineye takılır. Between drum and tub is wiped with a damp cloth (indicated with red arrow). Then new gasket or cleaned gasket is grouped machine.	
35. Körük nemli bezle silinir. Gasket is wiped with a damp cloth (indicated with red arrow).	

The detergent box group replacement manual includes 15 steps. Some examples from the manual are shown below:

10. Pano braket ve deterjan kutusunu bağlayan vida sökülür. Bracket – detergent box connection screw is removed (indicated with red circle).	
11. Gövde ve deterjan kutusunu bağlayan vida sökülür. Cabinet – detergent box connection screw is removed (indicated with red circle).	
12. 2818440200 stoklu kazan su giriş hortumu sökülür. 2818440200 - tub inlet hose is removed removed (indicated with red circle).	

The drain pump group replacement document included 35 steps. Some are shown below:

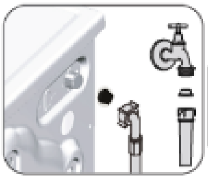
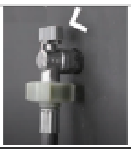
16. Ön duvarın sağ ve solunda bulunan vidalar sökülür. Screws on the right and left of the front wall are removed (indicated with red circle).	 
17. Filtre kapağını açın. Kapağın üzerindeki tırnağı aşağıya doğru bastırıp, parçayı kendinize doğru çekin. Open the filter cap. If the filter cap is composed of two pieces, press the tab on the filter cap downwards and pull the piece out towards yourself.	 

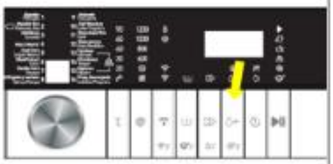
18. Kilit açma kolu çekilir. Door opening arm is pulled (indicated with red circle).	
19. Tornavida yardımıyla tekmelik çıkartılır (Adım-1). The kick plate is removed with the help of a screwdriver (Step-1).	
20. Tornavida yardımıyla tekmelik çıkartılır (Adım-2). The kick plate is removed with the help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

33. Pompa körük bağlantı hortumu kelepçesi sökülür (Adım-2). Pump - gasket connection hose's clamp is removed (indicated with yellow arrow) (Step-2).	 
34. Boşaltma hortumu kelepçesi sökülür. Discharge hose's clamp is removed (indicated with yellow arrow).	
35. Sökülmüş pompa resmi. Picture of drain pump.	

A washing machine cleaning procedure was created for C-SERVEES demo products. It included 24 steps for cleaning. Document languages are Turkish and English and Spanish. This procedure will be followed before second-hand use of demo washing machines. Some steps were shown below.

Información Técnica:	Versión: r1	Fecha: 26.10.2020

Tipo:	Cleaning Procedure	
Asunto:	WASHING MACHINE CLEANING PROCEDURE	
Estado EN ESTUDIO	7150341600 DNM C-SERVEES	
Introduccion:		
Explicación:	This procedure has been specially prepared for use in C-SERVEES demo washing machine products. This procedure will be followed before second hand usage of demo washing machines.	
	Cleaning the water intake filters 1. There is a filter at the end of each water intake valve at the rear of the machine and also at the end of each water intake hose where they are connected to the tap. These filters prevent foreign substances and dirt in the water to enter the washing machine. Filters should be cleaned as they do get dirty.	
	2. Close the taps.	

20. Makinenin çekmece panosu açılır. Makinenin 2 numaralı deterjan gözüne çamaşır makinelerine kazan temizleme maddesi koyulur. Open the detergent drawer front cover. Put special cleaner (like Quick&Shine) or machine cleaner in Spain Market for washing machines into the detergent compartment no.2.	
21. Kazan temizleme programını seçmek için yardımcı fonksiyon düğmesi 4'e 3 saniye basılı tutulur. 3'' To select Drum Cleaning+ programme, press and hold the auxiliary function key 4 for three seconds (indicate with yellow arrow).	

22. Kazan temizleme programında sıcaklık 90C, devir 600 rpm'dir. Süre ve sıcaklık değiştirilemez. Bu bir yıkama programı değildir. Bu bir bakım programıdır. Bu programı, makinenin içinde herhangi bir şey varken çalıştırmayın. Çalıştırmayı denediğinizde makine otomatik olarak içeride yük olduğunu algılar ve programı sonlandırır. For Drum Cleaning+ programme, temperature is 90C, max spinning is 600 rpm. This is not a washing programme. It is a maintenance progrramme. Do not run this programme when there are any objects in the machine. If you try to do so, the machine will automatically detect that there is a load inside and abort the programme.

23. Program bittikten sonra kazan körüğünü temiz bir bez yardımıyla silerek kurulayın. When the programme is over, wipe with a clean cloth.	

4.4. Reverse logistics ICT tool

RINA-C has developed a Logistic Platform which aims to optimize the sustainable and cost-effective transportation of materials/products/WEEE from the collection points to the manufacturing/use/treatment/recycling sites. The platform is able to work as a stand-alone platform, but it also works as integration of the overall ICT platform. In the tool it is possible to create supply chain customers and assessing the already existing ones. It is able to simulate and compare different scenarios and identify the best route to collect recovered materials or end-of-life products in term of energy consumption, transportation time, CO_2 and other main pollutant emissions.

For this demo case, the aim of the logistic platform is to define the order of the nodes among the different stakeholders (i.e. suppliers already existing or new ones) where to collect products or materials useful to create the final product and identify the number of trucks needed to minimize the total travel distance. The platform also suggests the best route connecting all the nodes of the supply chain to save CO_2 emissions, time and costs.

The following figure shows this process:

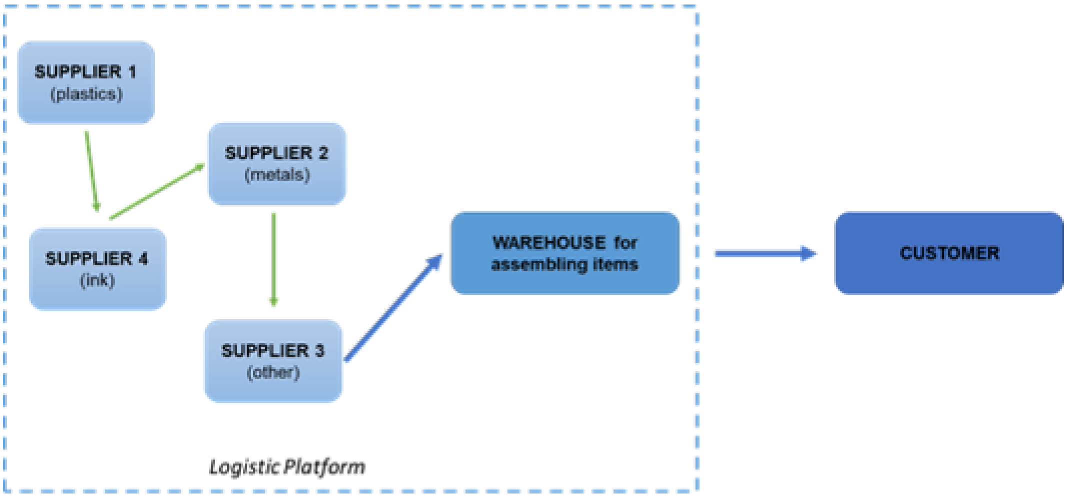


Figure 4. RINA-C logistic platform working scheme

One registration was created for ARÇELİK for RINA-C tool, Logistic Platform, and the tool has been populated with the inputs provided for both Arçelik demo cases.

The following figure shows the data input for the WM demo case and for the TV demo case; the data related to the WM demo case have been therefore highlighted in a box to distinguish them from the others.

The inputs include:

- Final destination of the goods (i.e. Arcelik warehouse in Turkey) (see following figure)
- List of suppliers where to collect goods/materials (see following figure)
- List of products and their characteristics (i.e. volume, weight, supplier where the goods are available, availability date of the product)
- Type of truck used for the logistic operation

Destinations

action	Name	Location
EDIT DELETE	Warehouse 1 - Arçelik Ele. Plant	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Warehouse 2 - Arçelik Ele. Plant	Beylikdüzü/İstanbul, Turkey
EDIT DELETE	Warehouse - Arçelik WM Plant	Tuzla/İstanbul, Turkey

ADD

Suppliers

Action	Name	Headquarter	Warehouses
EDIT DELETE	Supplier 1	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Supplier 2	Göttingen, Germany	Göttingen, Germany
EDIT DELETE	Supplier 3	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Internal production (WM production plant)	Tuzla/İstanbul, Turkey	Tuzla/İstanbul, Turkey
EDIT DELETE	Supplier A	Gebze, Kocaeli, Turkey	Gebze, Kocaeli, Turkey
EDIT DELETE	Supplier B	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ
EDIT DELETE	Supplier C	Gebze, Kocaeli, Turkey	Gebze, Kocaeli

ADD

Products

Action	Name	Code	Supplier	Warehouse	Availability date	Volume	Weigth
EDIT DELETE	Front cover	000-2	Supplier 1	Supplier 1 warehouse	24/06/2021	1	1
EDIT DELETE	Ledbar	000-3	Supplier 2	Supplier 2 warehouse	24/06/2021	1	1
EDIT DELETE	Metal back cover for display	000-4	Supplier 1	Supplier 1 warehouse	24/06/2021	1	1
EDIT DELETE	Detergent Box Group	2412700600	Supplier A	Supplier A - warehouse	24/10/2021	0.008	0.5
EDIT DELETE	Front Door Group	2467200700	Supplier A	Supplier A - warehouse	26/10/2021	0.03456	1
EDIT DELETE	Motor	2843120300	Supplier B	Supplier B - warehouse	27/10/2021	0.005712000000000001	0.1
EDIT DELETE	Cabinet	2833790100	Internal production (WM production plant)	WM production plant	27/10/2021	0.26544	1.5
EDIT DELETE	Front Panel/Wall	2835953500	Internal production (WM production plant)	WM production plant	25/10/2021	0.01488	0.5

Figure 5. Arcelik collection data used for Reverse Logistic demonstration

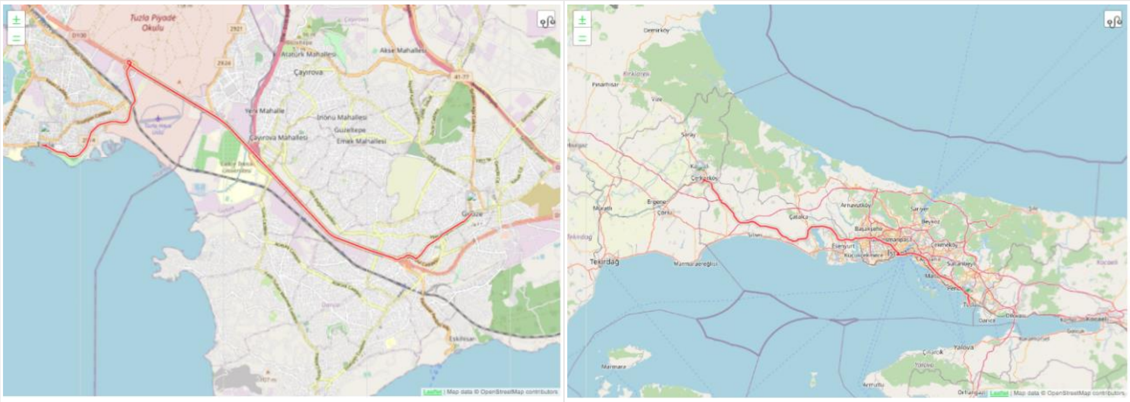
At the moment of the analysis not all the data related to products are available, as for example the number of pieces and therefore the volume and weight of the batch, but it is assumed that the total volume and weight is compatible with a Heavy Duty Trucks Rigid Type 1 (Max Load 23). It has been also assumed the class of the vehicle is Euro V, but comparison analysis using a different type of vehicle can be done.

The following figure show the results of the analysis. It is worth mentioning that, although the goods can be delivered using only one trucks, due to the location of the warehouses where goods are available (Çerkezköy and Gebze) and the final destination (Tuzla) it is more sustainable to use two trucks and therefore reduce the kilometers and the CO2 and pollutants emissions.

	Path	Total CO2 (kg)	Total Nox (kg)	Total PM10 (kg)	Total distance (km)	Truck	Delivery Time	Shipment Date
	[Gebze-Türkiye, Çerkezköy-Türkiye, Tuzla-Türkiye]	105.55	0.47	0.02	161.88	2	2:11:53	24/10/2021
1	Gebze-Türkiye -> Gebze-Türkiye	0.00	0.00	0.00	0.00	Truck 1	0:0:0	24/10/2021
	Gebze,Türkiye -> Tuzla,Türkiye	10.37	0.05	0.00	15.90	Truck 1	0:14:22	24/10/2021
2	Çerkezköy-Türkiye -> Tuzla-Türkiye	95.18	0.42	0.02	145.98	Truck 2	1:57:30	27/10/2021
	Tuzla-Türkiye -> Tuzla-Türkiye	0.00	0.00	0.00	0.00	Truck 2	0:0:0	27/10/2021
	Tuzla,Türkiye -> Tuzla,Türkiye	0.00	0.00	0.00	0.00	Truck 2	0:0:0	27/10/2021

Figure 6. Logistic Platform Output for the WM demo case

The first truck will collect goods in Gebze (which is located north of Tuzla) and the second will collect goods in Çerkezköy and then in Tuzla. The following figure shows the paths.



Gebze - Tuzla	Çerkezköy - Tuzla

Figure 7. Maps of the sections of the best route

5. Printers and laser toner cartridges demonstrator

The activities conducted in the distribution and use phase were derived from the PRINT-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 D2.3. The table below presents the PRINT-CIRCMODE canvas sub-components and their validated short-term CE actions corresponding to the distribution and use phase, as presented in Table 24 in D2.3.

Table 4. Validated short-term PRINT-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the distribution and use phase.

PRINT-CIRCMODE Canvas Sub-Component	PRINT-CIRCMODE validated short-term Circular Economy Actions
PRINT_C1.1 Diversify circular activities	PRINT_A1.1.2 Identify levers to reduce dismantling and refurbishing cost by setting various operating models
	PRINT_A1.1.3 Provide information about printers to LEXMARK recycling partners
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-CIRCMODE Canvas Sub-Component	PRINT-CIRCMODE validated short-term Circular Economy Actions
PRINT_C3.3 Address partnerships' cultural issues that would encourage economy business models to be widely adopted	PRINT_A3.3.1 Active lobbying at EU and/or national level for wider acceptance and promotion of circular business models
	PRINT_A3.3.2 Active media/PR campaign on refurbished printers
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
PRINT_C7.3 Introduce and/or enhance products or services that will improve sustainable consumption patterns and respective intangible benefits	PRINT_A7.3.1 Devise an eco-design strategy for printers during dismantling activities
PRINT_C9.4 Implement and/or enhance strategies and/or practices to address the challenges of promoting options with lower lifetime rather than lower initial costs	PRINT_A9.4.2 Investigate economics of more CE suitable materials coming from end-of-life cartridges or printers

CE actions PRINT_A1.1.2, PRINT_A1.1.3, PRINT_A1.5.2, PRINT_A1.5.3 and PRINT_A7.3.1 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, PRINT_A2.3.1 and A_9.4.2 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.

5.1. Assessment of opportunities to enhance circularity of current PSS

To enhance the circularity of current PSS, various activities were carried out addressing two main issues: on one hand, the cost of refurbishing a printer, made of reverse logistic, spare parts and labor costs; on another hand, customer acceptance.

- → To address the cost issue: the first activity relates to recovering part from recyclers and how to make the case positive (5.1.1), the second one is about 3D printing and how it can contribute to save cost on spare parts (5.1.2), the third one is on making refurbishment more cost efficient (5.1.3).

→ To address the customer acceptance, qualitative face to face surveys were conducted with eight key and representative customers to better understand customers' expectations as it relates to refurbished products (5.1.4). Then refurbished products were prepared and shipped to four representative parties (5.1.5) to gather their feedback not only on functionality but mainly from a cosmetic angle, indeed these were assembled with various cosmetic defects. This last activity one will also address the cost issue.

5.1.1. Dismantling printers for part recovery

Following the first dismantling demo ran early 2020 during the first phase of the demonstration which drove various eco design recommendations for the dismantling/disassembly process of printers and toner cartridges, it was highlighted by both Indumetal and Greentronics that using the regular service manual to dismantle a printer was not fully appropriate and even drove higher time to dismantle than standard recycling technics. Indeed, this service manual is set for servicing the printer (changing spare parts, proceeding with maintenance and troubleshooting).

It was also highlighted in the demo outcomes (see Deliverable 4.2. Demonstration of design and production phase for target products, section 5.2.2.) that there could be more monetary value for the various stakeholders in dismantling a printer and recovering parts rather than recycling it as it is recycled today by shredding the entire unit and then sorting the various pieces of raw material.

Recovering parts to be used as spare parts for printer maintenance or refurbishing can bring added value to the recycler, the OEM and the environmental conscious customer. Experience at Lexmark has proven that we can reuse many parts when refurbishing a printer and some of those parts can come at a high cost when procured from the original manufacturer. Some of these parts can be reused as is after a cosmetic and visual quality check (mechanical type parts) while others composed of various components (fuser, controller board, flatbed scanner, laser printhead) require systematic repair to be suitable for reuse. This activity is today carried out at the printer refurbishment location on collected printers.

But what about the "business case" of such dismantling operation at a recycler location? Would the dismantling and other logistic and repair costs be sufficiently competitive versus the cost of importing new parts?

In order to answer the above questions, Lexmark as demo leader with the support of the C-SERVEES partners Indumetal, Greentronics and Gaiker proceeded with a follow up demonstrative activity by developing and using a dismantling manual for end-of-life printers.

The objective of this demo activity is to determine if recovering parts from non-functioning/end of life printers which end up in recyclers' facilities could be profitable. Therefore, a short list of parts was selected for a given printer with the purpose of determining the cost of recovering those parts, and to compare this cost to the cost of procuring new parts. This objective aligns with PRINT-CIRCMODE_A1.1.2 'Decrease cost of the printer refurbishment and parts recovery model' and A1.5.2 'Salvage working and repairable parts from collected/return printers and use on refurbished printers', as well as A7.3.1 'Devise an eco-design strategy for printers during dismantling activities'.

Early 2021 Lexmark requested Syncreon (Lexmark European subcontractor) to put together such dismantling manual for a given printer, ref MS 812, a recent mid-range model, seen as being representative of the most sold model. This meets the objective of CE action A1.1.3 'Provide information about printers to Lexmark recycling partners'.

Figure 8. MS 812 printer at Indumetal facilities

Based on its experience, Syncreon put together such a manual containing instructions as well as pictures to illustrate the various dismantling phases. The final intent was to have a document easy to use for someone not familiar with the technical aspect of a printer and quick to dive in. The manual drives the operator toward dismantling the various valuable parts which can be reconditioned and used as spare parts to refurbish printers or service installed printers.

Some abstracts of the dismantling manual are shown below. The complete manual is composed of 22 pages.

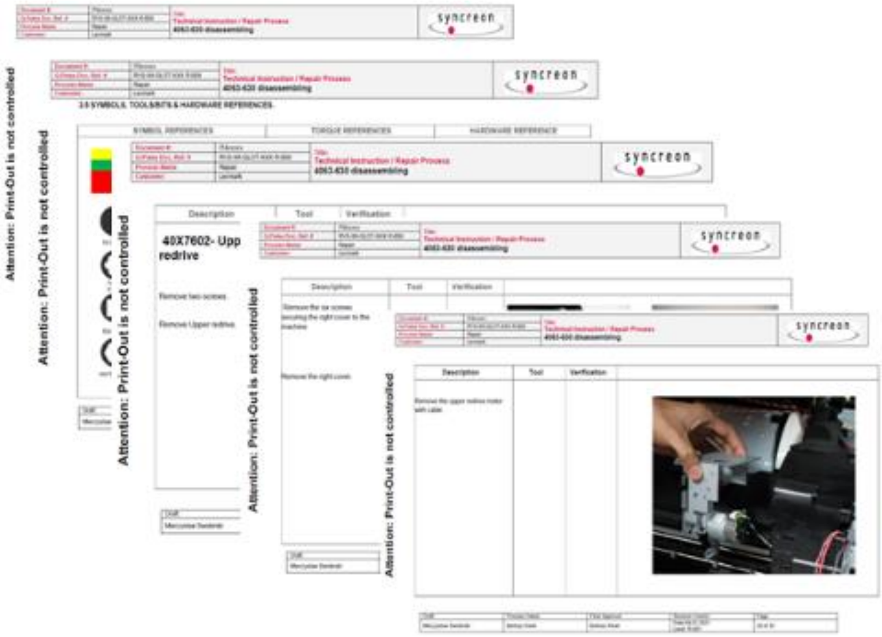


Figure 9. Examples from the dismantling manual for Lexmark printers

The manual as well as 20 printers (10 for each location) were provided to Indumetal and Greentronics, which then proceeded with another dismantling test (see Deliverable 4.2. Demonstration of design and production phase for target products, section 5.2.1), following the new dismantling manual instructions and reporting the associated cost and time of these operations. Figure 10 shows several pictures of the dismantling operations.

	
Dismantling at Indumetal - Fuser	Dismantling at Indumetal – Left cover
	
Dismantling at Indumetal - Mother board	Dism. at Indumetal – Duplex motor with cable

Figure 10. Examples from the dismantling operations for Lexmark printers

The study was conveyed on a set of 12 key parts per printer and 10 printers at both recyclers' locations. There is a bias here as all those parts are not changed when refurbishing a given printer, but it will give an indication of whether there is a path moving forward. With the outcome of this exercise, the next step will be to proceed with some cost estimate for the most expensive parts amongst those 12 key parts.

Outcomes of the activity

1. Improvement of the dismantling manual

One of the expected results from this exercise is related to potential improvement of the dismantling manual as suggested by Indumetal. Indumetal advised one page per part to be recovered to speed up access to the information, it also suggested a different structure to put the detailed instructions and pictures into context by adding a picture of the printer to locate the part to be recovered, see below abstracts. In addition, Indumetal also proposed a new dismantling order to access the target parts, minimizing thus the number of times that the operator must rotate or move the printer and therefore enhancing its ergonomics and working conditions. These should drive efficiency and bottom-line higher benefit in recovering parts and lower printer refurbishment costs.

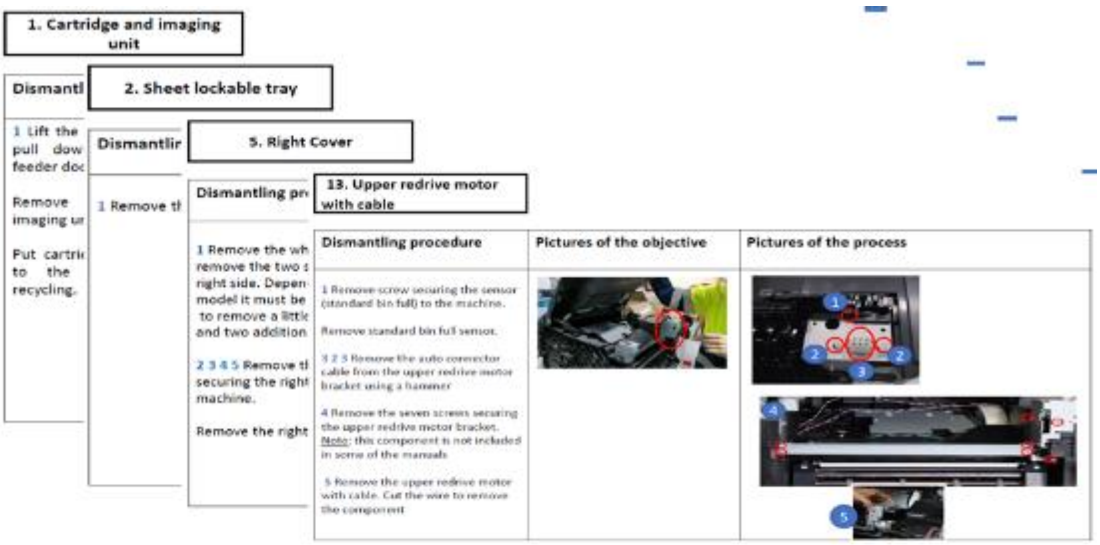


Figure 11. Examples from the revised dismantling manual

2. Economic assessment of the business case

The other (main) outcome is related to the business case for the recovery of printer parts from end-of-life printers. Below the economic assessment is detailed.

The net cost reported by the recyclers to dismantle 10 printers is between 104€ and 142€, including revenue generated by the non-recoverable part. Adding to this cost the necessary packaging to protect and ship the parts to the printer refurbishing site as well as the freight cost, we end up with a cost per printer of **41€** for Greentronics and **55€** for Indumetal to get recovered parts dismantled, packed and shipped to the printer refurbishing site. This cost gap is explained mainly by freight cost difference.

While instructions and specifications are passed to the recyclers as it relates to the quality aspects of the recovered parts, it is assumed that defects will be incurred anyway upon arrival at Syncreon. With local engineers, a conservative assumption is made of 70% rate of "good" parts.

This drives the per unit cost respectively to **58€** and **79€.**

Adding the necessary repair cost (actual cost incurred today when recovering parts at Syncreon), as well as some cost to account for additional sorting that Syncreon would need to perform, the total cost is respectively **119€** and **140€** per unit.

	Greentronics		Indumetal	
Cost to dismantle 10 printers	€	181	€	140
Revenu ot of the non recoverable parts	€	39	€	36.5
Net cost to harvest parts on 10 printers	**€**	**142**	**€**	**104**
Packaging cost for parts coming from 10 printers	€	72	€	70
Associated labor	€	130	€	120
Freight cost to syncreon	€	62	€	260
Total	**€**	**406**	**€**	**554**
Per printer	**€**	**41**	**€**	**55**
per printer cost	**€**	**41**	**€**	**55**
Assumed yield		**70%**		**70%**
Average per printer cost	**€**	**58**	**€**	**79**
Handling/sorting cost @syncreon	€	10	€	10
Repair cost @ syncreon	€	51	€	51
Total	**€**	**119**	**€**	**140**
Cost to buy new parts	**€**	**172**	**€**	**172**
Potential benefit	**€**	**52**	**€**	**31**

To be compared with the cost of procuring new parts: **172€** (doesn't include other logistic, inventory and other OH which would apply also to the recovered parts at recyclers).

All in all, **an average of 40€** potential benefit per printer assuming all parts from the short list are re-used when refurbishing a printer, which is not the case as mentioned in the introduction.

It drives the conclusion that recovering parts at a recycler location can be cost efficient.

Looking at the most expensive parts amongst the 12, part A and part B, these require repair operations. Subtracting this repair cost from the new cost we end up with 54€. Knowing that these require less than 5 mins to dismantle as per Greentronics and Indumetal study, even with a yield of 70%, it looks like there is significant room to absorb the various cost to get these recovered and shipped to the refurbishing location and result in a positive case, meaning bottom line, a lower printer refurbishing cost which is the ultimate target.

	Repair cost		New part cost		Gap	
Part A + Part B	€	56	€	87	€	54

During this demo activity other interesting feed backs from Greentronics and Indumetal were collected as well:

- The major challenge faced by recyclers is that dismantling activities are out of the recycler business as usual scope, meaning that they had to organize accordingly for such activity. What is true for Indumetal and Greentronics is certainly true for the recycling industry. Would there be a willingness to have recyclers playing a role in recovering parts from WEEE products, the needs to change recyclers scope must be considered.
- Another major issue for recyclers remains the existence of hazardous material, therefore they recommend having these, if present, highlighted in the dismantling manual.

Combined with the ICT tool, recovering parts at a recycler could be a powerful approach: there is potential to have dismantling manuals embedded into a QR codes for various EEE products and links to drive recyclers to liaise with the OEM and quickly determine what parts can be worth recovering.

3. Technical assessment from the recyclers' perspective

Additional outcome resides in the feedback from Greentronics and Indumetal (recyclers) who've been asked for suggestions and recommendations related to what changes would be required, would they have later on to integrate dismantling activity of WEEE equipment into their business as usual activity of recyclers.

Major points are as follow:

In order for recyclers need to play a larger role to significantly enhance CE, these are significant issues to be taken into consideration

- Products to be dismantled must be segregated after sorting from the WEEE received. A barcode or QR code can help to identify products "eligible" to dismantling from the other ones.
- A specific area must be dedicated to the dismantling activity, separate from the usual recycling.
- It would also require recyclers to adapt their processes and organization according to the dismantling activity requirement: as an example, quality check of the dismantled parts would require specific processes which are not present at recycler location.
- Staff would need to receive specific training as well as skills, as an example, English reading would be needed to understand the dismantling instructions available in the dismantling manual. This could be addressed by providing recyclers with dismantling videos. A suggestion to be investigated.
- Recyclers would need to have an easy access to a dismantling manual to efficiently access the parts. Which dismantling manual should be updated as appropriate

- Color coding is also highly recommended to easily identify the parts. This was an outcome already identified during the first phase of the demonstration and included in D4.2.
- Products received in the WEEE stream are considered as waste and quite often damaged upon arrival at the recycler location. This would require significant change in the reverse logistic supply chain to maximize the benefit out of the dismantling.

4. Technical assessment from the remanufacturer's perspective

We also shared the finding with Syncreon. Syncreon is not only Lexmark's manufacturer for cartridges and printer refurbishment operations, they are also refurbishing other EEE products and have therefore experience in this field.

- When dismantling parts from a product, there are fix costs associated (handling, preparation…), therefore it becomes cost efficient to dismantle a product only if a minimum of parts is recovered. Syncreon, based on their experience estimate that a minimum of 10 parts should be recovered (which matches the 12 parts identified in the dismantling manual). And these parts must be used to refurbish printers to get the business case positive.
- An option to make dismantling more cost efficient is to have modular design of the products, allowing quick and easy access to those parts, which sometime is a challenge as the parts are in the heart of the product. This was an outcome already identified by recyclers during the first phase of the demonstration and included in D4.2.
- Volume is also seen as a cost efficiency factor: the more products an operator dismantles, the more efficient it is.
- Moving forward, with the trend being to extend the lifetime of the products, which to some extent can be seen as the best CE option, there is a risk that the product will be so old after a second or a third life that getting used parts may become a significant challenge.

Conclusion

This demo has demonstrated 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 as well as the cost the OEM is ready to pay for 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.

A next step, but not in the scope of C-SERVEES, would be to scale up such demo with more printer models and be more granular to have a cost from recyclers at part level associated with an ICT tool and a QR code.

In a next step, we'll need to test the ICT tool capabilities to grant dismantling manual access to recyclers through a QR code.

5.1.2. 3D printing for spare parts/refurbishment

On February 2021, Lexmark initiated a demo on 3D printed parts for Printers in partnership with Particula (C-SERVEES partner) as well as company Syncreon located in Poland (Lexmark cartridges manufacturer and printer repair center), in agreement with CE action PRINT-CIRCMODE A.1.5.3 'Explore competitiveness of 3D printing for smaller plastic parts for repair'. While Lexmark printers are manufactured in south East Asia, Syncreon is Lexmark's partner to repair and refurbish printers locally in Europe (Poland).

The purpose of the demo was to investigate potential benefits of using 3D technology to print parts when refurbishing printers and changing damaged parts instead of using new parts or refurbished parts. For this demo we targeted molded plastic parts. It is to be noted that spare parts (made of parts as well as subassemblies) are the first cost contributor to the total cost of refurbishing a printer. The subject matter is therefore of high interest for Lexmark but also of course for C-SERVEES as reducing those costs and gaining flexibility could be a significant help to boost Circular Economy in the ICT Product industry.

Current practice and options as it relates to replacing mechanical parts in a printer are as follow:

- New parts: these are costly as they mostly come from oversee suppliers which require a certain Minimum Order Quantity (driven by the molding process), this drives financial cost of carrying inventory as well as warehousing cost with a high risk of obsolescence ultimately as all the ordered part are not always used. New parts require excellent forecasting skills. New unused parts can have a negative environmental impact if they need to scrap at the end of life of a product model.
- Refurbished parts: these have a cost advantage versus new parts as they are recovered from used printers but has the disadvantage of reducing the number of available printers for refurbishing. Another disadvantage is the reverse logistic cost as well as the carbon footprint, indeed, depending in which part of Europe they get recovered the cost and carbon footprint could negate the case.

While Lexmark investigated opportunities on cartridges, we ended up using printers for this demo. Indeed, mechanical spare parts cost is not an issue when remanufacturing a cartridge: those parts are small and at a lower cost and on top of that, they are available locally as Lexmark cartridges are produced at Syncreon in Poland. Therefore, no anticipated benefits were identified for cartridges. We therefore elected to use printers for this demo and selected model MS 812, a high-range mono printer, recent model, representative of Lexmark core market. The first step has been to identify candidates (parts) to be 3D printed. This step proved to be a significant challenge for several reasons.

We first asked Syncreon which is very familiar and knowledgeable of the printer parts to proceed with printer dismantling and propose a short list of representative parts which it sees as being good candidates for 3D printing based on their experience of changing parts when refurbishing printers. Prioritizing parts based on their cost, Syncreon proposed 6 parts from various printer model as shown below.

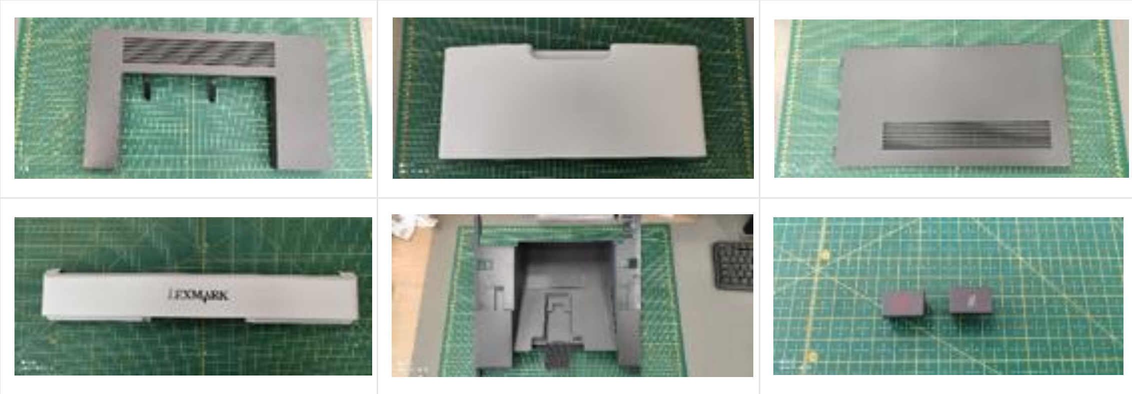


Figure 12. Printer parts selected by Syncreon for 3D printing

After reviewing with Particula these were declared as being not eligible to 3D printing for the following reasons: 5 of them show a textured surface and are visible parts, it appears that those highest cost plastic parts which are replaced during the refurbishment of a printer and are visible ones, called the covers, are by nature visible and therefore subjected to cosmetic criteria. After discussion with Particular it's been clear that those wouldn't be good candidate for the 3D printing based on the roughness of 3D printed parts and the difficulty to match the color. The 6th one was being quite complex and therefore was not selected either.

Based on above findings, we therefore asked Syncreon for a second selection round. Syncreon came back with 3 new candidates.

Figure 13. Final printer part candidates selected by Syncreon for 3D printing

This selection was then submitted to Particula which narrowed down the selection to one part, the one shown above on the right, named "deflector", others were being not appropriate for 3D printing, one based on its geometrical complexity, the second one for its mechanical characteristics.

This selection was also submitted to Lexmark's engineering & design center which raised a preference for the "front cover", parts on the left side and raised concerns on deflector due to its function: "*This part is the fuser entry guide, and it has some very specific requirements around the smoothness of the ribs and flat surfaces. We have had issues in the past with roughness along these surfaces, possibly to improper fill of the material during the molding process. I would be concerned with the surface quality on this particular part, if we were to use a 3D printer to create it*."

Bottom line, the only potential candidate, despite the identified challenge linked to the surface due to its function seemed to be the deflector.

Appropriate STL files were provided to Particula to 3D print samples.

Particula 3D printed 4 samples with different materials which were sent to Syncreon for analysis. Below are pictures showing the 3D printed parts and comparing them with the original molded part. Material commercial references are as follow: PETG, Facilan C8, rPETG and PLA.

Figure 14. 3D printed samples from Particula

As we can see on the pictures, the surface of the 3D printed parts is very rough and wavy.

Despite this roughness, we proceeded with a functional test (assemble the part in a printer and print 1000 pages) which revealed to be positive but based on experience with this part and its sensitivity to various types of paper during the lifetime of the printers, decision was taken by Lexmark engineers to not pursue the testing. It must be said that such printer is designed to print more than a million of pages of various media with appropriate maintenance and request high quality and durable parts.

Particula made a proposal to polish the parts so to avoid the surface issue, while this could fix the surface issue it would add significant cost, see below.

- The cost of the 3D printed part itself is estimated by Particula to be about 20€: 5 hours to process the part, 40g of material or 13m of filament.
- As per Particula, it would require about 2 man hours to polish the part, depending on the country where this activity would be performed, cost would vary from 12 to 20€ per part, to be added to the cost of the 3D printed part itself.
- Particula also mentioned that those costs, 3D printing plus the polishing, can be significantly decreased (50%) by proceeding internally. It would result in a cost of minimum 7.5€ for the part and 10€ for the polishing, a total of 17.5€.
- The cost of a new molded part is less than 0.5€ when ordering many, for about 100 parts, it is estimated that the cost could be between 5 to 10€ max.

Would we just need to replace few parts per year, 3D printing may be a workable option, anticipating several parts a month it doesn't look to be a workable one.

As a conclusion, for the purpose of B2B printer refurbishment while 3D printing technology may be appropriate for small parts (and this demo didn't 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 can't 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's been decided to not pursue 3D printing testing for printer refurbishing.

5.1.3. Printer refurbishment efficiency investigations

In May 2021, this activity aiming at identifying efficiency levers in printer refurbishing was launched. This is a two- step activity, the first one consisting in qualifying a printer model, and the second one in working on efficiency gain assuming process changes to refurbish a printer.

Printer qualification

The first step of the activity consisted in qualifying the refurbishment of a printer model (MS 823/821) and identifying its associated cost. Indeed, before refurbishing any model, it must be qualified to ensure proper performance and associated warranty for the customer, and it looked important to first go through and detail this important stage.

Some key points to qualify a printer:

- Need to get enough units collected and sorted to end up with 10 fully refurbished units which are required to qualify a model.
- Set the necessary process & documentation (process instructions, control plan, qualification plan, quality instructions). This step requires specific skills and knowhow.

- Develop appropriate packaging locally. Printers being originally manufactured in a different geo, at their end-of-life stage, packaging needs to be recreated locally. Packaging is a key piece of the product, especially for mid-range and high range product based on their weight.
- Procure necessary components and packaging.
- Proceed with operators and technician training.
- Proceed with printer refurbishment and run qualification plan.
- Perform Transport test. This is an important step to validate the packaging.

For the given model, the associated qualification cost is a onetime cost of 2966€. To be attractive, a minimum number of units should be refurbished to absorb such fixed cost.

Figure 15. Refurbished printer, qualified and ready to be packed

Efficiency gain investigations

The second part or the activity consisted in investigating the efficiency gain related to the refurbishment process. For this activity we selected two models: MS 823, a mid-range mono already referenced and used in previous demo activities and CX 725, a mid-range color, both representatives of the most sold products.

To optimize the associated cost, we elected to select from the collected unit low page count products to not change all expensive components.

We decided to proceed with 10 units of each model to conduct the activity. To fully refurbish 10 units of each model, 20 units of each model were used, a yield of 50%, target agreed upfront with Syncreon when launching the activity.

It is to be noted that the yield number is not a fixed number, it varies and depends on the quality of the printer collected, their page count as well as the available spare parts. Higher the yield, higher is the cost as more new spare parts are needed. Lower is the yield, less printers can be refurbished.

In the table below we can see the cost impact related to spare parts (including parts dismantling/harvesting) associated cost with given yield points.

Yield	50%	65%	80%
Cost	€ 172	€ 189	€ 245

Assuming 100 printers available form collection, for a yield of 50, the cost of changing parts is 172€ per unit while it would be 245 for a yield of 80, on another hand, in the first scenario, we can only refurbish 50 units compare to 80 in the second one, an interesting challenge. While we may elect for a low yield and associated low cost to be competitive, we would end up with not enough supply and higher collection cost as we would need to collect more units.

For this activity, it was agreed up front internally that we would shoot for the lowest yield point and therefore harvest as many parts as possible from collected printers to minimize the total cost.

Engineers set a base line by processing one printer of each model. At the same time, they observed what can be changed in the basic process (called standalone) to improve the cycle time (measured in minutes).

They identified various parameters of which the following have been determined as being the most impactful:

- Need to implement a Kanban loop on components close to the workstation
- Put in place rotary tables to facilitate access to the various side of the product and use dedicated carts to transport printers
- Use larger rework station
- Pretest and select printers before initiating the refurbishment process
- Process printers by batches and process 2 printers at the same time and set up minimum batch length to gain better efficiency (longer batch allows to reduce repair time per printer and allows to set up repairs in progressive line)

The equipment cost to implement above improvements is in the range of 0 to few hundreds of euros per step.

Engineers then processed the remaining printers by applying above improvements when feasible with existing means/equipment and when not available, they simulated the improvement step to time the mins savings.

When refurbishing printers today, based on the low demand, printers are refurbished in less than 2 digits lot size. Implementing the listed improvements would only make sense with increasing volume. While it’s hard to define exact numbers, engineers estimate such volume increase from one to 750 units a year.

For each step, the time was measured and reported as detailed below.

MS 82X	Base line	Kanban implementation	Rotary base / Carts for transportation	Bigger work station	Pretest and selection before repair	Longer repair batches / 2 printers test in parralel
Process time in minutes	305	295	285	280	270	245
		-3%	-3%	-2%	-4%	-9%
			-7%	-5%	-5%	-13%
				-8%	-8%	-14%
					-11%	-17%
						-20%

From very few units till 750 units a year

CX725	Base line	Kanban implementation	Rotary base / Carts for transportation	Bigger work station	Pretest and selection before repair	Longer repair batches	2 printers test in parralel
Process time in minutes	445	430	425	420	410	400	380
		-3%	-1%	-1%	-2%	-2%	-5%
			-4%	-2%	-4%	-5%	-7%
				-6%	-5%	-6%	-10%
					-8%	-7%	-11%
						-10%	-12%
							-15%

From very few units till 750 units a year

Improvements are sizable: between 15 and 20% cycle time reduction for a fairly low cost of equipment when any.

Volume, as for most industries, can be a key efficiency element. Usually the higher volume, the lower is the cost, due to i) the higher absorption of fix cost (we won't investigate this part here) and ii) lower cycle time.

We therefore asked Syncreon, based on their expertise and experience to provide us with an estimate of the volume impact on cycle time, see below table:

MS 82X min	Base line	Kanban implementation	Rotary base / Carts for transportation	Bigger work station	Pretest and selection before repair	Longer repair batches / 2 printers test in parralel		
<750 a year	305	295	285	280	270	245		
>750 <2000 a year	280	270	260	255	245	220	-10%	
>2000 a year	265	255	245	240	230	205	-7%	-16%

CX 725 mins	Base line	Kanban implementation	Rotary base / Carts for transportation	Bigger work station	Pretest and selection before repair	Longer repair batches	2 printers test in parralel		
<750 a year	445	430	425	420	410	400	380		
>750 <2000 a year	380	365	360	355	345	335	325	-14%	
>2000 a year	360	345	340	335	325	315	305	-6%	-20%

While it is an estimate, raising volume up to more than 2000 a year could drive cycle time reduction of 15 to 20%.

Outcome

Qualifying a product is a must to ensure product performance and warranty and it comes at cost, which cost should be amortized over a minimum quantity.

Linked to volume, significant efficiency gain can be realized with very minimum investments (few low-cost equipment) which will help the final business case for OEM to make product refurbishment an attractive activity and help generate higher customer traction.

5.1.4. Lexmark Qualitative Survey

In April and May 2021 Lexmark conducted several interviews with customers and partners based in Germany, France and Italy as per agreed PRINT-CIRCMODE A3.2.1 ‘Engage with key customers to understand their needs and requirements as it relates to refurbished products’. Those companies are either distributing printers and copiers or using their own printer fleet for sales or logistic purposes. They are highly specialized in their segment and have many years of experience in selling and managing printers. Most of them are also used to manage lease printing systems. Almost all interviewed companies have some direct or indirect experience with refurbished ICT products. The objective of the interviews was to better understand their needs, expectations and outlook on how to boost refurbished printers and other ICT devices. Under Annex 1 the content of 8 anonymized interviews is listed. Lexmark decided not to publish the names of the interviewees for confidentiality reasons.

1) End of life approach towards refurbishing

Most companies have a very well-defined approach for end-of-life printers. The objective is to optimize the end-of-life cost structure and recuperate end-of-life resources. Companies are highly concerned by climate change and want to participate actively in reducing their environmental footprint. There are already many players in the EU market which invest in making refurbishment a positive financial business case. Indeed, companies are only at the beginning of their learning and efficiency curve. Actors offering leasing programs to their customers have a competitive approach towards refurbishment. Managing its own fleet is a key advantage to optimize the end-of-life and reverse logistics structure.

There is no single approach to determine when a printer should be considered for replacement. Various parameters are used as a trigger:

- Time: for how long the printer is in service. This is a fairly basic approach which is still in use by some actors in the market, most of the time driven by contractual agreement with customers.
- Software/connectivity/security: connectivity and security are two major parameters when using a printer these days, technology is making ongoing progress in this area driving products to become obsolete rapidly, it's a real challenge for OEMs to keep track with those changes and design product which can be upgraded.
- Number of pages printed versus maintenance cost: Depending on how many pages have been printed on the device, it is anticipated that major maintenance cost will be incurred to keep the printer up and running at an acceptable performance level. Therefore, decision is taken to change this product and get it refurbished at a manufacturing location where professional equipment is available.

A typical approach towards end-of-life products can be described as follow. Once products are collected and shipped back to the warehouse there is a mix of several end-of-life alternatives.

1. Refurbish products inhouse that are of high monetary value and quality and replace some spare parts (this alternative still represents less than 5%).
2. Keep some good working printers in stock for exchange requests or spare parts needs (this alternative represents less than 5%).
3. Sell printers to a) recyclers or b) brokers who will export those products for second use in Africa or Eastern Europe (this alternative still represents around 90%).

In general, those companies don't sell back their end-of-life printers to the respective OEMs. For various reverse logistic reasons, only few buying back programs exist for end-of-life printers. Reverse logistic cost seems to be a significant issue.

Companies prefer to refurbish printer models that can be sold with an attractive margin. The main focus lies on high end A4 and A3 printers (generally worth over 1000€) that still offer a real value at their end-of-life. A very low focus lies on entry to medium A4 printers. Those products have low market value and can often be replaced by new models that offer better technical and security features at an equal or lower price than equivalent refurbished products. In general, low and mid-range A4 printers only get refurbished if there is a concrete need for solving an emergency. Very few actors work on a project basis to sell large batches of refurbished printers. Most actors have a case-by-case approach and work with small volumes to satisfy specific customer demands. Project-based approach with larger refurbished printer volumes will automatically be in price competition with new products. The decision to refurbish a product is mostly taken if the business case is more attractive than acquiring new products. Most new A4 printers would be cheaper or equally priced to a refurbished printer. A4 machines loose most of their price value after 4 or 5 years.

Refurbished solutions are easier to put in place for the B2B than for the B2C market. Refurbished products need to go through a professional quality testing process before they are sold to the customer. A bad quality refurbished product can negatively impact the brand image of the OEM, reseller, or partner.

2) Price and qualitative expectations toward refurbished products

Price and quality are the two most important criteria for refurbishing a product. The quality must be high and the price of refurbishment low. This is the challenging equation that each company needs to solve while keeping at the same time an attractive sales margin.

Companies constantly assess how much resources/parts need to be invested in order to bring a refurbished product to the newest quality and security standard. Some second-hand products can already be obsolete because of missing software, security or cloud technology access. It's not only a question about spare parts availability (quality and price).

The price challenge is the most important one to be solved in a highly competitive environment. No actor will refurbish printers if the price equation is not solved. Nobody wants to lose money to preserve the environment if selling new products represents the cheapest and easiest solution.

The quality challenge offers more flexibility. Companies can opt for Grade A or Grade B refurbished products. Refurbished Grade A offers the best quality of refurbished printers. Near-mint condition, excellent cosmetic level, and little signs of previous use are expected. All typical maintenance parts are replaced independent of the number of printed pages. Refurbished Grade B offers the second-best quality of refurbished device. Light scuffing on the bezel and light scratches on the case or body as a result of gentle use are tolerated. Minimum maintenance parts are replaced. One way to reduce the old or uneven color aspects of the plastic housing is to use black color plastic (similar to the current black cartridge housings). Indeed, most refurbishment actors prefer Grade A products which represent a higher investment. On the other side Grade A products offer the highest quality and security standards.

Since most printers are connected via the internet cybersecurity is an essential topic. Users need to securely manage their network devices, defend them from hackers and physically protect the stored data. That's why printer manufacturers offer regular design updates to deliver solutions-capable printers that provide unhindered access to the right users, while keeping out the pretenders. Unsecure and obsolete devices can offer an easy entry point for cyberattacks into small business, enterprises, and government departments.

Grade B products can impact the brand image or increase financial risks. Service costs can for example increase exponentially if the quality level is not equal to new. This obviously depends on the risk approach of each partner and user dealing with refurbishment. Service cost (maintenance cost) is seen as a key driver: a printer can be refurbished at a fairly low cost by replacing few spare parts which will result in an attractive product price. Indeed, high service cost can entirely offset the price benefit for the customer and drive additional technical and security issues. Resellers involved in the refurbishment market tend to recover “acceptable” spare parts from end-of-life products, which reduce opportunities to refurbish more products.

In general customers can accept products that have slight cosmetic “defects”. The customer who gets an attractive refurbished price offer can accept products that don’t look like new ones. It seems like there is some subjectivity related to which kind of cosmetic “defects” customers are willing to accept. C-SERVEES can be an opportunity to investigate the tolerance rate of cosmetic “defects” in more details.

Besides, many actors are looking for a 30% to 50% price gap between new and refurbished products so that they can sell it with an acceptable margin. They often reach this margin by mixing refurbished with new printers (mixed calculation approach). Innovative solutions and volume calculation is needed to boost refurbished products.

Once this challenging equation is solved challenging % refurbishment target can get defined over time. Currently most companies only collect and refurbish less than 5% of their products that they place on the market.

Most actors have not yet solved the price and quality equation to their satisfaction and prefer to pay a premium for acquiring new products in a very price aggressive market environment. At regular intervals OEMs have large volumes of new products coming from their Asian based factories that need to be liquidated at any price.

3) Pain points and enablers to boost refurbishment

Companies agree that there is a mix of enablers to boost refurbishment. No one believes in the single silver bullet.

The main important enablers to encourage the use of refurbished products are listed below (without any order of ranking):

a) Environmental laws for manufacturers offering a bonus / malus system.
b) Public Procurement targets for refurbished products
c) Eco-design laws forcing manufacturers to design their products to be repaired and put back into circulation.
d) Legal obligation for manufacturers to produce spare parts necessary for the repair and functioning of the products.
e) Security features to a same level as new products
f) New or prolonged warranty and associated services

The market is moving towards more and more thoughtful and reasoned consumption, with the example of food consumption in a short circuit. Environmental laws are helping to accelerate this trend. Some actors are very optimistic and are convinced that the refurbished market should weigh around 30% over the next 5 years. Other are less optimistic and still see weak user demand for refurbished products (even in public administrations and schools).

Customers would need to better understand the environmental advantages of acquiring and using refurbished products. Customers should get data on how much energy is saved with a refurbished device compared to a new device. What is the CO2 impact of a refurbished product versus a new one? Is the CO2 impact negative, neutral or positive? The environmental story told by all actors in the refurbishment chain needs to be improved. This would also be the best way to move away from the pure price driven discussion. A customer could for example get a "green" certificate with the acquisition of his/her refurbished printer. The right environmental story telling will drive Circular Economy solutions.

Many industry actors are already driving innovative environmentally friendly solutions.

Another opportunity to boost refurbished products are delivery problems for new products. Most products are produced in Southeast Asia. At regular intervals serious delivery issues occur for ICT products for many different reasons (e.g. container shortages, natural disasters, trade tax discussions, Covid Pandemic, Suez Canal blockage by container ship getting jammed across the canal in March 2021). Refurbishment can offer local solutions to mitigate product delivery issues and reduce inbound supply chain constraints and lessen the impact on the environment. Due to refurbishment, the past model, where manufacturing is concentrated in just a few countries like a world factory will change to a more decentralized model.

One thing is sure: the refurbished market will continue to increase in the next years. Refurbished products can satisfy specific customer needs when flexibility, quick solutions and aggressive price offers are needed. Not all customers need the latest product model on the market.

4) Innovation to automate refurbishment

Innovation is one of the key elements to move from a manual to an automated refurbishment model. Innovation is also a key element to improve the cost equation of refurbishment and democratize its offering.

C-SERVEES is currently checking the acceptance of innovative solutions like the QR code. A QR code can be used to solve several bottlenecks of refurbishment.

Actors in the market see several QR advantages to boost innovation:

a) Communicate environmental related information to users such as CO_2 footprint or energy impact, Blue Angel compliance.
b) Better assess the value of an old printer and its spare parts.
c) Retrieve information on the product history (e.g. date of installation, paper and energy usage, nr. of technical interventions).
d) Achieve a better price when selling end-of-life printers to brokers. Each individual printer can be attributed a financial value depending on its product history.
e) Speed up inhouse refurbishment processes to save time and money.
f) Attribute a fair market value to each spare and plastic part.
g) Decide if a product shall go for A Grade or B Grade refurbishment and optimize the financial investment.

QR codes are not a magical solution to solve all issues of refurbishment. They can help to accelerate the acceptance of refurbishment and improve the business case. All interviewed persons are interested to know more about C-SERVEES QR code solutions to help them automate their inhouse refurbishment processes.

Learnings

Many companies are still at the beginning of their learning curve regarding higher volume refurbishment. Refurbishment is still a niche activity that is slowly gaining in importance. Businesses with a clear focus on leasing programs and "selling a service" will benefit most of the upcoming refurbishment boom. Environmental Legislation will start to accelerate refurbishment in public procurement (e.g. reuse targets in France and Italy). Companies that have experience with leasing better control complex and costly refurbishment reverse logistics processes. They are closer to their customers and can include refurbishment as one solution towards multiple customer expectations.

Most OEMs have a good understanding on how to refurbish their own products from a technical point of view. OEMs must improve mainly two bottlenecks to boost their refurbishment volumes. They need to improve a) their reverse logistic processes and reduce costs and b) better market their refurbishment offers to their customers and sales community. One major pillar to achieve those goals is to improve the eco-design of new product generations. Products need to be designed in such a way to increase their value after the end of life. Generally, eco-design thinking stops at the end of life. It doesn't go beyond end-of-life thinking. Innovative eco-design conception can improve the cost and time efficiency of refurbishment. Products need to be designed in a modular approach. An end-of-life product needs to be easily updated with the latest software and firmware and integrate the latest security features. A good benchmark is the Fairphone approach. A Fairphone is designed for longevity, easy repair and modular upgrades and helps changing the make-use-dispose mentality. A modular designed printer (a bit like Lego bricks) would make the refurbishment business model far more attractive for OEMs, dealers, customers and recyclers. As refurbishing is on track to become more and more popular, another area of improvement for OEMs is the spare parts lifetime. Spare parts represent one of the major cost elements when refurbishing a printer. Spare parts should be designed for more durability and multiple lives.

5.1.5. Refurbished printers with cosmetic defects

One of the major customer acceptance parameters resides in the cosmetic. Customers are looking at a refurbish product which look like new, perform as new with the same warranty but cost much less, hard to solve such equation. Up to now, for the refurbished product sold by Lexmark the specification is as per customer current request: product must look like new, also called E2N (equivalent to New). Meaning that very minor "defects" are deemed accepted. See below actual specification table.

Table 5. Lexmark quality specifications for refurbished products.

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 $1m^2$)
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 $1 m^2$)
Cracks	N	N	N	N	N	N
Foreign objects or Stickers	N	N	N	N	N	N

The purpose of this activity is to see how far the cursor can be pushed to have customer accepting little cosmetic defect, such as scratches, dents or decolorization and adjust the above specifications or as appropriate determine several grades of refurbished printers and therefore several specifications.

Four printers, 2 mid-range mono MS 823 (already referenced and used in previous demo activities) and 2 mid-range color CX 725 representatives of the most sold products were refurbished, assembled and shipped to 4 selected parties to gather their feedback. It is to be noted that this is a blind test, in other words, customers are not informed about what defect, on which side… In parallel a questionnaire was developed to gather feedback on specific topics and support an interview that will be conducted at the end of the 3 months test. An average of 6 specific cosmetic issues per printer. High-definition pictures were taken for each cosmetic detail (see below some samples) to be able later to interact with customers and identify what is acceptable and not acceptable for them.

Below are some samples of the mentioned cosmetic defects (all together there are 24 different pics/cosmetic issues).

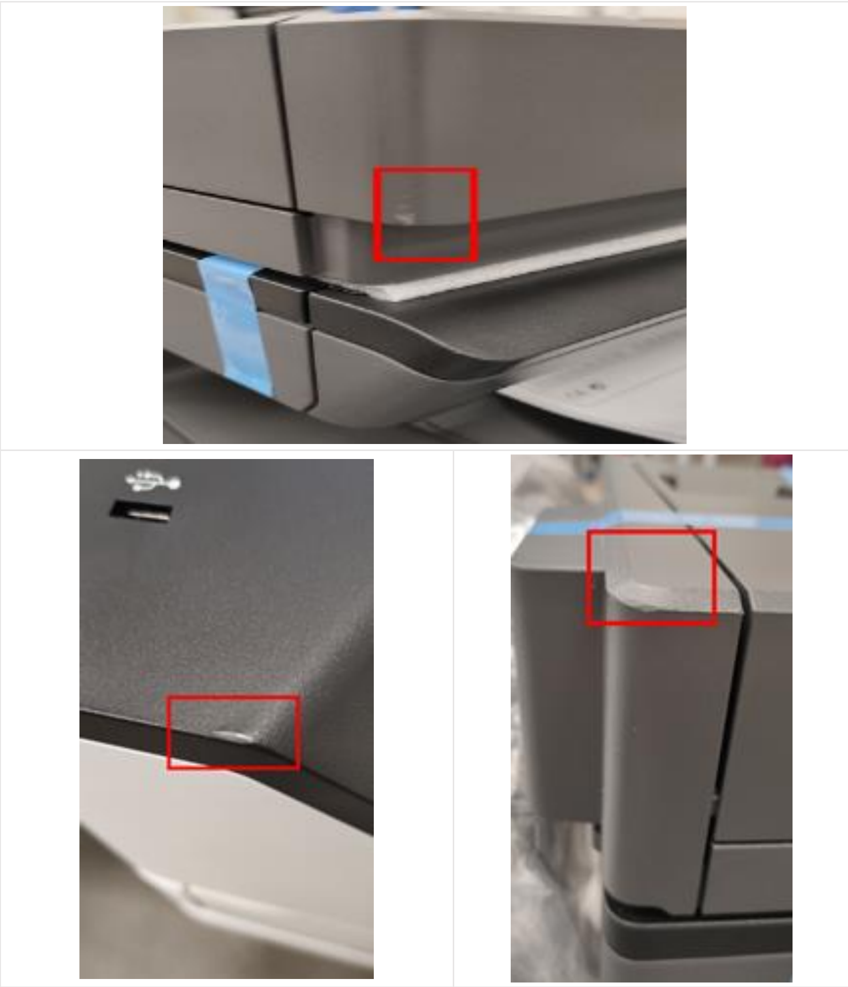


Figure 16. Cosmetic defect samples in refurbished printers

Various technics and products have been used to mitigate the cosmetic damages by cleaning/polishing the various parts/areas. It is to be noted that despite using supermarket off-the-shelf products to clean and polish the parts, it required Syncreon to gather approval from their EH&S department and therefore take all necessary measures to ensure products are safe for the operators, even in case of long-time exposure.

The spec table as well as pictures of cosmetic issues could be provided to recyclers with a dismantling manual (ref 5.1.1) so as to maximize good part received at the refurbishing location.

Would customer be willing to accept such cosmetic defect, it would drive a significant benefit. The manufacturer of these housings being in Asia, like for the entire industry, procuring these as spare parts comes at a high cost driven by MOQ (minimum order

Quantity) as well as packaging and freight, without counting the environmental impact (CO_2 emission). And bottom line it makes the refurbishment business more cost effective and helps to increase yields on refurbishment as more parts can be reused. Indeed, comparing E2N methodology with potentially "acceptable" cosmetic defect as shown above would drive respectively 17€ and 53€ per unit cost down from MS 823 ad CX 725, which represent 50% of cost of the targeted parts.

See below tables, the first part of the table lists the parts and percentage of replaced parts for each methodology.

MS 823

pn	description	E2N	with cosmetic defects
41X1054	MS82x SVC Cover top	90%	48%
41X2690	MS82x SVC Bezel 2.4" display	100%	50%
41X2839	MS82x SVC Cover Top	90%	40%
41X1067	Left cover	50%	23%
41X1066	Right cover	20%	15%
41X1065	Rear cover	60%	34%
41X1126	Rear door	10%	6%

Total €	€ 34.06	€ 17.01
	Gap	€ 17.05
	%age	49.9%

CX725

pn	description	E2N	with cosmetic defects
41X0262	CX72x SVC Scanner ADF	90%	40%
41X0263	CX72x SVC Scanner FLATBED	20%	12%
41X0268	CS72x SVC Tray Insert SHEET ASSEM	40%	25%
41X0401	CS72x SVC Cover TRAY INDICATOR	10%	5%
41X0403	CS72x SVC Cover IMAGING DOOR	10%	5%
41X0408	CS72x SVC Cover REAR TRAY	30%	16%
41X0410	CS72x SVC Cover BIN EXTENDER	10%	6%
41X0424	CS72x SVC Cover REAR HANDLE	10%	5%
41X0433	CX72x SVC Cover OUTPUT BIN ASM	10%	8%
41X0437	CX72x SVC Cover MFP FAÇADE	10%	5%
41X0442	CX72x SVC Cover FRONT DOOR	10%	5%
41X0543	CX82x SVC Bezel 7" op-panel	10%	8%

Total €	€ 105.94	€ 52.72
	Gap	€ 53.22
	%age	50.2%

The result of the customer test is expected by the end of year and therefore will be included in the coming report.

Outcome

While this activity is not yet completed, it so far reveals the importance of the cosmetic criteria for refurbishing products, especially big products such as printers. Indeed, moving from 'equivalent to new' approach to 'potentially acceptable damages' drives significant cost impact and can play a major role in the final business case.

5.2. Assessment of the potential to increase material circularity

While enhancing circularity of the Printer is a high priority, there will always be products ending up being recycled and therefore increasing material circularity is an important topic. Lexmark already uses 37% of recycled resin in its cartridge products and is looking at even using more (50% by 2025 is the latest target). The issue is mainly on the offer end, indeed, there are only very few players on the market which drive material scarcity as well as price issues. While using recycled resin, customers become more and more sensitive to the subject matter and are looking for evidence that the product they buy contain a minimum percentage of recycled resin or material. This is what this activity is addressing.

5.2.1. Result of recycled materials from EoL printers and toner cartridges

Within the Printer & toner cartridges demo Lexmark has performed a case study on recycled resin. The main objective of the study was to analyze the technical feasibility of reusing the ABS plastic from end-of-life products and incorporate the recycled plastic material into new cartridges, using the Circularise ICT tool to track and prove the recycled content at each stage of the supply chain. With this case study, Lexmark intends to explore the potential to increase circularity in its business model while making use of certification by ICT and blockchain.

Therefore, the aim of this exercise is two-fold:

- Evaluate the potential of recycled ABS from end-of-life products (both Lexmark and non-Lexmark) to be incorporated in new Lexmark products. This objective is in agreement with 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' and A9.4.2 'Investigate economics of more CE suitable materials coming from end-of-life cartridges or printers'.
- Evaluate the potential of the ICT tool to facilitate the certification process in the CEBM, ensuring verification of the recycled plastic content, as per PRINT-CIRCMODE A2.3.1 'Use ICT to support information sharing related to recycle content across supply chain' and A2.1.1 'Assess options to reuse material from End-Of-Life as well as WEEE printers'.

For the sake of the study, ABS plastic materials were collected from 3 different flows:

1. Lexmark printers
2. Lexmark cartridges
3. Other OEM Printer brands

to examine whether the origin of the ABS plastic is relevant and if it influences the outcome of the process.

1) ABS material from end-of-life Lexmark printers

Indumetal has used Lexmark printers from the disassembly exercise they performed previously (D4.2, Section 5.2.1) to provide the plastic parts needed for this activity. They manually separated only ABS plastic parts without considering the printer model (CX510, MS812, X950) and in total they collected 30 kgs of ABS materials.

2) ABS material from end-of-life Lexmark toner cartridges

The other batch of material derives from cartridges which was provided by Syncreon. They had on stock Lexmark used cartridges from various models that they dismantled to set aside the housings parts (cartridge large external parts). According to the technical data sheet these housings parts can be made of either ABS or HIPS. Syncreon receives cartridges from different locations through LCCP (Lexmark Cartridge Collection Program) but the acronym of material is engraved on the parts and the possible contamination can be avoided while sorting. After dismantling and sorting and based on the available units Syncreon had on hand at that time (about 300-350 units) they were able to collect 20 kgs of ABS parts. More ABS parts could have been recovered on this lot, but this would have required a specific equipment not available at Syncreon.

3) ABS material from non-Lexmark printers

As part of the printer and toner cartridge demonstration Lexmark planned to carry out a study on the possible usage of non-Lexmark ABS plastic parts from end-of-life products. The material derives from other brand’s printers which were collected at the recycler partner, Greentronics, in Romania.

An additional challenge was found to ensure only ABS was collected from end-of-life printers (it can be extended to other end-of-life IT products and EE equipment). As an example, some Lexmark printers depending on model contain PC/ABS or ABS housing parts or components. This requires a very thorough examination of the dismantled printer parts by the operator at the recycling facility, to make sure only ABS pieces are collected. PC/ABS contamination of an ABS batch would render this batch unusable by Lexmark. This would be apparent only once the chemical and physical analysis are performed, however all the previous work undertaken to prepare these recycled flakes would be wasted.

Since Lexmark (as a manufacturer) is working together with companies which operate on other business fields (e.g., a recycler in this case), the given instructions or information should be evident for the parties and the processes which are not part of their general operation in order to avoid internal misunderstandings and ensure the technical and economic feasibility of the circular economy approach envisaged.

Following Lexmark's instructions, Greentronics collected an ABS-only batch of parts, making sure these were ABS parts coming from non-Lexmark branded printer products. The around 25 kg of shredded plastic material were shipped to Gaiker for grinding and chemical testing. The received particle size was between 5-10 cm, then was grinded to 8 mm. Afterwards it was washed and dried to remove dust and dirt. Other visible contaminants like metal inserts stickers and non-ABS particles were manually removed and the remaining metallic contaminants were eliminated by eddy current separator, which removes non-ferrous metals. The samples (same as to the other two batches of ABS samples) were characterized based on the requested tests (see the tests more detailed in the following paragraph). Lexmark engineers need to analyze the samples as well and confirm if the material meets all requirements to continue the procedure. In case the results are positive a test production of cartridges with recycled content will be carried out at Lexmark molder. For the time being Lexmark has not received yet the "green light" to proceed, the analysis is still going on.

Figure 17. ABS plastic material obtained from WEEE printer parts of other brands

The first two batches, meaning the ABS from printers dismantled by Indumetal and the cartridges disassembled by Syncreon, were shipped to Gaiker in Spain in order to grind them into 8-9 mm flakes. This is the maximum size of particles that the equipment can handle by Lexmark molder. Other possibilities were considered to grind the material in order to reduce shipment costs but at this point it was not possible to find any other companies which were able to grind into the required size of flakes. Whether in Poland, Romania or Spain, identifying a company which can grind plastic resin in small batch is a challenge, something worth considering assuming would Lexmark intent to move from pilot to production.

The materials were processed at Gaiker. 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 which derived from printer parts were a mixture of black and whitish grey colored since the printer parts have different colors. The other batch of flakes made of cartridge ABS are homogenous black as all parts were identical.

Figure 18. ABS plastic parts from Lexmark printers (left) and ABS flakes obtained after processing (right)

Figure 19. ABS endcaps from Lexmark cartridges (above) and ABS flakes obtained after processing (below)

Gaiker then carried out a chemical analysis to compare the properties of recycled ABS material obtained from Lexmark printers and cartridges with the properties of virgin ABS used for the Lexmark products. A small quantity of recycled materials has also been sent to Lexmark engineers who carried out the same analysis as Gaiker. They also reviewed the report we received from Gaiker and agreed to continue with the demo.

Gaiker was instructed to carry out the following tests on three samples:

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

The samples were (1) Virgin ABS pellets from Jabil, (2) Recycled ABS pellets from Lexmark printer parts and (3) Recycled ABS pellets from Lexmark toner cartridge parts.

It was previously discussed that the last step, to convert the material into pellets could not be performed by Gaiker since they only have a small extruder which is not suitable to process large amount of material and it would take extremely long time and effort. The extruder has filters to ensure the pellets come out clean. Skipping this step increases the risk of contamination remaining in the material.

The grinded ABS resin from printers (25kg) and cartridges (15kg) were then shipped to the molding company Jabil/Plasticast to Hungary.

Jabil produced about 200 cartridges housings, mixing 20% of grinded material received from Gaiker with virgin material, on the 160 first ones as welding has to be done just after molding, they then proceeded with subassembly and welding and kept the last part to perform measurement reports to compare with the Lexmark specifications. Outcome of the measurement report being positive, they finally proceeded with a welding quality test by destroying those units, this test was also positive. 20 welded subassemblies were sent to the Lexmark engineers and 70 units were sent to Syncreon for final assembly and test.

Figure 20. Welding process at Jabil

From the 25 kg of ABS material derived from printers they could only produce 80 pieces due to metal contamination as they found big particles of metals and they were not able to continue with the process in order to avoid further damages in the tool. Investigations took place to identify the cause of such contamination despite of the various warning and cautiousness taken during the various process steps. The 80 welded subassemblies being potentially contaminated and the housing parts not any more available for a dimensional report, there was no more choice than stopping the test of this resin batch.

The presence of metal particles in the recycled flakes would not have happened if the flakes had been extruded to obtain recycled ABS pellets. In this exercise, it was not possible due to the large quantities of materials involved and the lab scale at which the partner Gaiker was operating. However, for an upscale of this operation as intended by Lexmark, the final step in plastic recycling, which typically consists of extruding flakes to obtain pellets, should be included as part of the recycling process. The recycled ABS pellets would then be analyzed for compliance with physical, chemical and mechanical requirements.

Figure 21. Metal particles found in recycled ABS from printers

Syncreon has received 70 pieces of housings. The Special Build Request for 10 pieces included the incoming inspection, assembly and Functional Test, Drop Test, PPVT Print Test (Performance Printing Verification Test). They have proceeded with a “remanufacturing cartridge type test” by making assembly and disassembly with screws several times in the same housings to see if the cartridge can be used more than one time and can be remanufactured. They unscrewed and screwed the endcaps for 5 times and the result was positive since they have not noticed any issues. Syncreon has provided Lexmark with a Special Build Request Report, several pictures and videos of all the 10 cartridges and related tests, measurements.

Figure 22.Sample of cartridges produced from recycled ABS material

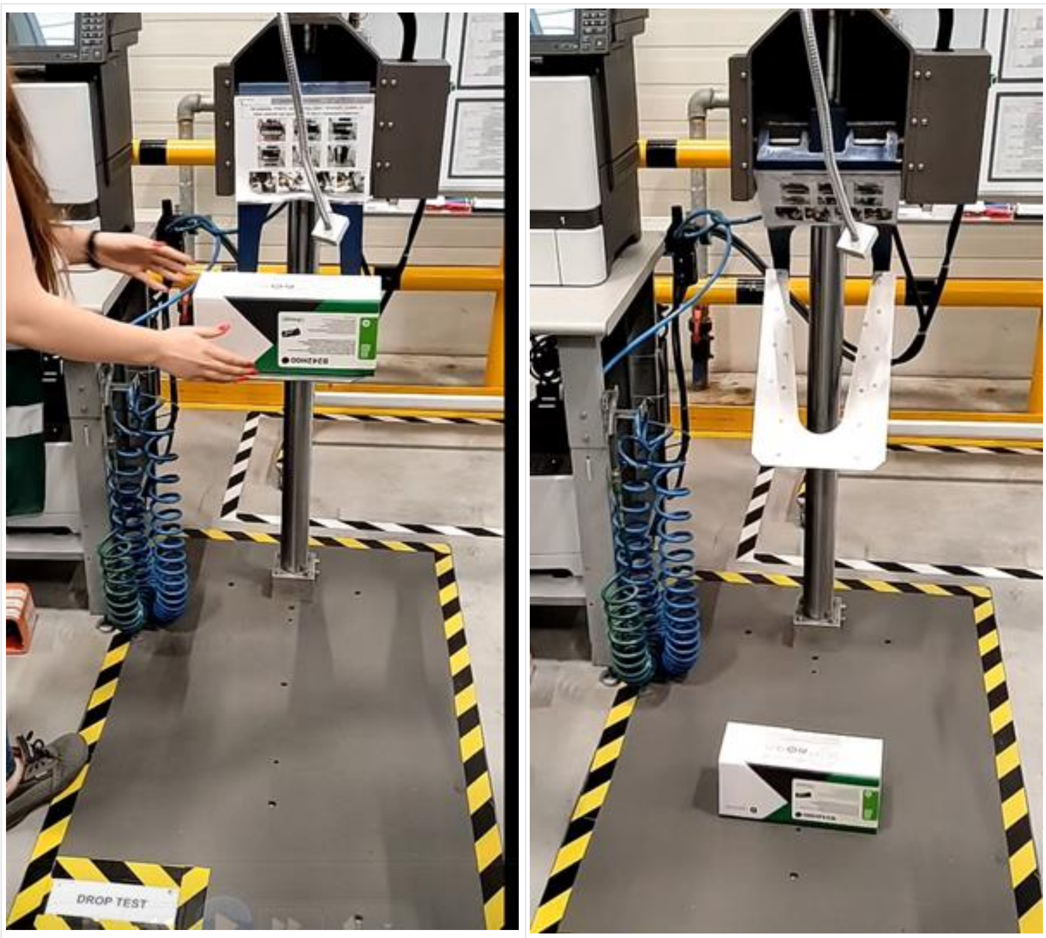


Figure 23. Drop Test at Syncreon

Outcome and conclusion

In the recycled resin study ABS plastic materials from dismantled Lexmark printers and cartridges were used in a test production to recycle the material, incorporate into cartridges and evaluate if the newly built products with recycled content meet the requirements and could be integrated into regular production. The ABS material used for the demo derived from two sources. One batch of material was collected from dismantled Lexmark printers and the other batch derived from end-of-life Lexmark cartridges. A third batch of material from waste printers of other brands has been analyzed but no test production took place for the time being.

This activity highlighted various interesting points to bear in mind moving forward:

1. Contamination with other resins (which should be avoided with careful sorting and classification at the recycler's facilities)
2. Contamination with metals (which should be avoided by including a metal separation and pelletizing of recycled materials)
3. Grinding and pelletizing capacity (which requires the inclusion in the value chain of a company providing this service)
4. Communication on requirements when dealing with multiple players

The first three points above must be tackled in order to further pursue the economic assessment of this circular economy approach and business case. Lexmark analyses the possibility to invest internally in such equipment, but it appears to be not worth based on the volume at stake. In fact, Lexmark privileges the remanufacturing of used units and therefore ends up with low volume of non remanufacturable ones which can be used for resin reuse.

One of the main positive conclusions of the study is that the cartridge housing made of recycled ABS from end-of-life toner cartridges passed every required test, from chemical analysis to finish good assembly and functional test. The result is very satisfying, and this type of material could be used in regular processes as well after having a PPAP that approves the use of this kind of material up to maximum 25% of recycled content. PPAP is a standardized process in which the company utilizes to qualify components for use in assembly. The process verifies the component meets the Lexmark specifications and functions properly. This is accomplished by dimensional checks, as well as, functional tests with pilot builds at the manufacturing sites. Assuming a positive business case and sustainable volume, Lexmark will be willing to pursue this direction.

On the other hand, the process with material reclaimed from printer parts was not that smooth and we have faced some obstacles. The most notable issue was the metal contamination in the material from printer ABS. This obstacle is mainly process/skill related and should easily be overcome but it highlights the importance of getting material properly sorted and processed, which require the rights means as well as skills. From Lexmark experience, such suppliers exist and provide OEMs with the right recycled resin specification, but with low volume and noncompetitive cost versus virgin resins.

The first challenge to overcome in order to scale up this process is to find a company that is able to grind the printer and cartridge parts into 8-9 mm flakes (as required by Jabil) and, ideally, extrude these flakes into recycled ABS pellets to avoid metal contamination issues. In the context of the C-SERVEES demo it was not possible to identify any candidate that is geographically close to Lexmark molder (Hungary) who can accomplish this requirement or can provide grinding services and due to this finally the partner Gaiker (in Spain) grinded it.

5.2.2. Certification of recycled content by ICT

An ICT tool has been developed by Circularise which aims to bring transparency to the supply chain and empowering businesses to move towards a more circular economy. The tool consists of a blockchain-based platform using smart contracts and latest encryption technology as well as a patent-pending zero knowledge proof technology to allow selective, decentralized communication of sensitive material data along the supply chain. With the tool they create a digital version of the physical supply chain and track the materials used at each stage. Suppliers are able to communicate quality criteria and use certifications to prove, for instance, recycled material content or low energy production facilities etc. The information exchange happens in a secure and transparent manner.

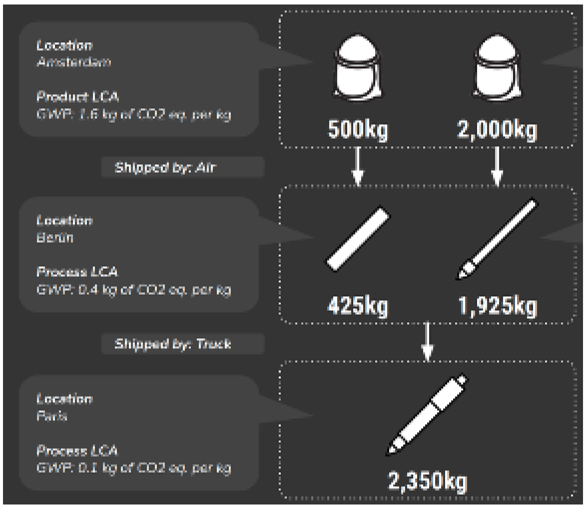


Figure 24. Digital version of the physical supply chain

The technology digitizes quality certification at the supply chain stages of the respective material creation and transfers the proof or material properties along the supply chain in a mass balance system that ensures that brands and end users obtain the exact proof of the material quantity of this quality level which they have received. This system avoids double spending of e.g. recycled material certification and digitizes and validates the certification process. As a result, all stakeholders can proof the recycled content and unlock the 15% increase in willingness to pay which customers indicate according to Deloitte 2019 when recycled material certification is provided. In the recycled resin study Lexmark and the rest of involved partners were testing the tool to determine the feasibility of introducing this innovative approach to track the recycled material flow in the supply chain and certify the recycled material content of products. The exercise is performed only for the cartridges including 20% recycled content, with the prospect that an additional demonstration will be conducted with the tool and its Smart Questioning functionality for D4.4. Therefore, the partners involved in this validation include:

- Syncreon – supplier of end-of-life cartridge parts
- Gaiker – processing of cartridge parts and obtaining recycled ABS flakes
- Jabil – molding of new cartridge parts including recycled ABS

The supply chain stakeholders received accounts on the Circularise System. With the ICT tool the partners can forward and receive the tokenized quantity of materials and add their own claims about material quality or add any information they want to share with their customers like general product information, warranty, product manuals. The stakeholders need to provide a certificate which proves the recycled material they add to their products and then forward the tokenized material which they have received from their suppliers.

Lexmark and the related partners in the demo have completed the physical process of ABS plastic recovery from Lexmark own products by August 2021. In September 2021, demonstrations were organized with the involvement of each of the companies which were part of the supply chain in the demo. The aim was to test the Circularise platform and do the token transfer of recycled resin of recovered ABS material from cartridges and track the flow between supply chain partners. In order to ease the demonstration process, the demonstration did not use any official recycled content certificates (e.g. EUCertPlast) as this would have involved further costs for the suppliers who are currently not certified. Instead purchase orders and shipment documents stating exact quantities and batch numbers were employed.

The participants were Circularise, Syncreon, Indumetal, Gaiker, Jabil, Lexmark and Greentronics (Greentronics was not a participant in this activity, but was involved to the account creation since they are suppliers of the third batch of non-Lexmark WEEE ABS, which will go through the same physical process as the Lexmark ABS batches assuming it gets the permission from engineer side to proceed). All partners have successfully created their own accounts. Important to note that the supply chain members are not able to see the suppliers or customers of other companies since the tool is based on blockchain technology which keeps all data safe. Only those information/documents are visible that partners feel comfortable to share. After creating the accounts, all stakeholders need to identify their suppliers and customers and establish virtual relationships, then the connected supply chain members are able to send the tokenized material and attach documents which prove the amount of recycled material and the physical transportation to each location.

	Description
Syncreon > Gaiker	Syncreon provided 20 kg of ABS plastic from cartridges to Gaiker.
Gaiker > Jabil	Gaiker grinded and tested the material then sent 15kg to Jabil
Jabil > Syncreon	Jabil produced 160 pcs of welded samples, of which 70 were sent to Syncreon
Jabil> Lexmark	They sent 20 pieces to Lexmark engineers to the US.
Syncreon> Lexmark	Syncreon produced 69 cartridges from the received housing of which **10 cartridges** were sent to Lexmark and 59 to a different customer

Figure 25. Supply chain of Lexmark cartridge demo

The token transfers on the system resemble the actual material transfers and the respective quantities of material. Syncreon started the demonstration with the creation of tokens based on the transportation document to Gaiker. Syncreon created 20 kilograms worth of tokens with the category waste and sent then via blockchain to Gaiker. Gaiker updated the token information by logging the production process of <<grinding>> with the outcome of ABS flakes. Afterwards 15 tokens were transferred to Jabil. 5 tokens remained on Gaiker's account proving the exact recycled material amount received by Jabil and the respective resulting recycled material percentage of the final product. In a resumed session Jabil used the tokens received from Gaiker, updated them by adding the production process producing welded samples and transferring 70 of the 160 pieces in respective material weight to Syncreon and 20 unites to Lexmark. The weight of one empty unit is 218 g which has the content of 20% recycled material and 80% virgin ABS. Jabil has used net 7 kg of recycled material for the 160 welded samples and the remaining 8 kg was production loss. Syncreon received the tokens and updated them by logging the production process of "producing cartridges" with the quantity 69. With the tokens received, Lexmark is able to prove to its end-users the exact percentage of recycled material in its products. This can be done via the website of Circularise which will be demonstrated in its full range during the End-of-Life stage of the C-SERVEES demonstrations.

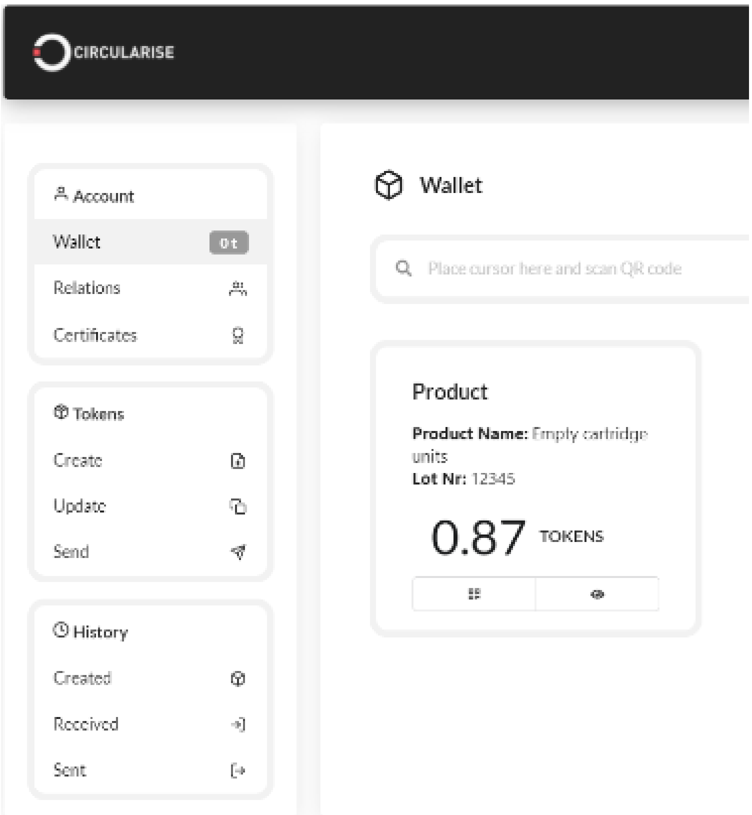


Figure 26. Lexmark account on the Circularise web platform

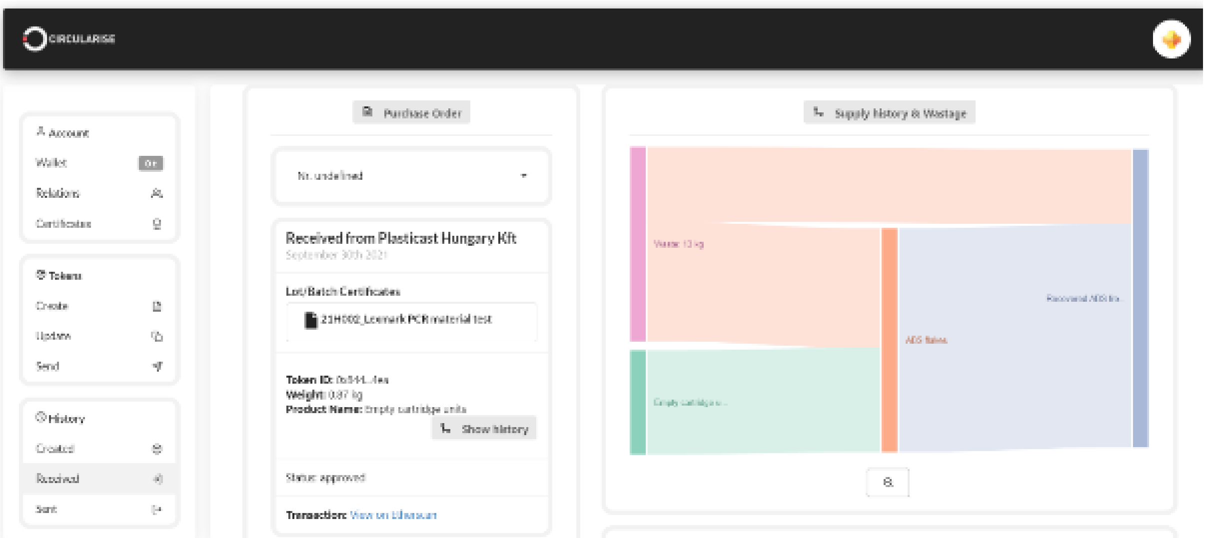


Figure 27. Supply history and wastage of cartridge production in Lexmark demo

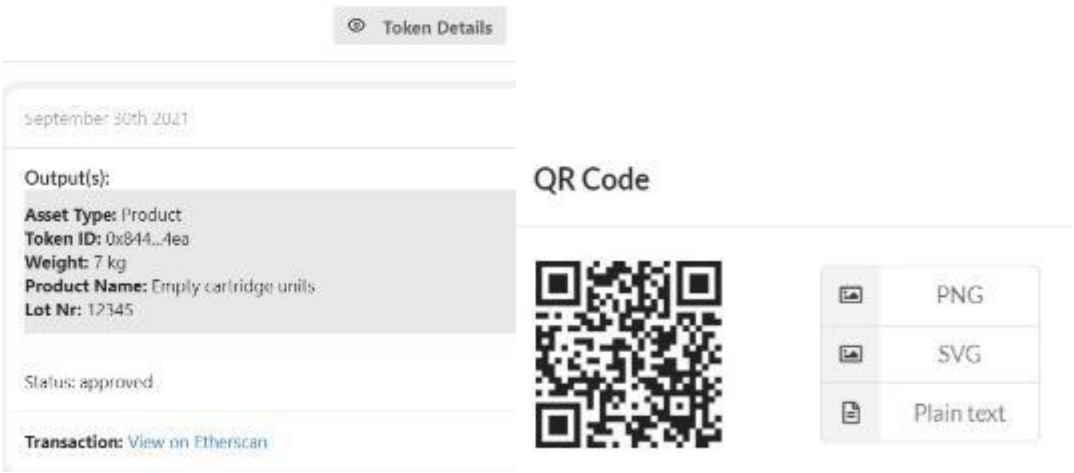


Figure 28. Token details and related QR code

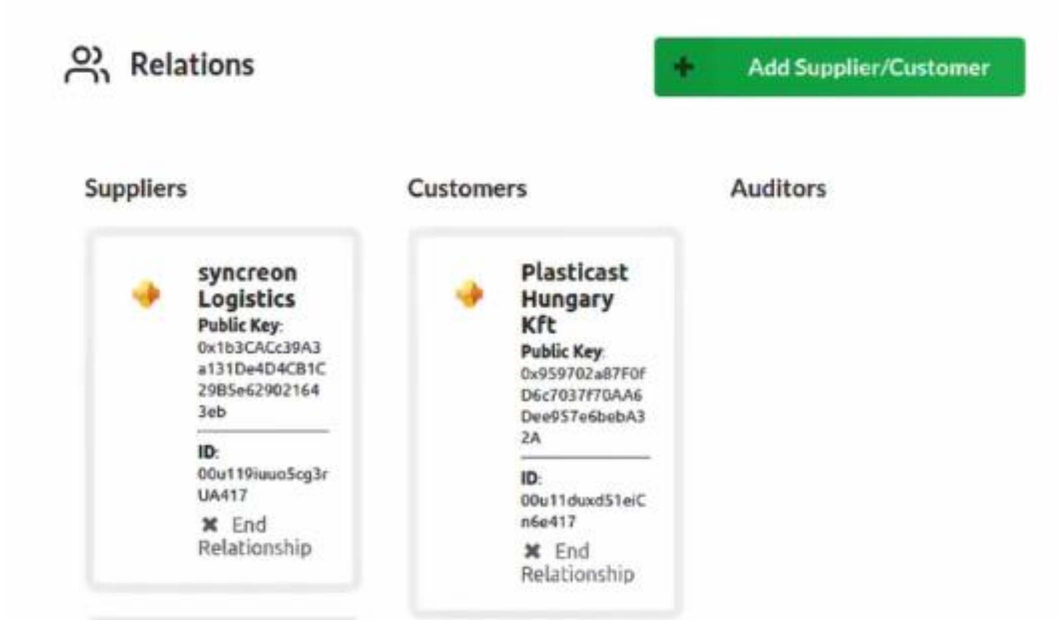


Figure 29. Virtual relations between the stakeholders

5.3. Reverse logistics in the supply chain

As mentioned previously, reverse logistic is a key cost element. The two activities below are aiming at bringing efficiency in reverse logistic, the first one is the extension of the Lexmark cartridges Collection Program platform to printers and the second one is the use of Rina C ICT Tool.

5.3.1. Extending the current LCCP online platform to printers

There is an internal project started at Lexmark this year, called EMEA SC Refurbishment project.

The aim of this project is to increase the EMEA refurbish volume by leveraging and enhancing all internal related processes, in agreement with PRINT-CIRCMODE A1.4.2 'Reduce the number of unnecessary and incorrect shipments' and A1.6.1 'Increase the flow of returned end of life printers by reducing the associated time and cost' and A1.1.1 'Expand LCCP (Lexmark Cartridge Collection Program' and/merge with LECP program (Lexmark Equipment Collection Program): collecting and refurbishing whole printers and key components'.

The project scope include developing the return flows for hardware, so the Lexmark C-SERVEES team is decided to participate financing the Mieux project and enlarge the already existing LCCP web platform for printers to improve our buy back and take back system - as this will accelerate our circular economy projects in Europe.

Since 1996 with the Lexmark Cartridge Collection Program, Lexmark seeks to recover components and parts of end-of-life products to reuse or recycle. Lexmark offers the possibility for its customers to reduce their waste and increase the number of Lexmark products that are reused and recycled in more than 60 countries.

Mieux is a French Agency, they have played a key role in the development of the new, fully digital platform for LCCP. They created a new identity with « Collected by Lexmark », improved the website, set up new efficient functionalities, and rolled out the program in 32 countries. Their team specialized in CSR and Circular economy.

Now we are in the test phase for the hardware part, and the final implementation could be end of this year.

How the Take Back (TB) – Buy Back (BB) process is working now:

- This is an online excel based process. 99% of the communication is via email.
- The advantage is that it is a mature process and well known for other parties. But it means intensive manual workload, the possibility of a human error is higher, and it is not user – friendly.
- As of today, the TB/BB program includes around 100-120 orders per year and all the processes are done manually.

And how it will work after the implementation of the new « Collected by Lexmark » webpage by Mieux:

- This is a webpage based on-line template. A semi-automatic process with less manual workload, database built automatically for reporting. Communication is automated, with a very user-friendly template. This platform is dedicated to be one single customer hub, and the goal is to optimize and converge the resources and to offer a smart and intuitive process flow, boost the refurbishment printer program and move from a manual to an automated process.

- The other big advantage is that one single customer friendly interface will be created for cartridge and printer collection as well. It enables the product and the team to be flexible and to add inputs on demand. The product is constantly evolving thanks to continuous user feedbacks.
- Using this kind of platform will make our collections easier and faster, will improve customer friendliness, and it could serve the refurbishment supply more effectively. And it will also lead Lexmark to be an innovative and sustainable partner for other companies.

5.3.2. Reverse logistics ICT tool

RINA-C has developed a Logistic Platform which 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. This functionality enables closing the loop for the EEE value chain in a sustainable and cost-effective manner. The lack of efficient management of the supply chain of reused/second-hand materials leads to being seen circular economy as a less attractive business model. The Platform eases implementing a circular business model by applying improvements of end-of-life product logistic and assessing the supply chain environmental benefits. It is able to work as a stand-alone platform, but it also works as integration of the overall ICT platform. In the tool it is possible to create supply chain customers and assessing the already existing ones. It is able to simulate and compare different scenarios and identify the best route to collect recovered materials or end-of-life products in term of energy consumption, transportation time, CO2 and other main pollutant emissions.

Within the demo, Lexmark has provided the required inputs/data that RINA-C could use to test the Platform, which were the following:

- Supplier name
- Location of supplier
- Product model
- Machine type
- Quantity
- Dimensions (mm) – unpacked printer
- Weight (kg)
- Number of pallets
- Preferred pick-up date

The data have been extracted from existing Lexmark Takeback transportation request forms. For the demo 4 requests have been used as source. Real pick-up addresses were used, but instead of real company names Lexmark preferred to rather use Company 1, Company 2 etc. Two companies are located in Germany, one in the UK and one in France. In total 53 printer models have been selected and Lexmark provided all the necessary information about them. The preferred pick-up dates are fictional dates. The destination in all cases was Zary, Poland where Lexmark's manufacturer, Syncreon is located.

The tool has created the possible scenarios and routes among the pick-up addresses. It shows the delivery time, air pollutant emissions like CO2 (kg), NOx (kg), PM10 (kg) and maps with the available routes. It also shows the truck type, here the "Heavy Duty Truck" type (max load 23 tons) has been considered but any other option is selectable. The tool can evaluate the total weight and max truck load and determine the minimum number of trucks required. In this demo case the transportation requires 1 truck since the total weight is 2.85 tons and the max truck load is 23 tons. The tool lists all combination of paths among pick-up addresses. In term of emissions, total distance, delivery time and number of trucks the "United Kingdom -France – Germany – Germany – Poland" order is the most favorable.

Products

Action	Name	Code	Supplier	Warehouse	Availability date	Volume	Weigth
EDIT DELETE	Printers (C792de MS812de MX611de X952dte XC4150)	8 printers	Company 1	Company 1 - warehouse	22/05/2021	3.84	1.3
EDIT DELETE	Printers (MS823dn MS812de MX317dn X862)	25 printers	Company 2	Company 2 - warehouse	20/06/2021	3.84	0.8
EDIT DELETE	Printers (XM1145 M1145)	18 printers	Company 3	Company 3 - warehouse	23/06/2021	1.92	0.287
EDIT DELETE	Printers (X950 X792)	8 printers (6 pallets)	Company 4	Company 4 - warehouse	27/06/2021	5.76	0.48

Figure 30. Lexmark collection data used for Reverse Logistic demonstration

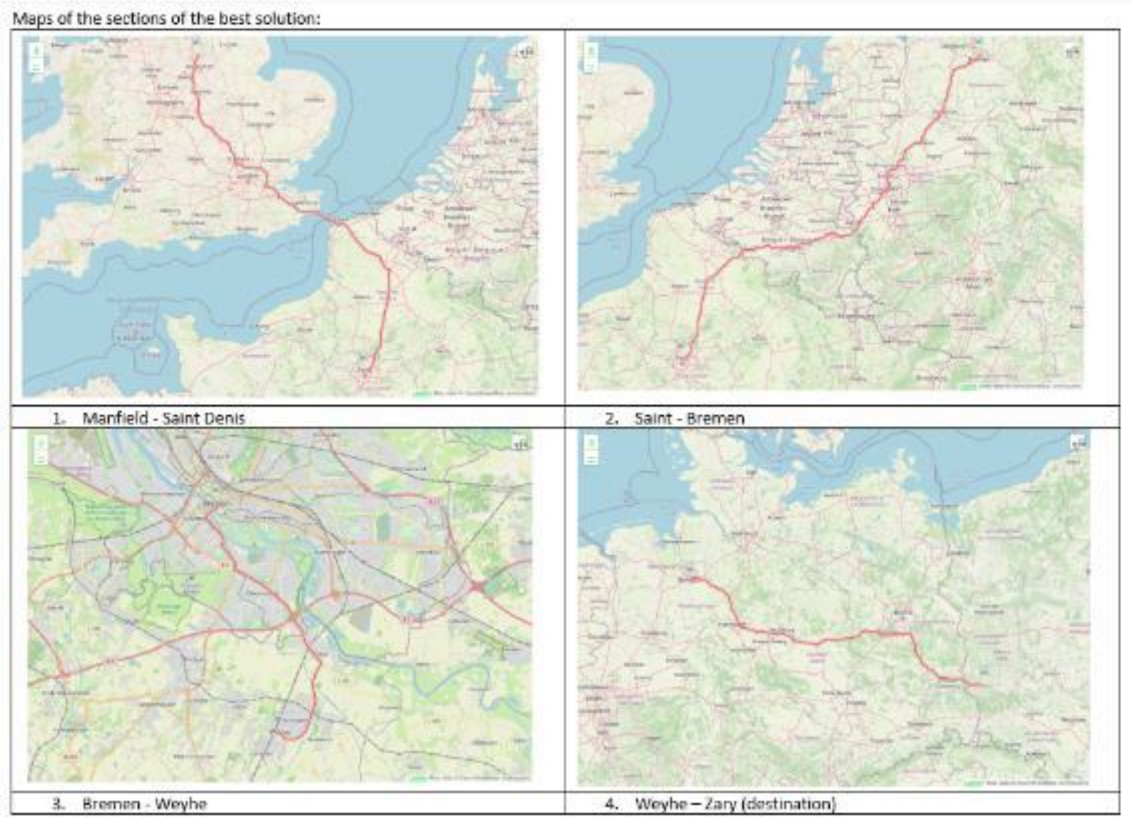


Figure 31. Maps of the sections of the best route

Lexmark considers the Rina-C reverse logistic platform as a good tool in terms of calculating air pollutant emissions, determining truck capacity needed, comparing the possible transportation routes and displaying the maps of the sections of the best route solutions. On the other hand, an opportunity for improvement could be to consider financial aspects as well, which would bring a wider view for comparison.

5.4. Active lobbying and PR campaign

Lexmark is lobbying actively for Remanufacturing and Refurbishment and considers it to be the backbone of the Circular Economy. This is in agreement with PRINT-CIRCMODE A.3.3.1 ‘Active lobbying at EU and/or national level for wider acceptance and promotion of circular business models’ and A.3.3.2 ‘Active media/PR campaign on refurbished printers’, as well as A4.1.2 ‘Promote refurbished printers’.

Lexmark is convinced that different key players (being OEM’s or third-party remanufacturers) need to collaborate and find joined Circular Economy solutions to promote the remanufacturing of cartridges and the refurbishment of printers. Lexmark is willing to jointly lobbying with competitors for ambitious reuse targets and incentives et EU, Member States and regional level.

One concrete example is Lexmark's active engagement within the Conseil Européen de Remanufacture.

https://www.remancouncil.eu/

Lexmark is represented at the board of the Conseil Européen de Remanufacture and has co-defined its key activities for the 2021 work program. This list of key initiatives is promoted by Lexmark in front of various stakeholders.

- Highlight the intellectual property (IP) issues relating to remanufacturing that need to be resolved (e.g. remanufactured items containing the patented components & brand names of OEMs that have been remanufactured by a third party).
- Provide insight and evidence to OECD, UNEP, WEF, EU and others in policy making.
- Promote public and profit-sector procurement of remanufactured and refurbished products.
- Reach out to new audiences beyond those engineers, academics and policy makers already familiar with remanufacturing.
- Identify issues of common interest, both amongst corporate members (in camera), and with EU and Member State policy makers (e.g. legislative barriers, standards, green public procurement, tax relief, communication of benefits & barriers, etc.).

Lexmark is currently working with the Council on an ambitious 2022 work program.

The Council is also preparing case studies to illustrate the three main types of remanufacturing business models and to highlight aspects that may be instructive to policy makers.

The below Lexmark case has been distributed to key stakeholders to actively promote reuse.

https://www.remancouncil.eu/studies/07d7d89bb982bbf5b677.pdf

Lexmark is also working under the umbrella of the Conseil Européen de Remanufacture with the European Toner and Inkjet Remanufacturers Association (ETIRA). ETIRA represents the interests of the inkjet and toner cartridge third party remanufacturers and related service providers, compatibles manufacturers in the EU.

Lexmark is actively promoting remanufacturing and refurbishment via social media like LinkedIn or Twitter. Lexmark is also regularly promoting C-SERVEES to key business customers, the press, NGO's and EU Institutions.

In the past (before Covid crisis) Lexmark invited key stakeholders to visit its remanufacturing lines in Zary, Poland. Lexmark tries to promote remanufacturing via its subcontractor Syncreon to explain how circular economy solutions work in practice. Stakeholder visits are again planned for 2022.

Lexmark speaks regularly to experts and a wider non expert audience via social media to promote remanufacturing and refurbishment business models. Lexmark has also conducted several interviews with CEPS, a leading think tank and forum for debate on EU affairs, ranking among the top think tanks in Europe.

Find below a Lexmark article that has been communicated via social media in 2021:

Boosting Refurbishment to Build a Circular Economy

Following the Paris climate agreement, countries and organisations around the world are working hard to set out plans for carbon neutrality. Such a transformative change is both exciting and can also feel overwhelming, so it can be helpful to look at what specific industries are doing and take your lead from them.

European Circularity

The circular economy is one such focus for organisations around the world – acting to redefine growth and reduce consumption of finite resources by prioritising re-use. It is an area we as Lexmark are prioritising through our membership of the European Remanufacturing Council and contribution to C-SERVEES, a European Union funded project, to prevent the waste of electronic equipment (WEEE). As well as recycling, in a circular model repair and refurbishing products for reuse rather than let them be thrown away after a single use is a priority.

Research conducted as part of the C-SERVEES programme on the print sector discovered some important issues which help identify where more can be done to boost the adoption of refurbishment and so accelerate the transition to a circular economy. Interestingly, very few organisations return their old devices back to the respective original equipment manufacturer (OEM). Even where OEMs do perform refurbishment and sell reconditioned devices elsewhere, they often tend not to be the more numerous smaller devices such as A4 printers. This is most likely because brand new A4 printers are already perceived as affordable, and there is a perception that it is easier, quicker and more reliable to replace a faulty desktop printer with a new one than investigate what's wrong with it or buy a refurbished model.

The research also found that price and quality remain an issue when it comes to boosting the refurbishment market. At its simplest, quality must be high to encourage buyers and the cost of refurbishment low to encourage OEMs – understandably, preserving the environment is a harder choice if customers prefer to buy new products because they are the cheapest and easiest solution.

Refurbishment Rules

The good news is that there are several ways regulators and companies can increase the uptake of refurbished products. The most important measures involve legislation, including laws that offer manufacturers a bonus for building circularity into their products from the design stage on. Supporting any new legislation must be ambitious public procurement targets to purchase refurbished products, and publicity campaigns aimed at educating customers, so they better understand the environmental advantages of acquiring and using refurbished products. Customers should receive data on the environmental footprint of a refurbished device compared to a new one. They should also be made aware of the CO2 impact of the product they choose, with the incentive of an enviable "green" certificate available only through the purchase of a used device.

Accelerating Acceptance

QR codes are being considered as a means to accelerate the acceptance of refurbishment and improve the business case. Linked to a blockchain so the information they hold can't be tampered with, QR codes could be used to communicate environmental related information to users such as CO2 footprint or energy impact. They can also make it simple to retrieve information on a product's history (e.g. date of installation, print usage and repair history). Taking printers as an example, the information stored on a QR code would enable a better assessment of the value of an old device and its spare parts and so ensure a better price when selling end-of-life printers to OEMs.

From QR codes to legislation and customer education, the argument for refurbishment needs to become compelling at each step of the supply chain to move the discussion away from being purely price driven.

Circularity Built-In

Aside from working on establishing reverse logistics processes and gearing up marketing efforts for refurbished products, the best approach for OEMs is to practice intentional engineering. They must design products in such a way that maximises their lifespan and increases their value beyond their end-of-life, thereby improving the cost and time efficiency of refurbishment. Products need to be modular so that an end-of-life device can be updated with the latest software and firmware and the latest security features easily integrated. Another area of improvement is the lifetime of spare parts which, as they represent one of the major refurbishment cost elements, should be designed for more durability and multiple lives. These actions would make the refurbishment business model far more attractive for OEMs, dealers, customers, and recyclers, giving it an acceleration boost to help ensure future growth.

With these boosting measures, the refurbished market should continue to grow in the coming years, which must be good for planet Earth.

6. ALM products demonstrator

The activities conducted in the distribution and use phase were derived from the ALM-CIRCMODE short-term actions validated in WP2. The final list of short-term CE actions to be implemented in WP4 were selected based on SMART objectives at the end of the CEBM validation process and included in D2.4. The table below presents the ALM-CIRCMODE canvas sub-components and their validated short-term CE actions corresponding to the distribution and use phase, as presented in Table 24 in D2.4.

Table 6. Validated short-term ALM-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the distribution and use phase.

ALM-CIRCMODE Canvas Sub-Component	ALM-CIRCMODE validated short-term Circular Economy Actions
ALM-C7.1: Adopting and/or enhancing circular options of providing products as a service	ALM_A7.1.1 In depth PSS analysis considering lifetime and other ICT products
ALM-C7.2: Introducing and/or enhancing offerings of leased, rented or shared product options	ALM_A7.2.1 Introduce or/enhance options for leasing, renting or sharing products
ALM-C7.3: Introducing and/or enhancing circular products or services that will improve sustainable consumption patterns	ALM_A7.3.1 Implement eco-design strategies across the life cycle of ALM products and the subsequent reduction of energy use
ALM-C8.1: Introducing and/or enhancing ADVA circular offerings that attract recurring revenues	ALM_A8.1.1 Expand the scope of PSS (moving toward vendor ownership)
ALM-C8.2: Adapting financial administration to enable circular economy business models	ALM_A8.2.1 Move towards a rental model for B2B customers

CE actions ALM_A7.1.1, ALM_A7.2.1, ALM_A8.1.1 and ALM_A8.2.1 are all related to the exploration and testing of new PSS models for the ALM system and are covered in sections 6.1 and 6.2. CE action ALM_A7.3.1 is covered in sections 6.3 and 6.4.

6.1. Assessment of new business models for ICT products

6.1.1. PSS overview

Our analysis of product-service systems (PSS) started in the first 18 months of the project, early results have been published in deliverable D4.2. The PSS overview there is based on [1]. As the next step, we complemented and corrected the overview diagram, the new version is shown in Figure 32.

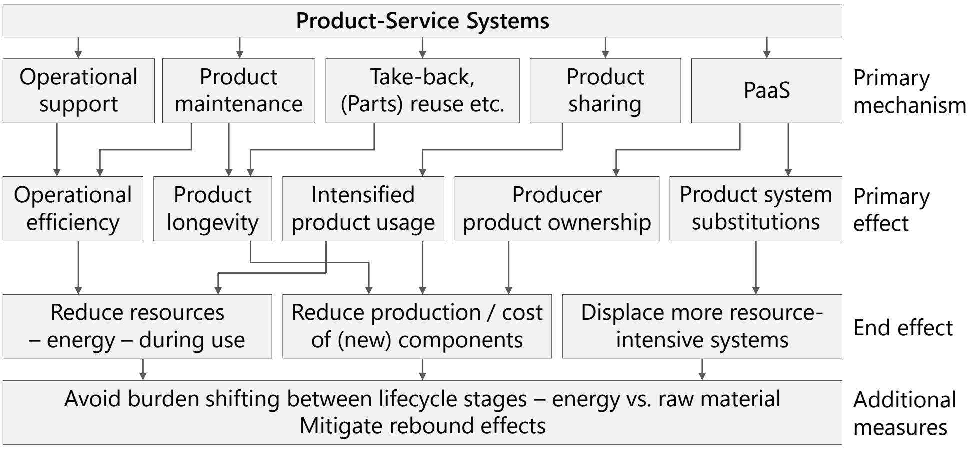


Figure 32. Overview on PSS, based on [1]. PaaS: Product as a Service.

The diagram shows several *primary mechanisms*, some of which can be combined for meaningful resulting PSS. These primary mechanisms lead to positive *primary effects*. Some of these can again be combined, leading to the main *end effect* of the respective PSS. All PSS shall be complemented by additional measures that aim at avoiding burden shifting and rebound effects. For several equipment classes, this includes measures for ensuring and increasing energy efficiency. This holds for equipment where the lifecycle environmental impact is dominated by the use phase via energy consumption. In these cases, **lifetime optimization** is required, i.e., determination of the optimum lifetime, above which even circular-economy measures lead to total net-negative results regarding emissions because of insufficient energy efficiency.

Commonly, PSS toward the right edge of Figure 32 are regarded most effective in terms of material efficiency [2], [3]. The reason is that the ownership of the product is retained by the manufacturer. In turn this forces efforts to design the product in a way that the owner gets highest value out of the product at the end of the regular product life. This requires that the product is designed for a maximum circularity indicator (e.g., material circularity indicators, MCI, according to [4]) for maximum reuse of parts and optimum recyclability. Correspondingly, aspects like disassembly and maintainability are optimized.

Any PSS analysis must always consider the product in its application context. For ICT (information and communication technology) infrastructure products, special restriction can then be identified. These have been discussed in [5]. The most relevant infrastructure ICT equipment restrictions on PSS are:

- Use-phase dominance, depending on emission factors (use of renewable electricity)
- Relatively long usage (around 10 years) in dedicated 24/7 use mode, leading to
    - Functional obsolescence toward end of regular use
    - Substantive energy-efficiency obsolescence toward end of regular use
    - Limit in lifetime optimization
    - Limits in parts reuse
    - No possibilities for further sharing or utilization increase
- No more-efficient alternatives (the opposite is true!)

Here, infrastructure equipment refers to equipment that is part of the ICT networks or data centres. This explicitly excludes end-user equipment like smart phones or laptops. This end-user equipment in many cases has different lifecycle behaviour, which has an influence on possible PSS.

Infrastructure equipment is mainly dominated by relatively long lifetime of about 8-10 years. This lifetime typically is enabled by modularity, maintainability and resilience. The long lifetime, together with the typical always-on use mode leads to lifecycle dominance of the use phase. Moreover, infrastructure ICT equipment has been designed for maximum utilization since more than two decades. This leads to two PSS paths in the diagram which are meaningless for ICT infrastructure equipment.

Note that similar analyses must be performed for any other classes of equipment in order to avoid following useless or net-negative PSS.

Figure 33 shows the first path through the PSS diagram which is not applicable for ICT *infrastructure* equipment. The main idea of this path is intensified product usage through product sharing. However, product sharing is contradicted by ICT's infrastructure equipment's standard use mode – *dedicated 24/7 always on*. In turn, equipment in the lower layers of the so-called OSI (open system Interconnection) stack [6] (layers 0-3) has been designed long since in order to *maximize utilization* and minimize cost. Further increase of sharing is therefore not possible in general.

An overview on the OSI layers is given in Table 7 for the readers reference.

Table 7. Overview on the OSI stack of seven layers

Layer	Name	Function	Protocol example
7	Application	Resource sharing, remote file access, and more	File Transfer Protocol
6	Presentation	Encoding, compression, encryption/decryption	
5	Session	Continuously managing communication *sessions*	
4	Transport	Segmentation, acknowledgement, multiplexing	TCP
3	Network	Addressing, routing, traffic control	Internet Protocol (IP)
2	Data Link	Reliable transmission of data frames between two nodes	Ethernet

Layer	Name	Function	Protocol example
1	Physical	Transmission / reception of raw bit streams over a physical medium	WDM (wavelength-domain multiplexing)
0	(Passive)	Passive infrastructure, e.g., fibre-optic cables (not officially part of the OSI stack)	N/A

The OSI stack is a general representation of the functions that are necessary to establish an end-to-end communications session (e.g., a phone call or file download).

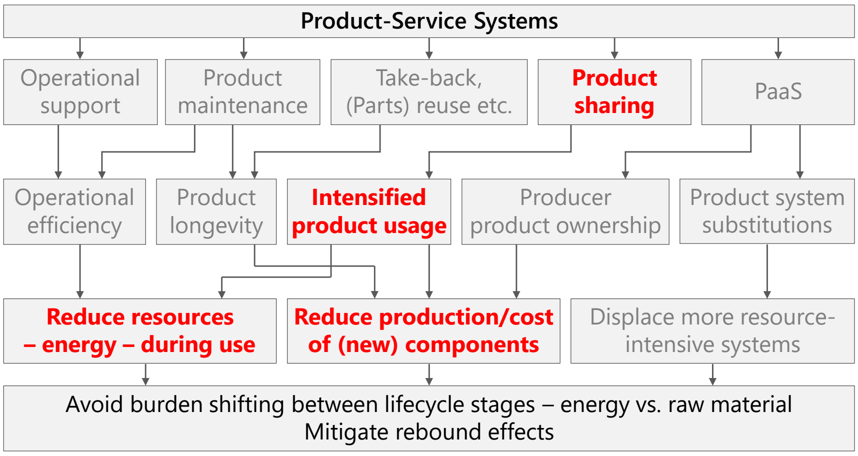


Figure 33. First PSS not suitable for ICT infrastructure equipment

Note that the respective service provider (network operator) who runs the network indeed can offer parts of his network in the form of a PSS. This is not true for the vendor unless he starts operating parts of the network.

Also note in this context that the Synchronous Digital Hierarchy (SDH) [7], formerly a very successful generation of network-infrastructure equipment, has been replaced to large extent by packed-based technology (Internet Protocol, Ethernet) for the reason of higher utilization [8].

The second non-applicable path is shown in Figure 34. This is the PaaS path that can lead to the *displacement of more resource-intensive systems*. It is the path commonly regarded the most efficient PSS in general.

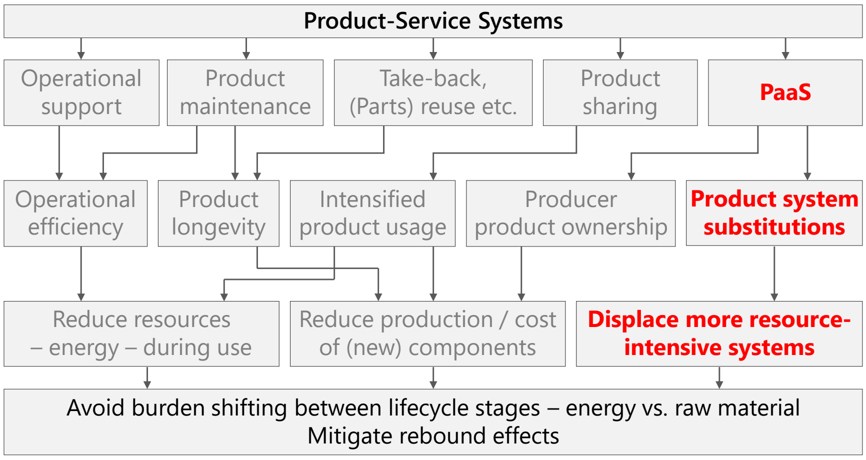


Figure 34. Second PSS not suitable for ICT infrastructure equipment

The reason this path is not possible for infrastructure equipment is that ***ICT in general is the enabler of virtualization, not the target***. ICT services can replace more resource-intensive systems. Examples include video conferences that replace physical travel. However, the ability of ICT equipment to being virtualized depends on the OSI layer [6].

Layer 0, passive infrastructure, is not possible to being virtualized. Hence, no PaaS PSS are possible here. This holds for the ALM (which is a Layer-0 device).

Layer 1, which comprises WDM (wavelength-domain multiplexing) equipment, is also difficult to being virtualized. Techniques like Spectrum Slicing exist that allow shared infrastructure and virtualization to a certain degree [9]. However, respective services must be offered *by the network operator* (who then becomes a service provider), *and not by the vendor*. TeraFlex, described later, is an example of an infrastructure WDM system.

The OSI Layers 2 and 3 (Ethernet, Internet Protocol) in turn are the main domain for virtualization. Based on this virtualization, improved sharing and the respective services can be offered, which is the case today. Again, this must be done by the respective network operator, not the vendor. This might change if the vendor starts operating parts of networks. So far, however, this is not seen on broad scale.

Likewise, there is no other, more efficient replacement for ICT.

The two path exclusions lead to three PSS for ICT infrastructure equipment that are analysed in the following sub-chapters. These paths are valid for equipment like the ADVA ALM, but also for other infrastructure systems.

For generalization, we conducted the analyses for the ALM and a second ADVA product line with deviating cost points regarding OpEx vs. CapEx. Further generalization is discussed further down below.

6.1.2. Product functional and ecodesign support

In general, PSS consist of business (support) aspects or processes and product aspects. That is, PSS can or have to be supported by certain designed product features. The product features that support PSS can be classified into three categories:

1. Application-specific support features
2. Remote supervision and control
3. Ecodesign

The first group of product features strictly relates to the context of the application. It therefore cannot be generalized to other application areas, these must be investigated independently from each other to identify suitable features in support of PSS.

In the context of ICT network infrastructure equipment, features (functionalities) like protection or restoration switching or remote equipment or network reconfiguration fall into this category. Protection or restoration switching allows bypassing failed equipment such that network connections can stay alive and the failed equipment needn't be taken out of the network for maintenance immediately. This may allow for better scheduled reverse logistics. Remote reconfiguration allows adaptation of the equipment or parts of the network to changing (network, i.e., traffic) conditions. This includes more energy-efficient network adaptation, e.g., overnight, and energy-saving modes of equipment, e.g., sleep modes. Obviously, the reconfiguration aspects have a strong correlation to energy consumption in the use phase. As mentioned already, respective features for completely different application areas must be identified individually and cannot be generalized here.

The second group of functionalities addresses remote monitoring and control. Remote control to certain extent overlaps with the first group (remote reconfiguration), but here, the focus is on remote monitoring, supervision and possible preventive control steps. Monitoring includes performance and preventive monitoring. This can identify if the respective equipment is still healthy and alive or may need, in the (near) future, maintenance. The latter can be identified via artificial-intelligence-based parameter correlation and prediction. This functionality obviously clearly supports scheduling of maintenance and (reverse) logistics. It can thus support longevity and reduce truck rolls. Remote control may include the deactivation of certain parts of the equipment in order to delay certain predicted failure and allow later scheduled maintenance.

The exact performance parameters to be monitored again depend on the application the equipment is designed for. It may, for example, include monitoring of laser-driver currents in ICT equipment as an indicator for the health of the laser diode. Such monitoring is common in ICT network equipment, where the required *backward or feedback channel* is automatically given via the network connection. In addition, for ICT equipment, monitoring of many equipment parameters has been developed over the last two decades or so.

Remote monitoring and, to certain extent, remote control can be generalized to some other (non-ICT) application areas. For other equipment, establishing a backward channel may not be that simple. However, all equipment connected to the Internet can also be monitored remotely, subject to security issues. This holds, for example, for TV sets. For even other classes of equipment, IoT (Internet of Things) technologies like wireless connection to Wi-Fi routers may be an option [13]. In cases where no backward channel has been established yet, the effort for doing so should be analysed with LCA in order to avoid any negative impact from equipment that has to be added for establishing the monitoring connection. Collection and analysis of the monitoring data and respective maintenance actions are then tasks for the respective service provider.

The third category of product features relates to ecodesign in favour of circular economy. Depending on results from the lifetime-optimization analysis, this may have to be complemented by ecodesign for energy efficiency. Generally, this ecodesign can be described as Design for X, DfX, where X includes disassembly, maintainability, parts reuse, refurbishment, and recycling. In addition, it may include modularity, certain degrees of resilience (e.g., duplicated power-supply units, PSU) and the capability to hot plug / unplug modules in powered-up mode. Details on the implementation again depend on the equipment and its application. For infrastructure ICT equipment, further details are provided in Chapter 6.4

Business and product aspects are described in detail for the three PSS relevant for ICT infrastructure equipment hereinafter.

6.1.3. Lifetime optimization

Consideration of the GWP

When calculating optimum EEE product lifetime, suitable measures must be used. For our calculations, we use the LCA midpoint parameter of global warming potential, GWP. Due to global warming and the urgently required actions to reduce carbon emissions, GWP is possibly the most important LCA midpoint impact category. However, circular economy and its related business models are primarily considering general resource depletion. This covers fossil resources and thus, indirectly, emissions. In addition, and more importantly on the long run, it also covers other abiotic resources, including critical raw material.

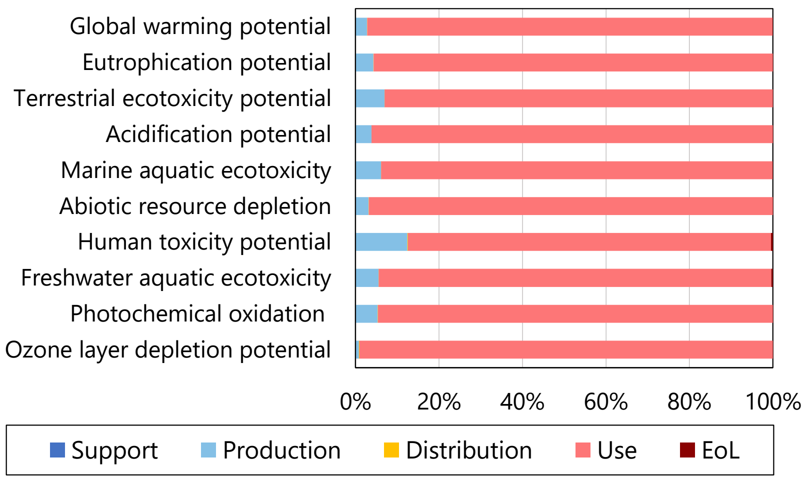
For the ICT products that are considered in this chapter primarily (not exclusively, we provide generalization), GWP is nonetheless a valid parameter for lifetime optimization. This follows from product LCA that considers various midpoint parameters.

Two LCA examples are shown in Figure 35 for the TeraFlex system. TeraFlex is an ICT product with characteristics that complement the ones of the ALM. Following, we will consider both systems, which will also allow to derive a generalization toward products other than ICT equipment.

We show two LCAs, one calculated using average EU electricity grid mix, the second one using 100% renewable energy. This is relevant since the related emission factors (with dimension [$kgCO_2e/kWh$]) obviously have high influence on LCA. Considering both emission factors (EU grid mix and fully renewable) is also relevant to compile meaningful results for the complete period up to 2050, when Carbon neutrality is targeted in the EU and when electricity must be based on renewable energy.

It can be seen that for grid-mix electricity, the use phase very clearly dominates. This holds for GWP and all other midpoint parameters. In particular, abiotic resource depletion has a result similar to GWP.

When renewable energy is used, things change but use phase is still mostly dominant. The reason is that we use a non-zero emission factor of EF_{RE} = 0.04 $kgCO_2e/kWh$ for renewable energy (RE). This value considers *lifecycle* electricity emissions that overall vary depending on the used renewables technologies. The share of renewable technologies and their emission factors of future energy market are not yet known. For example, lifecycle GHG emissions are in the range of 7-56 gCO_2e/kWh for wind energy and 5-217 gCO_2e/kWh for PV. Lifecycle emission factors cover a large range due to differences in technology, local resource conditions and methodological approaches for assessment [14]. Producing renewable energy is never carbon-neutral unless compensation techniques or techniques like CCS (carbon capture and storage) are used [15]. Note that again, abiotic resource depletion performs similar to GWP.



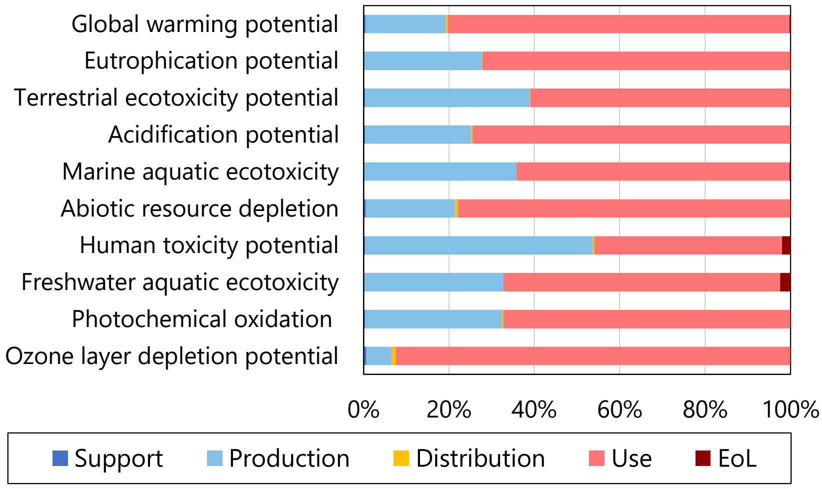


Figure 35. LCA for TeraFlex system. Top: use of EU grid mix. Bottom: Use of renewable energy.

Also note that LCA of the ALM is still similar to the TeraFlex example shown here, despite different product characteristics. The ALM use phase is less dominant, but again abiotic resource depletion and GWP behave similarly.

Therefore, GWP is a valid measure for lifetime optimization and is used hereinafter.

Parameter extrapolation

In order to derive optimum lifetime of an EEE product, several steps are required. First, we perform the derivation based on total resulting GWP, that is, emissions. This way, the production phase with its impact on raw material can be traded off against the use phase, which can lead to high emissions over lifetime. Next, we do not consider the other lifecycle phases here since typically, they are far less relevant in LCA. This simplification is certainly true for (infrastructure) ICT equipment.

Next, average emission factors need to be extrapolated into the future since we need to consider potentially long or extended lifetime that can go beyond 2040 or so. We use two sets of emission factors (EF) that are extrapolated up to 2050. The first set assumes a linear decline in the – average! – EF toward 100% renewables in 2050. Here, we consider an EF for 100% renewable energy (RE) of EF_{RE} = 0.04 kgCO_2e/kWh. This EF is non-zero, which caters for the fact that even wind, solar or water energy is not emissions-neutral since the construction of the respective plants causes emissions [14]. For true emissions neutrality, compensation techniques or techniques like CCS (carbon capture and storage) are required [16].

The second EF set is more aggressive than the first one. It reaches 100% RE in 2044. Although it might become necessary in the near future, even faster approach toward 100% RE is not seen realistic today. Note that the EF are *average*, this is, *global* figures.

Also note that these extrapolated EF are in line with the B2DS scenario of the IEA [16] and the RCP2.6 scenario of the IPCC [17], that is, scenarios that support less than 2°C global warming compared to the pre-industrial state.

The resulting emission factors are shown in Figure 36.

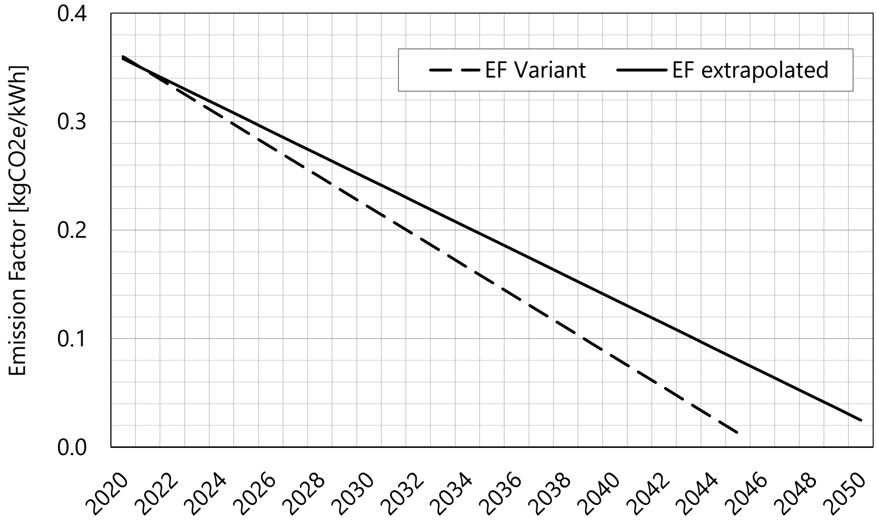


Figure 36. Extrapolation of emission factors. The EF variant comprises faster declining values.

The next parameter that is relevant for calculating GWP into the future is the development of the gain in energy efficiency in electronics and photonics. It is obviously relevant for ICT gear, but also, for example, for TV sets. The problem is that this gain *started saturating* since total efficiency is approaching some fundamental physical limits [18]. From [18], it is known that at today's pace, any gain in efficiency must come to a stop in around two decades, given that no disruptive technologies will be found. Also in [18], it is stated that in the last two decades or so, the yearly gain in energy efficiency for main classes of ICT infrastructure equipment (switches, routers, WDM transmission gear) was in the range of 14%. Therefore, we assume non-linear decrease of the yearly efficiency gain from 14% in 2020 toward almost zero in 2050. This may be regarded pessimistic, but it is not. For example in storage aerial density, saturation effects are already clearly visible. It is also clear that somewhere below 5 nm CMOS (complementary metal-oxide semiconductor) feature size, the CMOS development will have to come to an end. The resulting development in efficiency is shown in Figure 37.

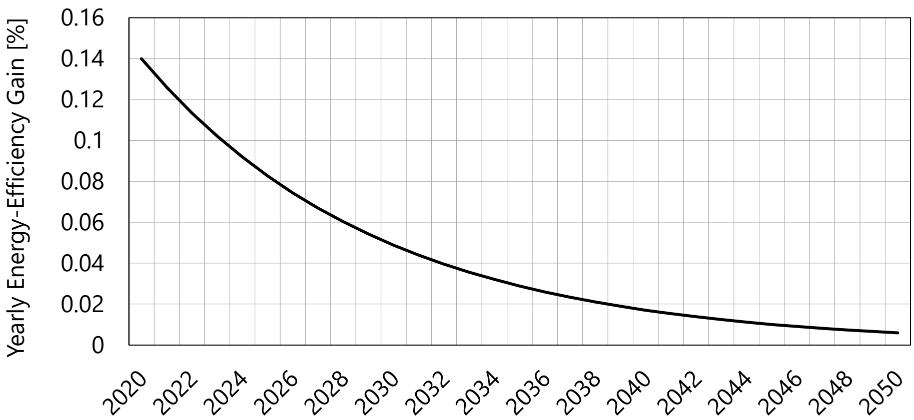


Figure 37. Extrapolation of yearly gain in electronics energy efficiency

ICT efficiency saturation was also discussed in the Annex of deliverable D4.2.

Figure 37 can be used to calculate the improvement in efficiency that a successor generation of a piece of equipment can offer after, say, 10 years. Obviously, this improvement also depends on absolute time (it is decreasing over time). However, in our calculations, we mainly consider the improvement after the first 10 years.

ICT infrastructure products

Based on the emission factors and energy-efficiency development discussed in the previous chapter, we calculated total-lifetime GWP for the ALM product in two scenarios. In scenario 1, the ALM (together with the passive sensors) is installed in the respective infrastructure. This can be passive fibre plant or a building to be monitored. Since the ALM is designed for relatively long lifetime and always-on use mode, it mainly consumes energy over time. This energy consumption causes emissions (GWP), with emissions slowly decreasing over time thanks to improving emission factors. In scenario 2, the original ALM is replaced, after 10 years, by a successor product. Here, we assume that the successor has better energy efficiency after 10 years according to Figure 37. This translates to a drop in energy consumption – for the *same* application! – by 55%. This is somewhat optimistic since, e.g., a successor might have been developed five years after the original product, in which case the efficiency gain is smaller. However, we use this value, an improvement of 55% in energy consumption, to clearly identify lifetime effects. The GWP that is accumulating over the lifetime is shown in Figure 38 for the two ALM scenarios.

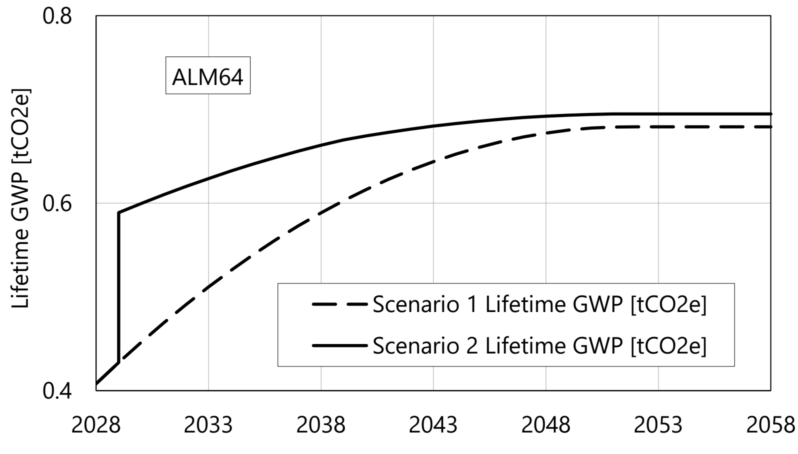


Figure 38. Lifetime GWP for two ALM64 scenarios

We consider the use-phase and production emissions, and the diagram starts in year 9, one year before replacement in scenario 2. The other lifecycle emissions contributions are almost negligible. This can be derived from LCAs across our complete portfolio, which we calculate regularly on a process basis. Transportation, EoL (end of life) and contributions from our sites will only have a very small impact and will not change the main result. Any variations of these parameters can be considered as secondary or higher-order effects.

In Figure 38, the step in the curve for scenario 2 caters the production GWP of the successor product. Both curves are flattening over time due to improving emission factors according to Figure 36. The curve for scenario 2 is even flatter due to improved energy efficiency of the successor. *However, the two curves **never** cross*. This means that in most realistic scenarios, the ALM should ***not*** be replaced due to improvements in energy efficiency – the ALM consumes sufficiently little energy! In turn this means that the ALM should be (and is) designed for longevity, potential parts reuse and recycling. This is to be supported by respective business models like most-suitable PSS.

To generalize our PSS analysis, we complemented the ALM calculations by respective calculations regarding a second product out of our portfolio. This was out of scope originally. It is seen necessary to come to meaningful conclusions.

As the second product, we chose an ICT core-network (infrastructure!) WDM-transport product of the latest generation, called *TeraFlex*. TeraFlex is based on high-performance chip sets for conducting the necessary transport tasks. The system supports highest bitrates of up to 600 Gbps per wavelengths, with up to ~100 wavelength maximum. Since the high-performance chip sets lead to relatively high power consumption, and since the use mode is again 24/7 always-on, the system is clearly dominated in GWP (and other mid-point LCA parameters) by its use phase. Note that in this case, absolute power consumption is high, but at the same time, TeraFlex is (one of) the most energy-efficient WDM systems globally. Here, energy efficiency is rated in W/Gbps.

We calculated the same two scenarios for TeraFlex as before for the ALM. The result is shown in Figure 39.

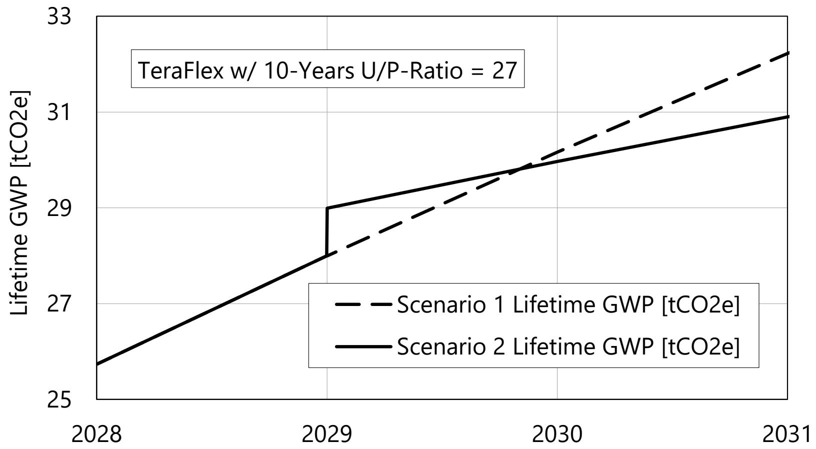


Figure 39. Lifetime GWP for two TeraFlex scenarios

In this case, the production of the successor caused a GWP of 1000 kgCO_2e. This was derived by LCA. The crossover between the two scenarios – given a successor with efficiency that improved over 10 years! – is within less than one year. This means that TeraFlex should be replaced, given that a massively more-efficient successor is available. With average system-generation lifetime of around 10 years, this also means that TeraFlex should not be used significantly longer – no extended or second life!

The relevant LCA parameters of TeraFlex and the ALM are summarized at the end of this chapter.

Variations of relevant parameters

We varied emission factors to see how stable results are, in particular for products with clear use-phase dominance (TeraFlex in our case). First, we used the more aggressive development of the emission factors from Figure 36. The result for TeraFlex is shown in Figure 40. Note again that we regard this emission-factor development as optimistic.

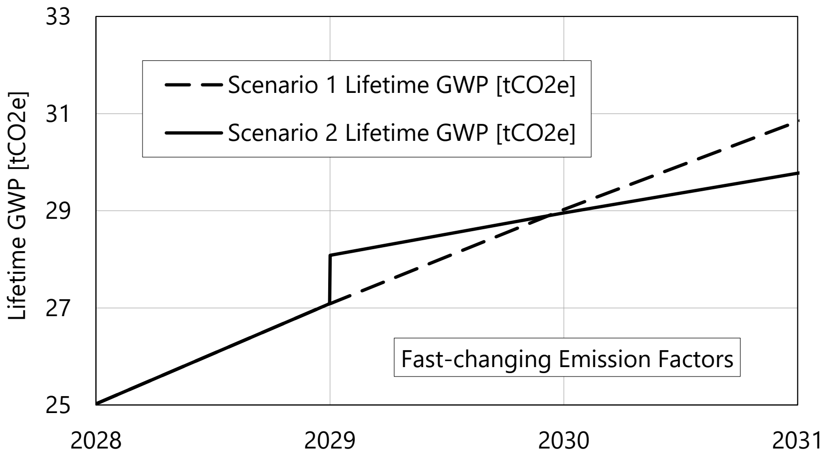


Figure 40. Lifetime GWP for two TeraFlex scenarios with faster-changing emission factors

The result does not differ significantly from the one in Figure 39. Crossover, where replacement causes less total resulting emissions, now is after slightly less than one year. Of course, total use-phase emissions are smaller.

We kept the production emissions constant, over time and with changing emission factors. This is not fully exact, but prediction how production LCA changes with changing emission factors is difficult. Production GWP certainly will get better over time, but the extent is unclear. We regard this another secondary effect which does not have significant influence on our results. Note that keeping the original high production LCA does penalize the more frequent replacement of products. For the ALM – no crossover and no replacement – this does not change anything. For TeraFlex, the crossover point in time would only come *even earlier*.

In the next step, we changed to 100% renewable energy for the use phase and respectively lower emission factors. Again, we used an emission factor for renewable energy (RE) of $EF_{RE} = 0.04\ kgCO_2e/kWh$. This factor considers lifecycle emissions that may result from the construction of the respective power plants. Note that certain market-based emission figures do state zero emission for certain renewable energy. In reality, this can only be achieved with either compensation of residual emissions or techniques like CCS.

Also note that considering renewable energy and related emissions yields the correct results for ICT network operators that already run their entire network with 100%

renewable energy. This holds for large network operators like British Telecom or Deutsche Telekom.

The TeraFlex result for 100% renewable energy for the use phase is shown in Figure 41.

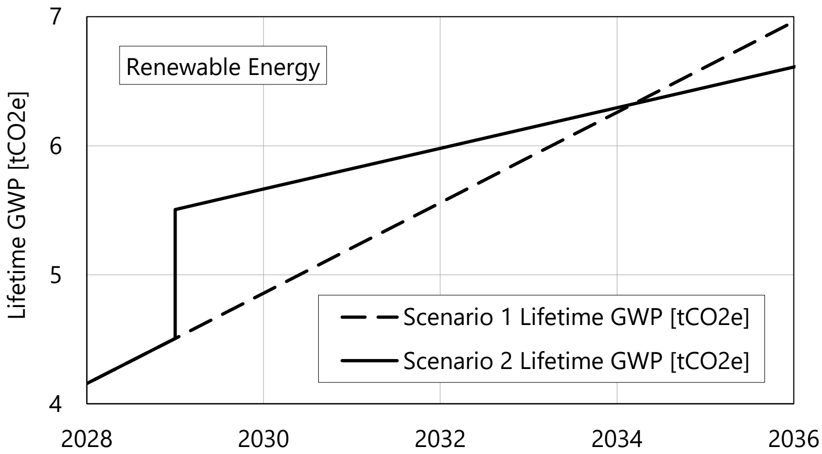


Figure 41. Lifetime GWP for two TeraFlex scenarios with 100% renewable energy

With the emission factor stated, the crossover now is reached after five years. This means that even when using 100% renewable energy, products with massive energy consumption should be replaced only a few years after more efficient successors became available. Of course this would change when using zero emission factors, but this does not fully reflect reality as discussed. Using non-zero EF for renewable energy, that is, a certain "penalty", also reflects the fact that these products should be replaced given more-efficient successors are available for operational-cost reasons.

Product generalization

So far, we investigated two ICT products with different characteristics of use versus production impact. We considered GWP, but according to our LCAs, similar characteristics hold for most other LCA midpoint indicators as well. In order to fully generalize our use-phase or lifetime optimization and the consideration if and when products should be replaced by more efficient successors, we defined the following **U**se-phase/ **P**roduction-phase **R**atio UPR_{10} for the GWP:

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

UPR_{10} is the ratio of 10 years use-phase GWP and the production GWP according to LCA. Note that the *first* 10 years in use shall be considered since over time, the use-phase GWP decreases thanks to improving emission factors.

Note that UPR_{10} does depend on the applicable emission factors. Due to the fact that emission factors for grid-mix electricity (Figure 36) and renewable energy develop differently, UPR_{10} cannot be normalized to the emission factor but must be considered for different emission factors separately.

In Table 8, relevant parameters for the ALM and TeraFlex are summarized.

Table 8. GWP parameters of the ALM64 and TeraFlex

Product	Power consumption	Production GWP	UPR_{10} Mix	UPR_{10} RE
ALM64	10 W	160 $kgCO_2e$	1.69	0.04
TeraFlex (fully equipped)	1000 W	1000 $kgCO_2e$	27	3.5

UPR_{10} for the ALM and TeraFlex differs by more than one order of magnitude. Also note the difference in the usage of standard grid mix emission factors (Mix) and renewable energy (RE).

Varying UPR_{10} across a maximum range and identifying if and when there is a GWP crossover point in time between the two scenarios (no replacement vs. replacement) now allows **full generalization beyond ICT products**. In Figure 42, this crossover is shown as a function of UPR_{10} for the case of extrapolated emission factors as per Figure 36.

The crossover time shows hyperbolic character. Below $UPR_{10} \approx 2$, there is no crossover anymore, it moves toward infinite duration. This is obviously the case for ALM, see Figure 38. This means the ALM is indeed at the one end of the UPR_{10} scale. For $UPR_{10} > 20$, the crossover is within the first year. Significantly higher UPR_{10} values are unlikely since this would require products with very high power consumption but low production GWP. In this part of the curve, it is clear that products must be replaced if more efficient successors are available. It is also clear that TeraFlex (with $UPR_{10} = 27$) is at the other end of the scale, compared to the ALM.

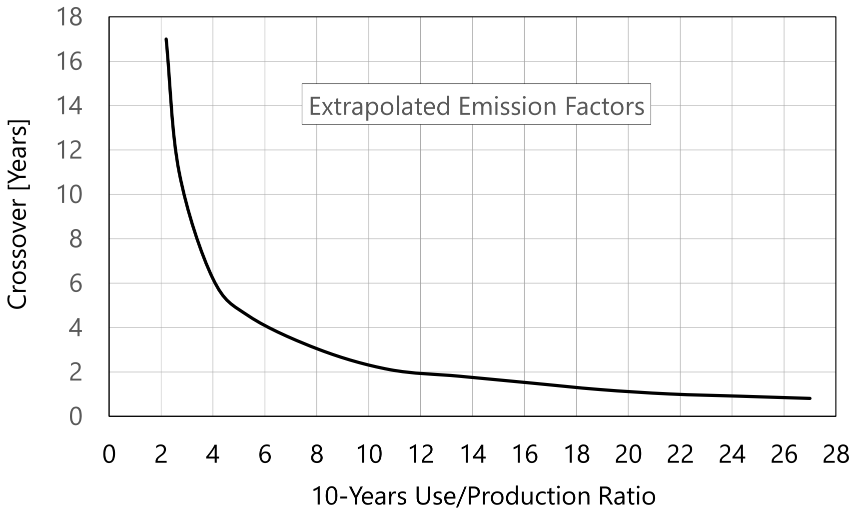


Figure 42. Crossover time toward total net-positive emissions for emission factors extrapolated up to 2050 as a function of the UPR_{10}

Next, we repeat the crossover calculation for 100% renewable energy. The result is shown in Figure 43. Not surprisingly, the crossover time shifted upward, and with 100% RE, no UPR_{10} values above 7 were reached. However, even when using 100% RE, the principle characteristic does not change. For products that are massively energy consuming in the use phase, replacement after a certain point in time makes sense in terms of total resulting GWP. This holds, as discussed, for small non-zero emission factors for RE.

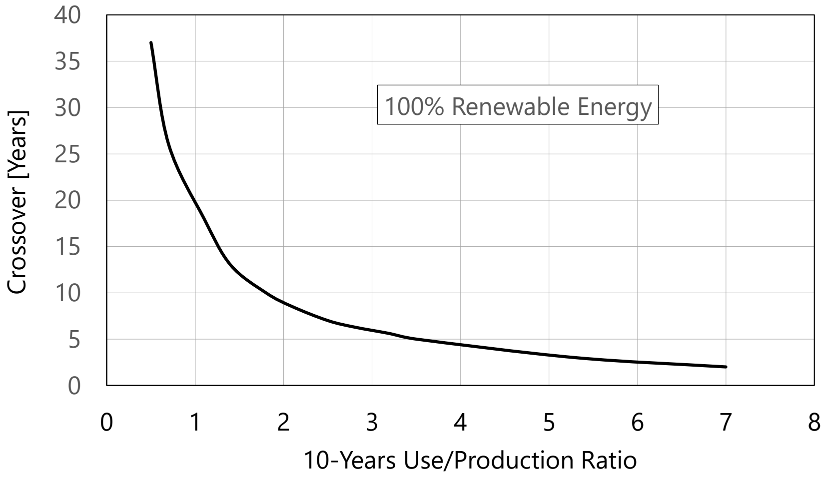


Figure 43. Crossover time toward total net-positive emissions for EF_{RE} = 0.04 $kgCO_2e/kWh$ for 100% renewable energy as a function of the UPR10

Next, two questions are to be answered:

1. What is the best replacement period?
2. What is the UPR_{10} value that separates the replacement and non-replacement domains?

The first question cannot be answered precisely for real products. The reason is that unrealistic assumptions regarding the availability of successor products must be made, which likely are not met by reality. However, a good approximate answer can be given. We derive this answer for TeraFlex since with a product with high UPR_{10}, any variation in the replacement period becomes clearly visible.

We also investigate the dependence on absolute time, that is, emission factors that are to be expected. The later the observation period, the smaller are the emission factors and with smaller emission factors, replacement becomes necessary later.

We also consider the fact that gain in energy efficiency depends on the time that was available for the development of a successor, see Figure 37. Over time, gain in efficiency saturates, as discussed earlier. The numbers in Table 9 were derived from Figure 37 for a product that consumes 100 W electrical power in the use phase in 2020 for a given service or application that remains constant over time.

Table 9. Development of energy efficiency / power consumption for same application

Year	2020	2024	2028	2032	2036	2040	2044	2048
Power consumption	100 W	70 W	50 W	40W	35 W	32 W	30 W	29 W

The saturation of efficiency gain, together with emission factors that are improving over time, lead to the fact that replacement becomes less frequently necessary over time. In general, availability of successor products as frequent as every 4 years is unrealistic for infrastructure ICT equipment. In addition, efficiency gain becomes smaller with faster replacement. For these reasons, we investigated combinations of 4, 8, 12, and 16 years as replacement periods. The result for TeraFlex is shown in Figure 44. Here, we assumed grid-mix electricity and its development of the emission factors as per Figure 36, extrapolated case.

Three scenarios for a product with UPR_{10} = 27 are compared in Figure 44: no-replacement, replacement every 8 years and a replacement scheme that is close to optimum. This shows that regular replacement, e.g., every 8 years, becomes less efficient over time. Faster replacement at the beginning might be better (for products with high UPR_{10}), but toward 2050, it performs worse. For TeraFlex, close-to-optimum replacement is achieved after 4, another 4 and 8 years, respectively. Replacement every 12 years or slower is not fast enough, and replacement every 4 years also perform worse than the optimum replacement.

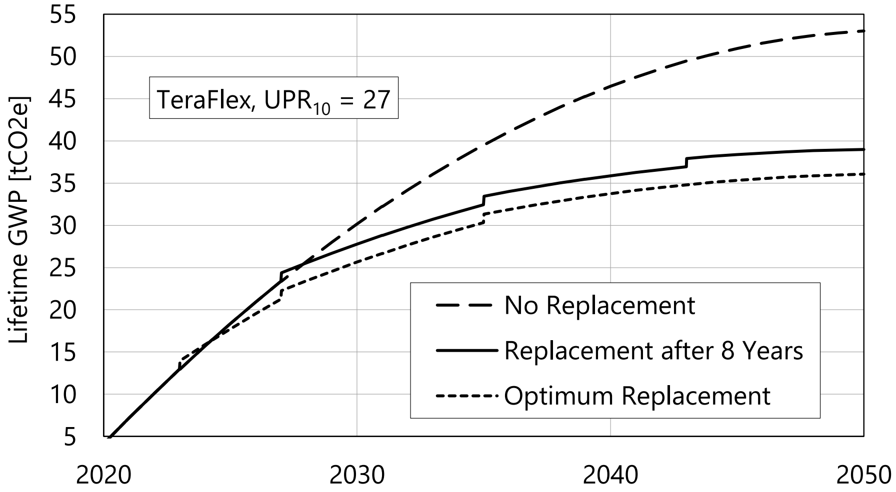


Figure 44. Optimum replacement cycle for TeraFlex, compared to replacement after every 8 years and to no replacement at all. Note the high UPR_{10} of TeraFlex for grid-mix electricity.

Note that in particular in the beginning, earlier replacement might lead to better results but is regarded unrealistic in general. Toward 2050, variations in replacement point in time become less relevant.

We also approximated optimum TeraFlex replacement when using 100% renewable energy, see Figure 45. Due to the low emission factor, in the period up to 2050, only one replacement should take place. Replacements after 8 and 12 years respectively achieve the same minimum resulting GWP. Replacement after shorter or longer periods lead to higher total GWP. For TeraFlex, optimum replacement when using RE (with non-zero emission factor) should take place after 8…12 years.

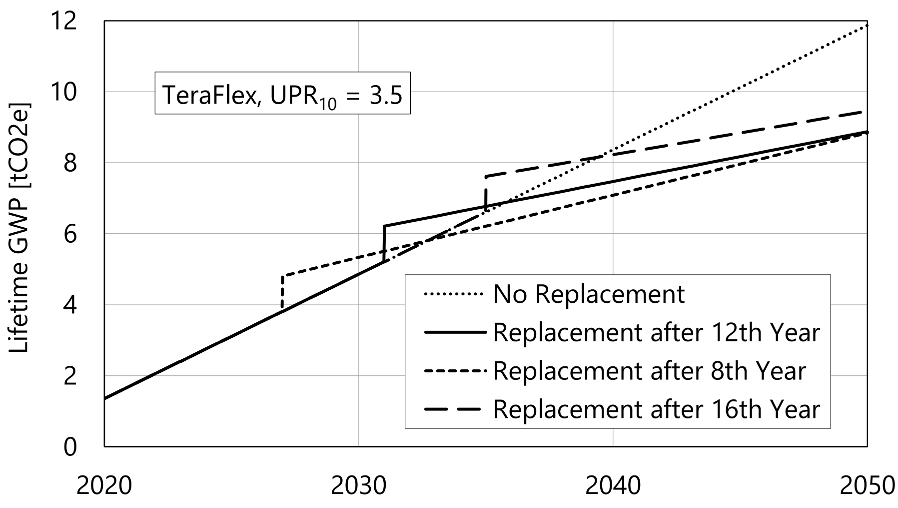


Figure 45. Optimum replacement for TeraFlex, when using 100% renewable energy. Note that *UPR_{10}* of TeraFlex changed compared to using grid-mix electricity.

For comparison, Figure 46 shows replacement scenarios for the ALM toward 2050 for the case of extrapolated grid-mix electricity according to Figure 36.

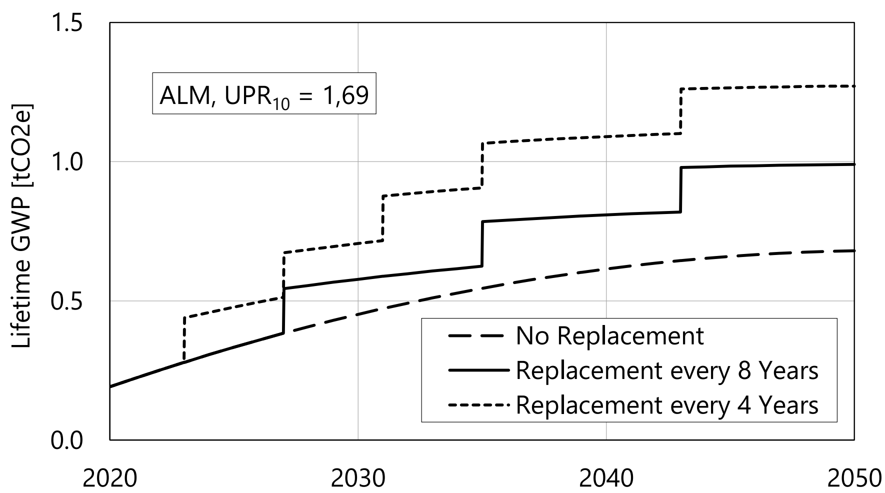


Figure 46. No replacement of the ALM, compared to replacement after every 4 or 8 years, respectively. Note the low *UPR_{10}* of the ALM for grid-mix electricity.

Not unexpectedly (compare Figure 38 and Figure 42), no replacement scenario performs better than the no-replacement scenario – the ALM has a grid-mix *UPR_{10}* of 1.69.

When using renewable energy, the ALM of course should not be replaced.

Next, we derived the *UPR_{10}* range that separates the replacement from the no-replacement domains. Again, this cannot be derived precisely in general (dependence on *UPR_{10}*, dependence on absolute time, dependence on emission factors, unknown development cycles of successor products). However, we can estimate the transition range for *UPR_{10}* that separates the replacement domains. In case a given product falls into this transition range, more precise calculations must be done.

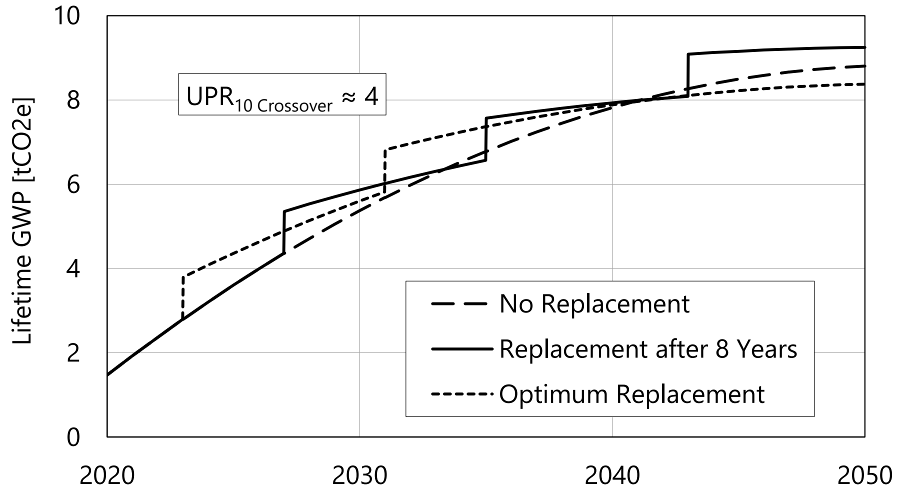


Figure 47. Crossover, where optimum replacement and no replacement yield approximately the same GWP in 2050. The crossover Use/Production Ration is in the range of $UPR_{10\ \mathrm{Crossover}} \approx 4$ in case grid-mix electricity with respective predicted emission factors is used.

The value of $UPR_{10\ \mathrm{Crossover}} \approx 4$ is in line with Figure 42. There, $UPR_{10} \approx 4$ is the range where the crossover-time curve most massively changes in slope.

Note that the period beyond 2050 is less relevant because RE emission factors must be assumed. Here, only products with high UPR_{10} require replacement.

Next, the $UPR_{10\ \mathrm{Crossover}}$ calculation is repeated for the case of running the equipment with 100% renewable energy. The crossover case is shown in Figure 48.

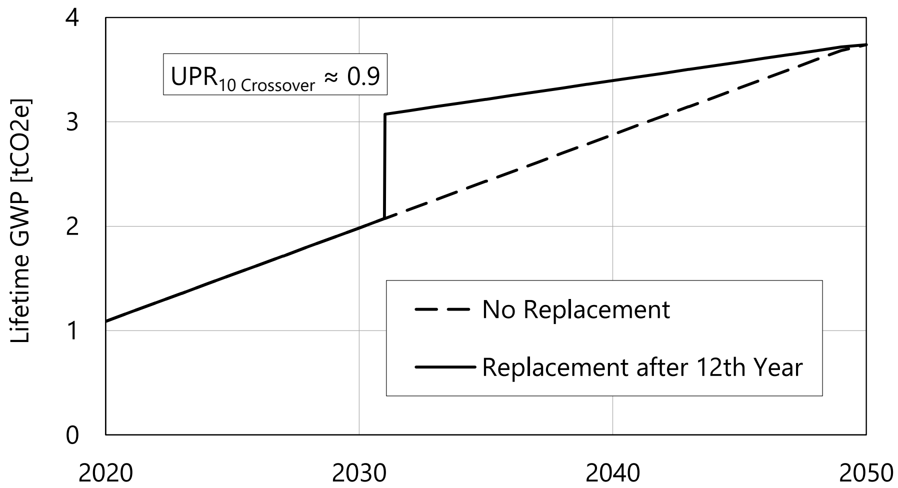


Figure 48. Crossover, where optimum replacement and no replacement yield approximately the same GWP in 2050. The crossover Use/Production Ration is in the range of $UPR_{10\ \mathrm{Crossover}} \approx 0.9$ in case 100% renewable energy with respective emission factors is used.

Now, $UPR_{10\ \mathrm{Crossover}} \approx 0.9$. Again, this is in line with Figure 43, where 0.9 is the range where the gradient of the curve clearly changes. Obviously, the smaller the emission factors are, the more the crossover point moves toward higher power consumption relatively to the production impact.

Note that these calculations must be adapted to the emission factors that the respective equipment will see in its future use phase.

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.

Further note that UPR_{10} may have an *influence on the choice of a PSS*. 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, however, certain PSS can have a massive influence on UPR_{10}. In particular, PSS that aim at massively improving product utilization, e.g., by better sharing, may also lead to massively 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.

6.1.4. PSS assessment for ICT infrastructure equipment

Assessment parameters

For the assessment of PSS, we first developed an Excel-based matrix that allows the calculation of relevant financial and ecological parameters over time, that is, the PSS runtime.

Economic parameters of the calculations included:

- Hardware revenues
- Hardware cost
- Service revenues
- Standard cost installation
- Standard cost service (maintenance)
- Standard margin, in % of revenue
- Gross profit, in % of revenue
- EBIT (earnings before interest and taxes), in % of revenue
- Overhead cost, incl. other cost of goods sold (COGS)
- Discounted cashflow, based on weighted average cost of capital (WACC)
- Net present value (NPV)
- Cumulative customer cost

These parameters were sequentially calculated over time. In the analyses, we display cumulative NPV and cumulative customer cost. The NPV is the EBIT, but discounted over time to account for profitability expectations on ADVA given the ADVA-specific risk profile. This is done using the WACC, which has to be adopted when repeating the calculations for other companies. Customer cost calculations follow the same concept.

The maximum duration for these calculations was taken from the UPR_{10} analysis. For the ALM, up to 30 years were considered, for TeraFlex, 16 years were considered, with one product replacement after 8 years. This single replacement does not represent the optimum replacement shown in Figure 44. However, the replacement after 8 years much better aligns with our experience. In general, replacement after 4 years is not possible in ICT since product development cycles are longer.

The hardware and service cost were considered per relevant (ALM, TeraFlex) sub-module. This is relevant since, e.g., for an ALM system, the passive sensors require disproportionately high maintenance effort.

In addition, we estimated the economic yield from parts reuse and EoL recycling, based on older ADVA investigations and processes. For parts reuse, we used the revenue that was achieved in former years in our *Supplier Sales* process, which was briefly described in deliverable D4.2. In this process and in certain years, up to ~1.5 MEUR revenue were achieved by selling components, which were extracted from products taken back, back to their original suppliers. This was in the **range of ~1.5% of total components spent**. On the other hand, the process was not fully blown yet, i.e., not covering the majority of products sold. In turn, the effectivity of parts reuse is strictly limited, as also described in D4.2 and in [5], [10]. Therefore, we estimate that **2-10% of total components spent can be reused** in a way that they replace new components that would have to be bought. The degree depends on the extent of ecodesign that supports this reuse. This extent also depends on the PSS. It is maximized for PSS which retain ownership, for reasons that have been described earlier. For our calculations, we used the yield numbers summarized in Table 10.

Table 10. EoL / take-back yield parameter for PSS2, PSS3

EoL / take-back yield, PSS2, fully-blown process	6%
EoL / take-back yield, PSS3, fully-blown process	10%

Note that these numbers have severe impact on the performance of PSS2 and PSS3. They may look small, but from all previous analyses, we do not have any indication that these numbers can massively be improved for equipment from a fast-paced market with functional obsolescence like the ICT market. Also, these numbers are clearly above what could be achieved today. When transferring our analysis to other equipment, however, these numbers must be re-considered and adopted.

For recycling yield, we refer to an analysis we conducted around 2016. Results were presented in [10], [11]. Several units of equipment, similar to active ALM units, were analysed by a certified WEEE recycler in Germany. The result was that (only) **up to ~1% of HW cost** can be retrieved by proper recycling. The latter includes manual disassembly and feeding of the respective material fractions (in particular the PCBA *without* iron or aluminium, and without any batteries) into most suitable recycling streams that can recover precious metal, rare-earth elements etc. *The range of 1% likely is an* ***upper*** *bound*. The reason is that over time, the amount of Gold in ASICs etc. is being *reduced* to maximum extent for cost reasons. This means that over time, WEEE loses value money-wise, unless other secondary critical raw material becomes more valuable over time.

Ecological parameters comprise use-phase energy consumption and related emissions, and LCA-based contributions from refurbishment, reuse and recycling. The latter are based on assumptions for the achievable respective impact or yield. This is based on our experience from take-back and successive assessment that is performed since a couple of years in our main factory in Meiningen, Germany. These numbers are conservative, but from the challenges discussion in Ch. 6.2.1, there is no evidence that they can be substantially higher for the equipment class considered.

The assessment matrix is complemented by calculations for ADVA as the vendor and for the respective customer, in an attempt to cover both sides of the business.

Several extensions were added to the original scope of the calculations. First, we complemented the ALM (the only product in scope of the DoW) by one member of our WDM products (wavelength-domain multiplexing, that is, fibre-optic data-transport equipment, which comprises the Internet backbone). The WDM system, *TeraFlex*, is the product within our portfolio with the highest dominance on carbon emissions by the use phase. This is derived from LCA. The system at the same time is amongst the most energy-efficient WDM systems globally, which is derived from TEER calculations (telecommunications energy-efficiency ratings) according to [22]. The use-phase dominance results from the fact that TeraFlex is designed to transport highest data capacity (up to 50 × 600 Gbps (Gigabit-per-second)), which leads to the respective energy consumption as already explained in the Annex of deliverable D4.2. The reason for the TeraFlex complement was to cover a broader range of use-phase-versus-production impact and thus, a broader range of products regarding lifetime optimization. At the same time, there is also a significantly other CapEx-versus-maintenance-cost ratio between the ALM and TeraFlex, thus providing further generalization of the ALM results.

In a second extension, we introduced a **dummy product** with the *variable* use-versus-production-impact ratio UPR_{10}. This aimed at real generalization beyond infrastructure ICT products with their use-phase dominance. Theoretically, this covers a broad range of EEE products. However, this must be checked individually in each case, since other individual product characteristics may apply that still may violate findings from our PSS analysis.

The dummy product also allows another variation across a broad range, the CapEx-versus-maintenance-cost ratio. This allows generalization beyond the ALM and TeraFlex, and possibly to certain extent beyond ICT infrastructure equipment.

Finally, in order to cover the other relevant parameter for lifetime optimization, we introduced variation to the pace of the change of the emission factors for electricity. This way, the two generic parameters relevant for and influencing lifetime optimization are covered – use-versus-production impact and changing emission factors in particular for the use phase.

PSS1 – operational efficiency

PSS1 is in support of operational efficiency. Potentially, it can improve both, material *and* energy consumption during the use phase. It is the only PSS specifically addressing the use phase. This includes material efficiency in the use phase, but may also include energy consumption in that phase. It is therefore particularly interesting for products whose environmental impact is dominated by the use phase, in the sense of a lifetime optimization. In Figure 49, the respective path through the PSS diagram is highlighted.

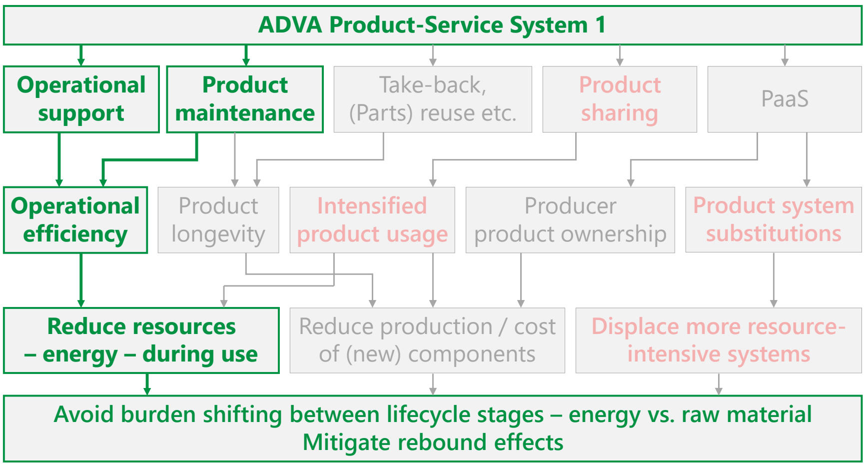


Figure 49. PSS with optimized operational efficiency

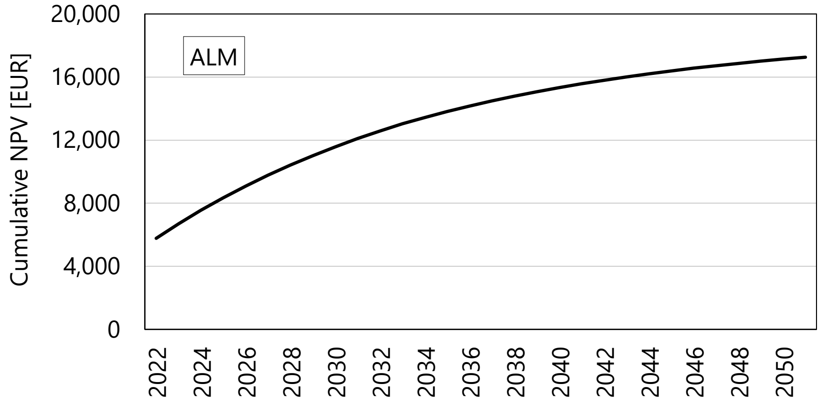
Business measures for product maintenance comprise of respective maintenance contracts. This can include (reverse) logistics, which can be optimized independently. It covers a range of potential maintenance actions, which are partially enabled by respective technical or product-design features. Operational support can include service actions as well as certain product features that ease operations. Details are provided in Table 11.

Table 11. Details of PSS1

Operational support	*Business aspects* Preventive maintenance *Product aspects* - Low-touch / zero-touch provisioning - Performance monitoring (remote), including failure prediction - Remote re-configurations, including energy-saving modes - Redundancy, e.g., duplicated power supply modules
Product maintenance	*Business aspects* - Maintenance contracts and capabilities / processes - Scheduled (reverse) logistics *Product aspects* - Performance monitoring, failure diagnostics - Modularity, all modules are hot pluggable during operations - Remote re-configurations, including resilience switching - Design for maintenance / maintainability
Operational efficiency	- Less truck rolls through redundancy / resilience, failure diagnostics and preventive and scheduled maintenance - Less material through predictive monitoring, failure diagnostics and preventive maintenance - Improved energy efficiency of the ICT product through remote re-configuration and energy-saving modes
Resources reduction	- Less energy through less, scheduled truck rolls - Less material (components) through improved longevity - Less energy (use phase) through remote re-configurations

It can be seen from Table 11 that PSS1 clearly has to be supported by several product features. Some of these features, e.g., remote performance monitoring and failure diagnostics, are typical for ICT infrastructure equipment. Consequently, this type of PSS is not uncommon in ICT today already. For massively increasing it also to other equipment, the necessity or at least usefulness of these functionalities must be considered.

The resulting cumulative NPV for the vendor of PSS1 is shown in Figure 50 for the ALM over the considered runtime of 30 years and for TeraFlex over 16 years, respectively. Note these runtimes make sense according to Figure 38.



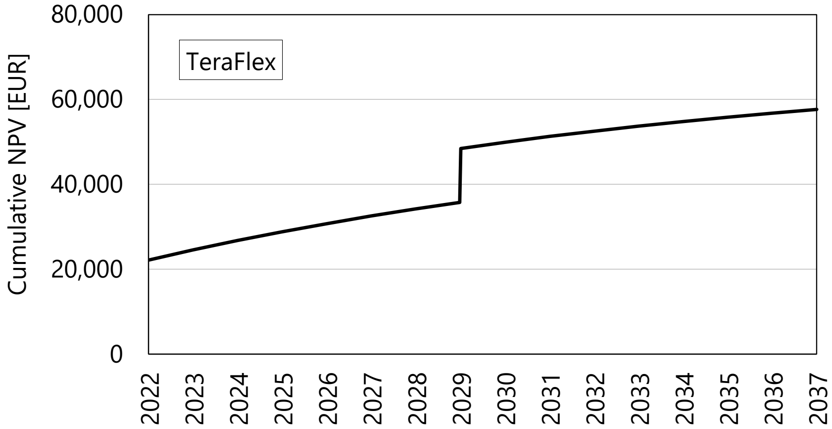
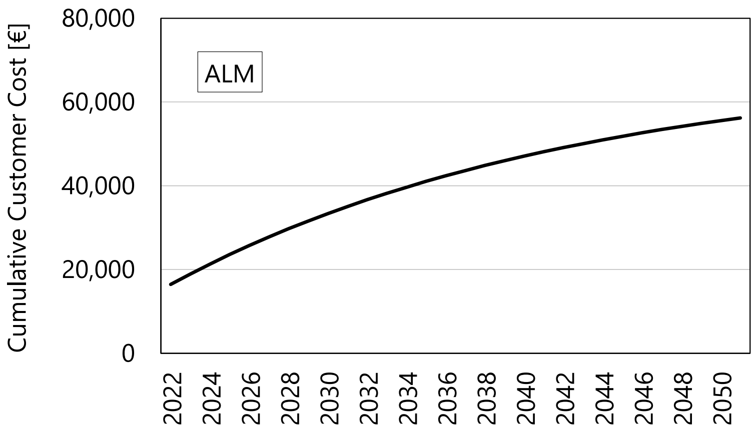


Figure 50. Cumulative NPV for PSS1 for the ALM with 25 fire sensors over 30 years (top) and TeraFlex over 16 years (bottom), product plus maintenance service sold

Not unexpectedly, EBIT starts with a relatively high value which results from initially selling the product. Afterwards, it steadily grows due to maintenance revenues. The slight change in slope is due to the consideration of the WACC. For TeraFlex, the step in the middle of the considered period results from selling a replacement unit after 8 years.

In Figure 51, the cumulative customer cost for PSS1 is shown for the ALM and TeraFlex, respectively. The step for TeraFlex results from replacement after 8 years.



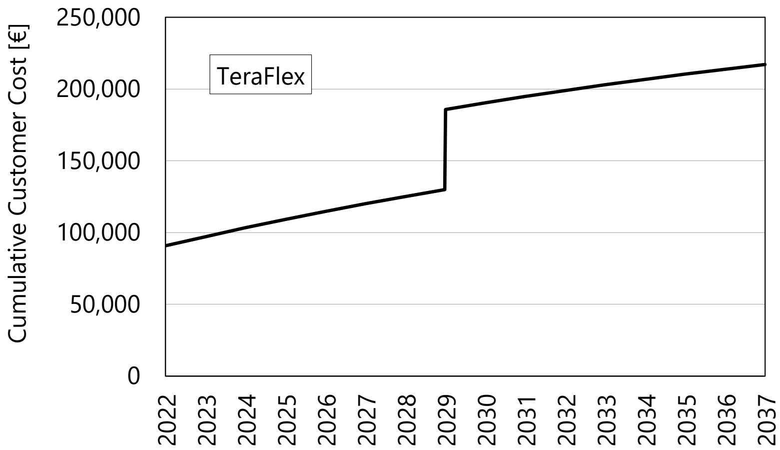


Figure 51. Cumulative customer cost for PSS1 for the ALM with 25 fire sensors over 30 years (top) and TeraFlex over 16 years (bottom)

Finally, Figure 52 shows the cumulative GWP for PSS1 for the two products. The slope change in both figures results from improving emission factors. The bend in the bottom figure for TeraFlex again results from the replacement after 8 years, where the successor unit has better energy efficiency and produces less emissions.

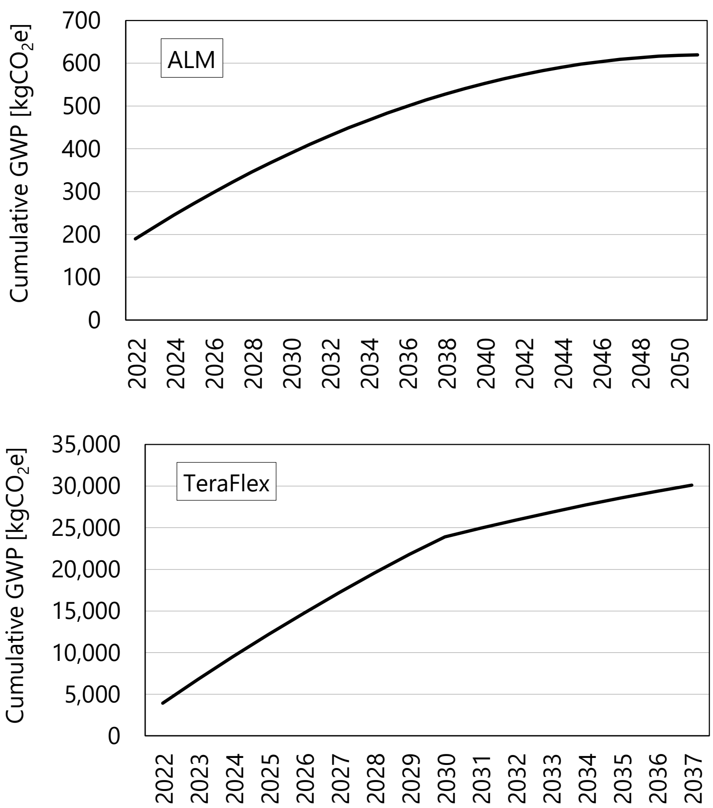


Figure 52. Cumulative GWP for PSS1 for the ALM over 30 years (top) and TeraFlex over 16 years (bottom). Note the production step in the middle for TeraFlex is hardly visible.

PSS2 – improved longevity

PSS2 again combines two of the primary mechanisms shown in the PSS overview diagram. It aims at clearly improved product longevity by providing maintenance services together with general End-of-Life (EoL) tack-back. The latter targets parts or components reuse and possibly whole-product reuse where applicable. In particular the latter is subject to end-to-end lifetime optimization, i.e., it may be limited or contradicted by total resulting carbon footprint. Unlike the first PSS, the primary goal is not use-phase resource reduction, but a more dedicated reduction in the production of components and whole products, together with an associated related cost reduction. This PSS is highlighted in Figure 53.

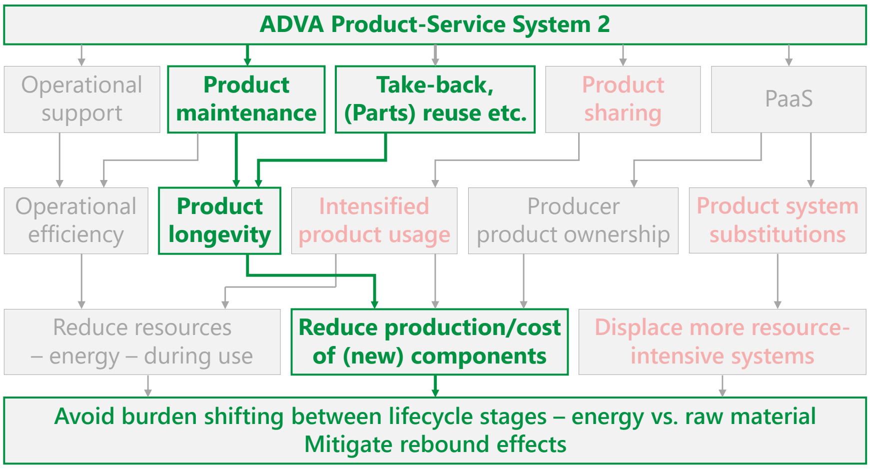


Figure 53. PSS aiming at maximized longevity

Business measures and product aspects for product maintenance are the same as in PSS1. In PSS2, they are complemented by general EoL take-back and analysis for maximized reuse. This goes beyond take-back for maintenance, as can be derived from Table 12.

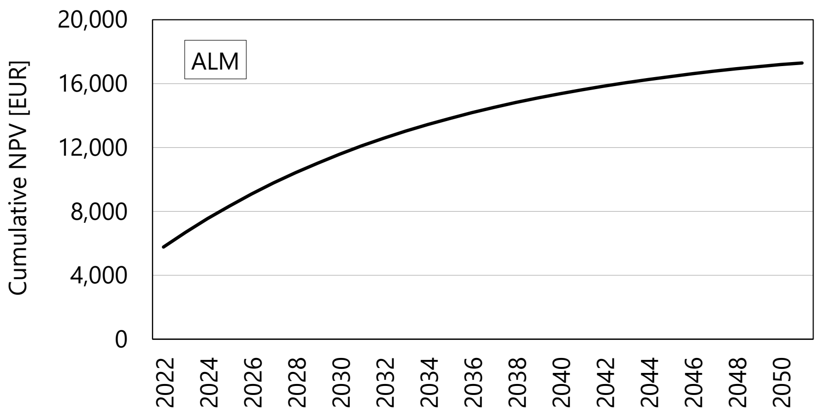
Table 12. Details of PSS2

Product maintenance	*Business aspects* - Maintenance contracts and capabilities / processes - Scheduled (reverse) logistics *Product aspects* - Performance monitoring, failure diagnostics, failure prediction - Modularity, all modules are hot pluggable during operations - Remote re-configurations, including resilience switching - Design for maintenance / maintainability
Take-back, reuse etc.	*Business aspects* - Take-back contract including additional (compared to maintenance) logistics-hub capabilities and processes o Systems and components analysis o Lifetime-optimization analysis o Stocks for refurbished parts etc. o Processes for using refurbished parts

	o Cooperation with suitable WEEE recycler - Scheduled (reverse) logistics *Product aspects* - Design for disassembly - Design for partial reuse, if applicable acc. To lifetime optimization - Design for recycling, i.e., optimized material yield in recycling. This includes choosing correct recycling streams for respective material fractions
Longevity	- Through maintenance, including service and product features - Through take-back and related (sub-) processes o Reuse, refurb, recycling o Product design support o Lifetime-optimization analysis
Production reduction	Given through extended longevity, which in turn is enabled by a mixture of services, supporting analyses, and product features. The outcome is subject to the lifetime-optimization analysis. This means the PSS may have to be complemented if the respective products are clearly use-phase dominated.

Compared to the first PSS, PSS2 requires substantially more business aspects or processes. This refers to (reverse) logistics that now become necessary and all processes that are required in order to analyse and reuse parts of the products taken back. These processes will cause certain operational cost, which may be partially or even over-compensated by the reuse and recycling yield. Note again that we used 6% yield at EoL or take-back for PSS2 as per Table 10. Details are provided in the quantitative analysis.

The cumulative vendor NPV for PSS2 is shown for the ALM and TeraFlex respectively in Figure 54.



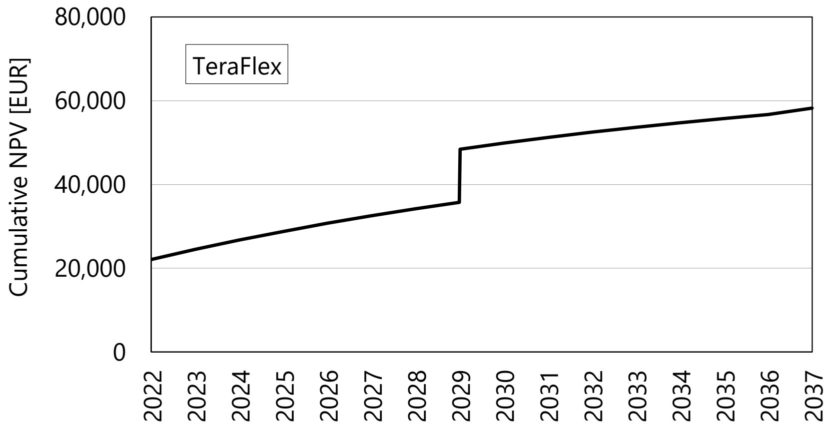


Figure 54. Cumulative NPV for PSS2 for the ALM with 25 fire sensors over 30 years (top) and TeraFlex over 16 years (bottom), product plus maintenance service sold, with take-back at EoL

All parameters remained unchanged compared to PSS1, with the exception of a small revenue that results from the products that are taken back plus the respective cost for (de-)installation. This caused a small negative effect for the ALM and a small positive effect for TeraFlex, caused by their ratios of unit to service cost.

Cumulative customer cost for PSS2 is identical to PSS1. Cumulative GWP is almost identical, with a comparatively small contribution from EoL take-back for PSS2.

PSS3 – retained product ownership

PSS3 is the "high-end" PSS for infrastructure ICT systems, since product-system substitution is no option for ICT systems as explained earlier. It is the PSS where the manufacturer retains product ownership and sells a service. We refer to this as Product as a Service, or PaaS. In addition, the product may be ***operated by the customer***, which is standard in telecommunications, or it may be offered by the vendor as a ***managed service***. This difference is relevant for PSS3.

The main objective of retained product ownership is optimized ecodesign with regard to the several circular-economy aspects. Since product ownership is retained, the manufacturer must have the highest interest in maximizing yield that results from reuse, parts reuse, maintenance, refurbishment and recycling. Consequently, products are designed to allow this maximized yield, within the boundaries of their application. These boundaries can be set by unavoidable functional obsolescence (e.g., in the case of ASICs) or energy efficiency as discussed elsewhere.

The respective PSS diagram is shown in Figure 55.

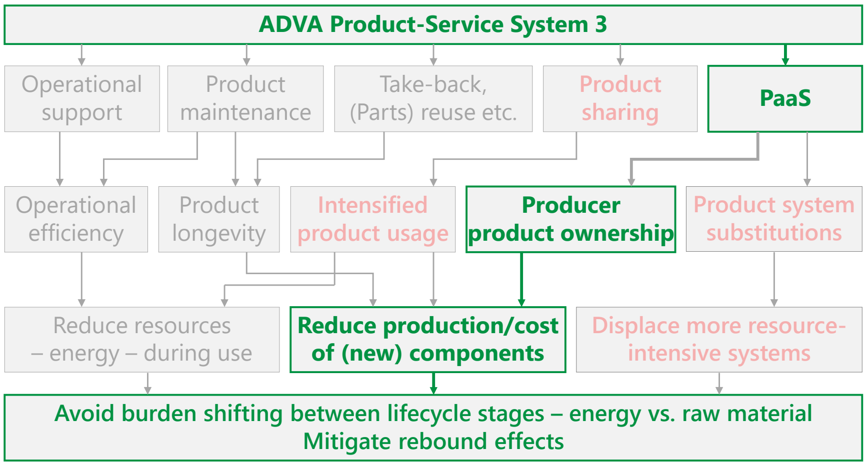


Figure 55. PSS with product ownership retained by manufacturer

The product aspects, as far as application-related functionality is concerned, are similar to PSS1 and PSS2. The same holds for remote monitoring. Ecodesign for circular economy is similar to the one required for PSS2, the difference is that here, the ecodesign result is maximized be the pressure that results from the need to making the most out of the equipment at every lifecycle stage due to the retained ownership.

All aspects are summarized in Table 13.

Table 13. Details of PSS3

PaaS	*Business aspects* - Maintenance services - Take-back services including logistics-hub capabilities and processes o Systems and components analysis o Lifetime-optimization analysis o Feedback loop into ecodesign process o Stocks for refurbished parts etc. o Processes for using refurbished parts o Cooperation with suitable WEEE recycler / own WEEE recycling - Scheduled (reverse) logistics - Network Operations Centre (NOC) (or similar for non-ICT PaaS / products) - Vendor financing services (cooperation with suitable bank) *Product aspects* - Performance monitoring, failure diagnostics, failure prediction - Modularity, all modules are hot pluggable during operations - Remote re-configurations, including resilience switching - Design for maintenance / maintainability - Design for disassembly - Design for partial reuse, if applicable acc. To lifetime optimization - Design for recycling, i.e., optimized material yield in recycling. This includes choosing correct recycling streams for respective material fractions
Product ownership	- Ownership must lead to most efficient ecodesign, having circularity in mind, and optimized reuse, refurb, recycling

	- Service for the customer must at least be as good as his own one - Vendor financing required (may be tricky at the beginning)
Production reduction	Given through vendor product ownership. Efficiency should be higher compared to maintenance / take-back since the retained ownership leads to most stringent ecodesign and related processes. This PSS must be complemented by measures for operational efficiency in cases where the underlying products are use-phase dominated (lifetime optimization!)

Compared to PSS2, in particular the two business aspects of running a Network Operations Centre (NOC) and the vendor financing service had to be added. Both have **severe financial impact**. In ICT, in order to being able to offer managed services (unmanaged services are no-go in ICT networks), one needs a NOC. The NOC can be sourced-out, or it is operated with own personnel. In either way, it causes the cost of the added personnel, the location (at least, one larger room that can accommodate at least 2-3 people plus the respective workspace with monitors, computer equipment etc.), plus the cost for the DCN connections (data communications network, i.e., the logically dedicated network that connects the network elements to the NOC). The DCN has been briefly described in deliverable D4.2. For more information, refer to [12].

Likewise, vendor financing has clear financial impact. Compared to selling systems, major revenue is delayed, and loans may become necessary that must be considered in the financial results. Also note that for PSS3, we used 10% EoL / take-back yield (Table 10).

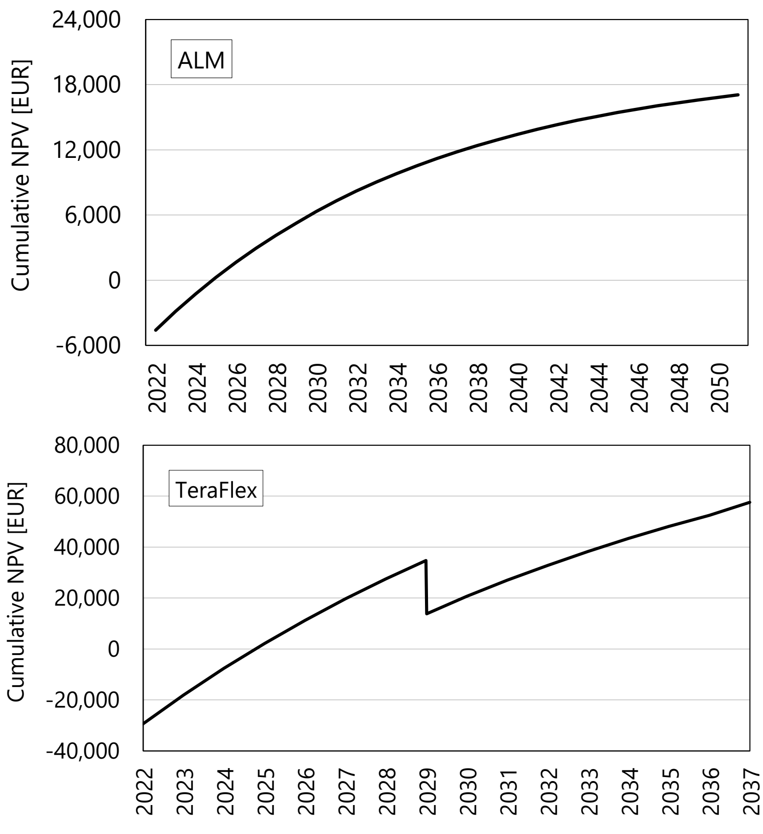


Figure 56. Cumulative NPV for PSS3 for the ALM over 30 years (top) and TeraFlex over 16 years (bottom), respectively, product ownership retained by vendor

Service cost for PSS3 has been set in a way that cumulative NPV was in the range of PSS1.

Figure 56 shows the cumulative NPV for PSS3 for the ALM over 30 years runtime and for TeraFlex over 16 years, respectively. Now, the cumulative NPV starts with a high negative value, which results from vendor financing. Afterwards, it grows steadily and slightly non-linearly, as explained before, to finally turn positive. Again, the sharp bend in the bottom figure for TeraFlex results from replacement after 8 years. The almost invisible bend at the end of the top curve for the ALM results from take-back.

Figure 57 shows the cumulative customer cost for PSS3 for the ALM and for TeraFlex, respectively. Both curves are smooth, i.e., without bends due to replacement. Cumulative results at the respective end points of the considered periods are in a similar range as, but not identical to, the values for PSS1 or PSS2 for TeraFlex. They are higher compared to PSS1 and PSS2 for the ALM, which is discussed later.

Cumulative GWP for PSS3 is shown in Figure 58. Cumulative GWP of PSS3 is similar to PSS1 and PSS2 for both products. Effects of EoL take-back are small (and visible in the case of the ALM).

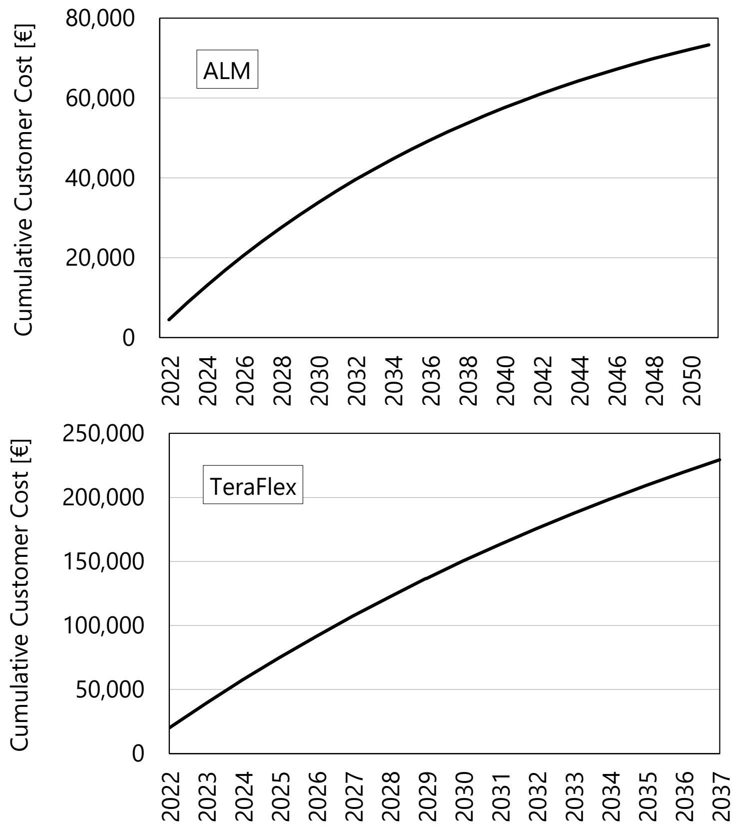


Figure 57. Cumulative customer cost for PSS3 for the ALM with 25 fire sensors over 30 years (top) and TeraFlex over 16 years (bottom), respectively, product ownership retained by vendor

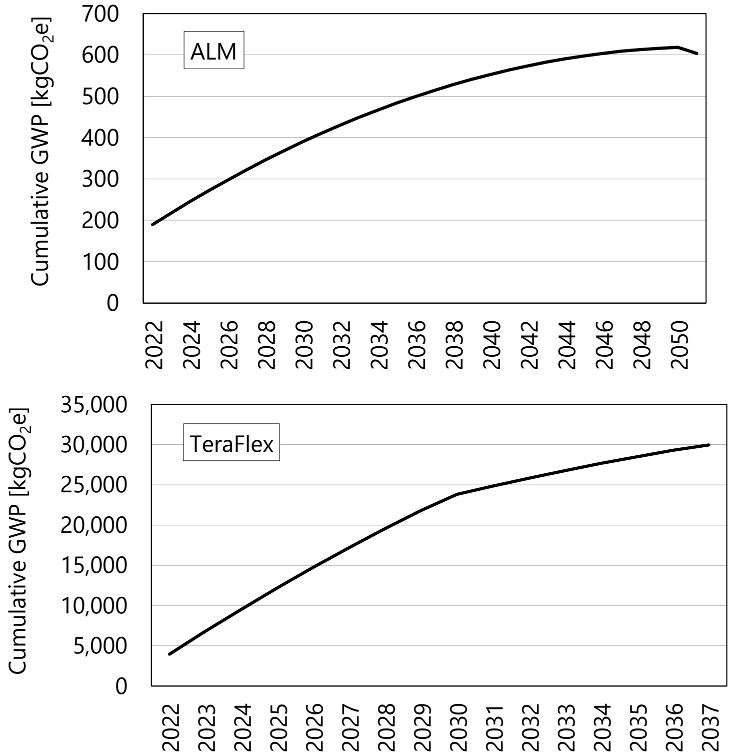


Figure 58. Cumulative GWP for PSS3 for the ALM over 30 years (top) and TeraFlex over 16 years (bottom), respectively, product ownership retained by vendor

Lessons learnt from old leasing approaches

In the years 2012-2015, ADVA already developed several early approaches for dedicated customers that could have led to leasing services. The focus back then was not on eco leasing, but general leasing instead of selling, plus offering managed services. The nearest equivalent to these offerings is PSS3 from our assessment.

These early approaches one by one failed. This had several reasons:

1. Unrealistic expectation by ADVA regarding own RoI (return on invest) in one case
2. One potential customer was looking to offload the network costs with no real mechanism to ever be able to pay for the network
3. One customer argued with CapEx vs. OpEx. Network equipment normally goes under CapEx, here it would have gone under OpEx, which typically is a different budget. He also argued with depreciation. In case of long equipment lifetime, the customer had depreciation over 10 years. The argument was that after 10 years, the customer would have had the equipment “for free”, instead of further paying lease.
4. The need to operating telecommunications networks (by ADVA). This included the necessity of operating an own NOC (network operations centre).
5. In one case, there was the requirement to combine the own offering with third-party items (large Cisco routers, which is a no-go in case one is not fully Cisco-certified)
6. Two cases where the potential customer wanted to lower his incumbent supplier in price and played tactical pricing games.

The first two items comprise of unrealistic financial expectations on both sides. We believe this can be avoided. However, leasing services remain critical in telecommunications since this is a highly competitive market, which, over almost two decades, so massively lowered its prices that many vendors did not survive this (which partially was caused by Chinese vendors). Therefore, effort needs to go into the identification of services with very good customer experience (CX) and acceptable price levels for both sides. It also needs to be considered that all large network operators claim that by far the biggest portion of their cost is OpEx, not CapEx. Nonetheless, they put very high pressure on their vendors regarding equipment cost (CapEx, in almost all cases). Depending on customer preference, either PSS1/PSS2 (lower TCO) or PSS3 (no day-1 invest, potentially combined with better CX) can be followed.

Item number 3 consists of at least two financial aspects. The first argument was that leasing further increased the OpEx (which is dominant, see the statement on OpEx above), and if leased, the assets would not show up in the financial statement. This was true back then. It only changed with *IFRS 16* [20] in 2019. Note that in other cases, IFRS 16 may pose a hurdle for leasing since now, leased assets do appear in financial statements. The second argument related to the customer's depreciation period, which was 10 years for infrastructure equipment. The argument was that, if bought, the equipment was for free after 10 years, whereas in the leasing case it wasn't. This obviously assumed long lifetime of >10 years, which is regularly the case for ICT infrastructure equipment. Item number 3 can be generalized in that other customers do argue with (reducing) day-1 invest and that in total, only few customers really consider total cost of ownership (TCO). Depending on customer preference, this may point either toward PSS1/PSS2 or PSS3, respectively.

Item number 5 is a problem in more complex turnkey solutions where third-party equipment may be required. In certain cases (e.g., Cisco routers that require Cisco-trained personnel), this may become a hurdle or show stopper. In the beginning of the PSS introduction, such combinations with third-party equipment may have to be avoided.

Item number 6 can always happen. Typically in ICT, the hit quota in winning new projects or customers is well below 30%. If the customer is not really interested in PSS, these cases shall be ignored.

Item number 4 is a challenge for offering telecommunications services. The reason is that telecommunication networks over the last decades have been considered critical infrastructure that require respective operations, in particular regarding reliability. Later, with market regulation (allowance of so-called competitive exchange carriers, CLECs), operators had to consider their customers' experience (CX), which again led to focusing on operations. Consequently, offering these services is not trivial. It requires profound knowledge of networks and their operations (which vendors can have) and experienced personnel. The latter may translate to initial cost when related services or PSS are ramped up. However, given that the offered managed service has better CX than what was available before, these services are feasible. In our assessment, this leads to PSS

It should be noted that historically, no successful vendor-operator is known. Network operators that started developing own equipment in almost all cases failed, and they never extended their vendor business. Likewise, vendors that successfully operate large networks are not known yet. This is expected to change only incrementally. There is a historic ICT equivalent to this situation. Manufacturers of CPUs (central processing units) in most cases do not produce complete computers, and vice versa. Few exceptions are known, e.g., Motorola, that failed. This indicates strong specialization of participants in complex value chains. Again, this can very likely only be changed slowly and incrementally. It may pose an additional challenge for offering PSS3 in ICT.

PSS comparison, discussion, generalization and combination

Comparison of PSS

Note that only PSS1 or PSS2 are shown since both perform very close to each other. Similar cumulative NPV at the end of the considered periods result since service charges have been adapted accordingly. This may be subject to negotiation in reality.

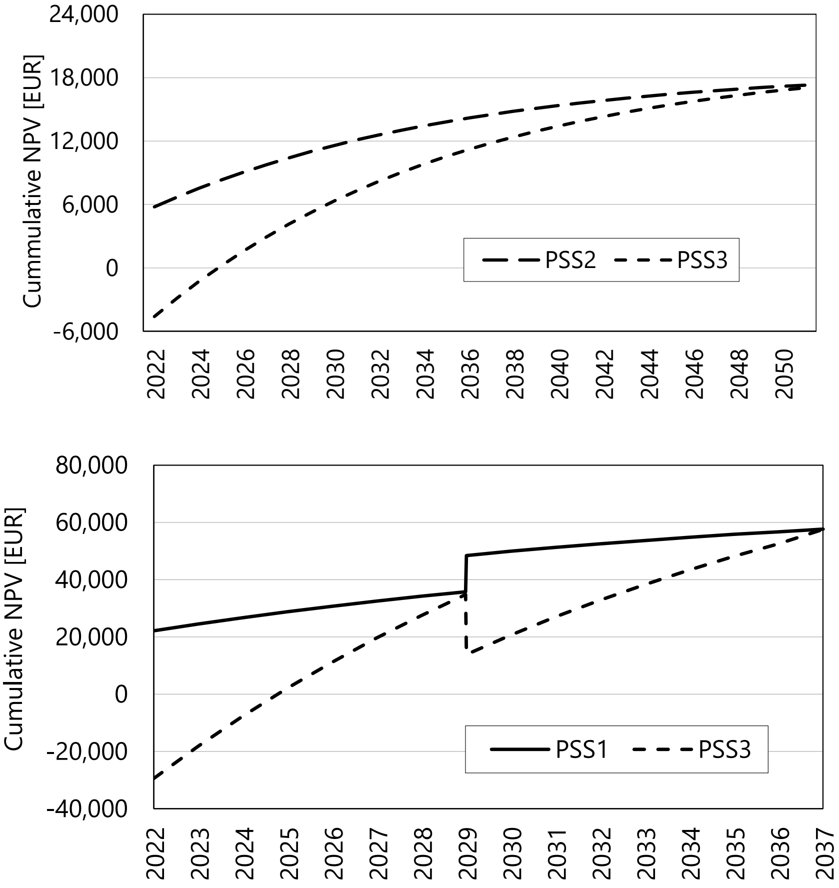


Figure 59. Comparison between PSS2 and PSS3 for the cumulative ALM NPV (top) and between PSS1 and PSS3 for the cumulative TeraFlex NPV (bottom)

The comparison of the corresponding cumulative customer cost of the respective PSS is shown in Figure 60. For the ALM, higher customer cost of +30% result for PSS3. This covers, in our calculations, the *managed ALM monitoring service*, which requires running an NOC by the vendor. For this service, +30% is regarded a ***very small*** mark-up. In real commercial offerings, the price mark-up for the managed service will likely be significantly higher. Therefore, PSS3 for managed services seems to be a promising PSS. It is interesting in particular for customers not running an own NOC. Whether it will be successful for network operators that do run their own NOC is not clear.

For TeraFlex, customer cost higher by ~6% result for PSS3. This covers the fact that the vendor now has the day-1 invest, which may lead to the necessity of cooperating with banks for financing.

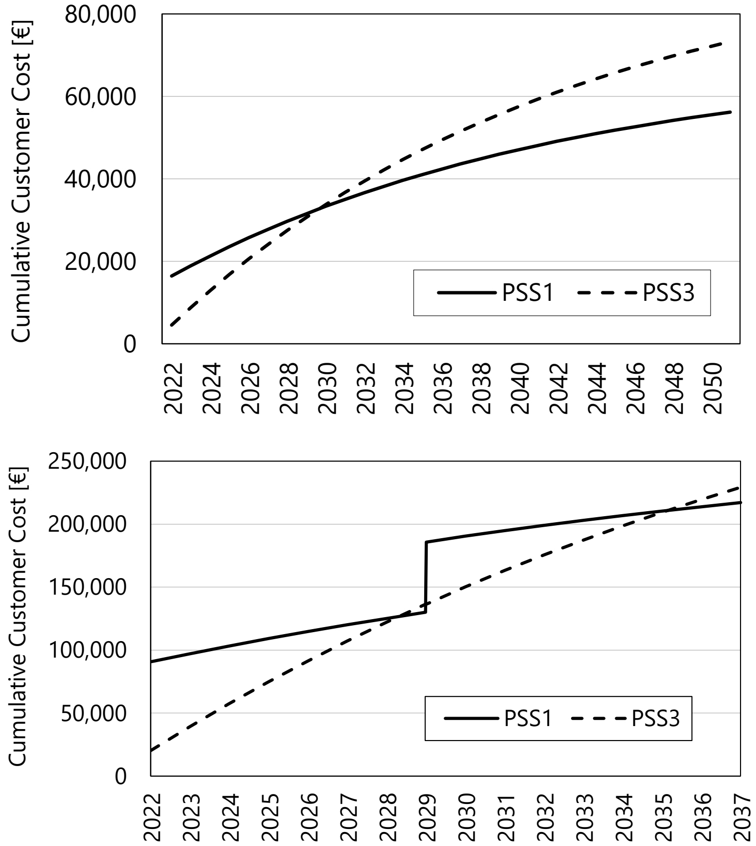


Figure 60. Comparison between PSS1 and PSS3 for the cumulative ALM customer cost (top) and TeraFlex (bottom)

Further results of the three PSS for the ALM is summarized in Table 14. Note the split in HW and maintenance cost between active ALM units and the sensors. Maintenance cost stated is the one in the beginning of the runtime. It is then increased on a yearly basis. We assumed an average number of **25 sensors per active ALM unit**. This number is in the range we have seen in installations so far.

Table 14. PSS comparison for the ALM

ALM64			
	PSS1	PSS2	PSS3
Runtime [Years]	30		
Initial HW sales	Yes		No
Take-back by ADVA	No	Yes	
HW cost active ALM [EUR]	3,000		
HW cost per sensor [EUR] (typ. 20 sensors)	100		
Maintenance cost active ALM [EUR]	56		155
Maintenance cost per door sensor [EUR]	7		25
Maintenance cost per fire sensor [EUR]	35		52
Take-back cost at EoL [EUR] (total)	NA	500	
Revenue at EoL [% of unit cost]	NA	6%	10%
Revenue [EUR]	107,703	108,143	162,446
Cumulative EBIT [EUR]	41,980	42,038	63,085
Cumulative NPV [EUR]	17,253	17,290	17,053
Cumulative customer cost [EUR]	56,180		73,296
Vendor WACC	8.8%		
Customer (average) WACC	6.0%		
CAGR of maintenance cost	1.0%		
CAGR of hardware cost	0.0%		
Power consumption [W] (in 2021)	10		
Cumulative GWP [kgCO_2e]	620	610	604

Note the difference in maintenance cost that had to be assumed here. Feasibility of these maintenance cost is discussed in the next chapter.

The vendor WACC (weighted average cost of capital) value is the one for ADVA. It represents the profitability expectations on ADVA given its risk profile. The customer WACC is lower. This is driven by large customers like DTAG that have lower WACC [21].

Table 15 summarizes the PSS results for TeraFlex.

Table 15. PSS comparison for TeraFlex

TeraFlex			
	PSS1	PSS2	PSS3
Runtime [Years]	16		
Initial HW sales	Yes		No
Take-back by ADVA	No	Yes	
HW cost TeraFlex [EUR]	43,200		
Maintenance cost TeraFlex [EUR]	2,420		2,470
Take-back cost at EoL [EUR]	NA	100	
Revenue at EoL [% of unit cost]	NA	6%	10%
Revenue [EUR]	296,735	300,190	367,288
Cumulative EBIT [EUR]	92,100	94,508	143,765
Cumulative NPV [EUR]	57,630	58,245	57,570
Cumulative customer cost [EUR]	217,128		229,290
Vendor WACC	8.8%		

TeraFlex			
	PSS1	PSS2	PSS3
Customer (average) WACC		6.0%	
CAGR of maintenance cost		1.0%	
CAGR of hardware cost		0.0%	
Power consumption [W] (in 2021)		1,000	
Cumulative GWP [tCO_2e]	30.1	30.0	29.9

Obviously, vendor cumulative NPV was adjusted for the different PSS to be close to each other. This caused PSS3 to get slightly more expensive for the customer.

Discussion

So far, the analysis has been done for three PSS and two ICT products that have clearly different UPR_{10}. Although the ALM has a small UPR_{10}, its use phase still has high impact. This results from the very long use period (30 years) and can be seen by the fact that effects of take-back and EoL treatment have limited impact.

From environmental viewpoint, there are no significant differences between the PSS.

Here, we assumed that the development of the energy efficiency was the same for all PSS. Also note that the relatively small environmental-impact difference results from the EoL values of Table 10. These values are regarded optimistic for infrastructure ICT equipment due to the fast-paces market and functional obsolescence. Obviously, these values must be adopted when other equipment is considered.

Therefore, the most interesting question is the one of revenue or NPV vs. customer cost and the related question of vendor financing for PSS3.

It is clear that PSS3 has advantages because it most effectively forces the vendor towards most efficient ecodesign. Therefore, financial parameters – service charge – must be adopted to allow acceptance on both sides (vendor, customer). In our analyses reported so far, we set the service cost such that the vendor's cumulative NPV was approximately the same for all PSS. This made PSS3 slightly more expensive for the customer for TeraFlex, while the vendor still has to finance its day-1 invest (plus beginning-of-year-9 invest in the TeraFlex case). Therefore, we believe the cumulative customer cost that is increased by ~5% should be acceptable. Obviously, service charge can be changed, e.g., to set cumulative customer cost constant across all PSS. This has been done, for TeraFlex, in Figure 61.

In this case, the service charge has been changed from 23.7% of the product price to 22.5% of the product price (while product price remained constant). This is a small change that indicates the range for the service charge that may be subject to negotiations. Note that the maintenance service itself remained the same for TeraFlex across the PSS. Also note that according to our analysis, the difference in environmental impact (or EoL gain) between the PSS was low for the ICT products assessed. Finally note that, unlike the ALM, TeraFlex was offered as a leased product ***without*** operating it by the vendor. TeraFlex is still operated by the customer since operating such equipment is network operators' core business.

For the ALM, with its longer lifetime and relatively higher maintenance cost caused by the maintenance effort of the sensors, cumulative customer cost is higher by ~20%. The major difference in our assessment, compared to TeraFlex, is that for the ALM, *monitoring is sold in PSS3 as a service, not the product*. This means that a ***managed service*** is sold, where the manufacturer operates the ALM. This obviously has massive impact on vendor *and* customer cost.

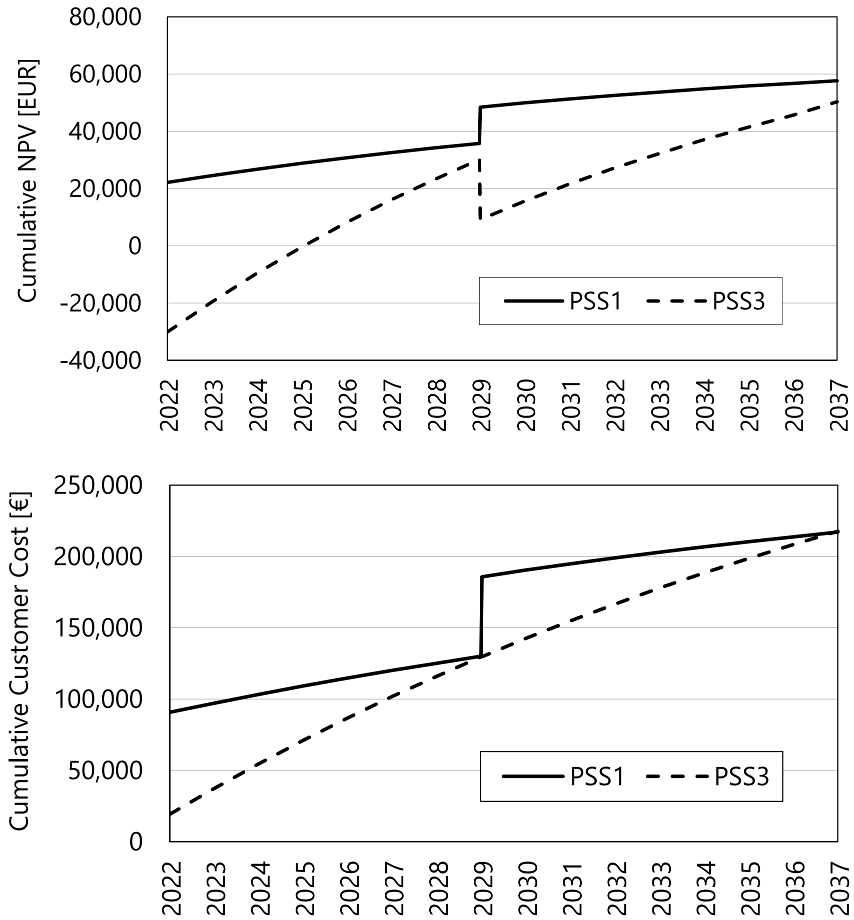


Figure 61. Comparison between PSS1 and PSS3 for the cumulative TeraFlex NPV (top) and the cumulative TeraFlex customer cost (bottom)

On the vendor side, in order to operate the ALM monitoring service, a (so-called) Network Operations Centre (NOC) is required. Since this is not typical today, it adds significant cost for the vendor. On the other hand, it releases the customer to operate the product. Instead, the customer gets the results of the managed service. This can massively lower operational cost on the customer side. In ICT, the total cost of network operators is clearly dominated by OpEx [19]. This is despite the fact that network operators have experience in operating their networks and have optimized this area over the last decades.

The managed service and its OpEx has two potential impacts:

- For network operators as customers, it is not clear if they accept a managed service, instead of managing it themselves. They do have all means for managing (parts of) their networks, network management is part of their core business. If they accept a managed service, the added cost (~20% in our case, compared to PSS1) should be *very* interesting.
- For other customers – facilities operators in case of the ALM fire and door sensors – it should be very interesting to offer the managed service. Again, the cost mark-up compared to PSS1 should be very interesting, e.g., to facilities operators since it is likely clearly below their own cost of managing the respective service.

Finally, we need to compare the PSS analysis to the *Lessons learnt from old leasing approaches*, see the respective earlier sub-chapter.

From the reasons for failure listed there, the first one (wrong expectation regarding RoI) can be addressed now. Looking back, it is very likely that the respective PSS cost for both sides, vendor and customer, has not been correctly considered, taking all aspects of our PSS analysis into account. This holds in particular for the operational cost for managed services. We therefore believe that the analysis presented here would have helped also for the respective failed leasing approach. The same is true for the case listed where the vendor would have had to operate an NOC.

For obvious reasons, our PSS analysis does not help in cases where the customer plays tactical pricing games.

Generalization

The generalization of PSS beyond the ICT equipment assessed so far and the related identification of suitable PSS must consider **two further aspects**.

1) CapEx vs. maintenance/operations cost. Certain PSS become more attractive if for example, maintenance or operations cost are relatively high compared to system CapEx. Therefore, it is useful to define a ratio that relates CapEx to maintenance cost. Similar to UPR_{10} we consider 10 years for the OpEx parameter:

$$CMR_{10} \coloneqq \frac{\text{CapEx of the product}}{\text{Maintenance OpEx over 10 years}} \qquad \text{(Eqn. 2)}$$

CMR_{10} is the ratio of the product CapEx to the OpEx generated by 10 years of maintenance. Note that we do not consider other OpEx like energy cost here.

In Table 16, relevant parameters for the ALM and TeraFlex are summarized. Depending on the type of sensors for the ALM, CMR_{10} for the ALM and TeraFlex can differ by more than a factor of 5. Two ranges with CMR_{10} </> ~1 can be discriminated.

Table 16. CapEx and OpEx parameters of the ALM64 and TeraFlex

Product	CapEx [€]	Maintenance per year [€]	CMR_{10}
ALM64 w/ 40 *fire* sensors	7,000	1,450	0.5

ALM64 w/ 20 *door* sensors	5,000	200	2.6
TeraFlex (fully equipped)	43,200	2,400	1.8

Smaller CMR_{10} reduces the influence of the necessary day-1 invest (either for the customer in cases of PSS1 and PSS2 or for the vendor in case of PSS3). Therefore, small CMR_{10} points more toward PSS3 from the vendor viewpoint and PSS2 from the customer viewpoint since the respective day-1 invest loses its relevance. Note that the CMR_{10} range listed in Table 16 may be exceeded by other EEE. In such cases, the indication toward either PSS1/PSS2 or PSS3 becomes even clearer.

Smaller CMR_{10} reduces the influence of CapEx on the PSS in general. This also means that the smaller CMR_{10} is, the more the PSS choice is allowed to be driven by environmental aspects (e.g., cumulative GWP).

2) Products w/o ICT challenges and ICT features. Generic EEE products may neither show all the ICT-products challenges, nor their beneficial features. In the context of circular economy and PSS, the main challenges of infrastructure ICT products can be summarized as follows [5]

- Very fast development cycles, therefore massive functional obsolescence. This holds for both, complete products and their components. It strictly limits reuse.
- Environmental impact dominated by use phase. Therefore, energy efficiency is most relevant during the next years to come (until emission factors get better), and again, lifetime may be strictly limited.
- In many cases, further improvements in utilization are not possible
- The ICT infrastructure cannot be virtualized

In turn, infrastructure ICT products in most cases have these beneficial features

- Remote monitoring and supervision via the DCN (data communications network, which is a logical part of the ICT infrastructure), including failure prediction
- Modularity, including duplication (resilience) of critical modules and high MTTR (mean time to repair)

We do not further consider the so-called Greening-by-ICT effects here, that is, massive emissions savings in sectors other than ICT [5], [18].

If the ICT-products challenges do not apply for generic EEE products, this can have influence on the most beneficial PSS. First, if functional obsolescence or energy efficiency are less critical, positive effects of reuse and parts reuse can become more apparent. In turn, this may make PSS2 and PSS3 of our assessment more attractive because EoL treatment may provide higher positive credits. This must be confirmed with LCA.

If the EEE products under consideration still have significant potential for higher utilization (e.g., by better sharing), than the PSS that focuses on sharing and product utilization should be investigated. It can potentially lead to high yield since it can be combined with measures for either the reduction of resources during use or during production. Consequently, this PSS should be investigated. Potentially, it may be limited by customer acceptance (e.g., acceptance of sharing a product with others).

Finally, there is a chance that certain EEE products can be substituted by less resource-intense systems. Examples may include the integration of further functions into smart phones that than replace dedicated electronics hardware that supported these functions earlier. In that case, the PSS at the right edge of the PSS diagrams (product system substitution) shall be assessed. Effects of such substitutions must again be calculated and confirmed by LCA.

ICT products also have beneficial characteristics other EEE products may not have. In the case of modularity, resilience etc., these characteristics are covered under the Product-longevity PSS and will be considered in a general PSS analysis. This may lead to the necessity to develop, over time, certain longevity features for the EEE product under consideration.

Remote monitoring and sophisticated failure analysis is common for ICT equipment and is clearly supporting all operations and maintenance aspects of the related PSS. This is particularly true since the respective monitoring features are already existing and do not need to be developed or implemented for any particular PSS. However, in the case of ICT infrastructure equipment, PSS1, PSS2 and PSS3 equally benefited from these features, i.e., they do not make a significant *difference* to the PSS (they do provide a significant *contribution*). In cases where certain monitoring functions were beneficial for EEE products but not yet available, the potential exploitation of IoT (Internet of things) technology should be investigated [15]. In general, IoT can provide for communications channels and thus enable a certain degree of monitoring. It is then up to the product vendor to also develop remote monitoring and analyses algorithms.

Finally, other EEE products may show stronger impact – yield – of EoL treatment. This can be enabled, e.g., by less or slower obsolescence. In these cases, our PSS2 and PSS3 will likely get more attractive since they generate some revenue or cost and material savings at EoL. However, we believe that the related commercial impact will still be limited.

Combinations of PSS paths

In the PSS diagram, the impression may be generated that either operational efficiency *or* longevity *or* producer product ownership are supported by a particular PSS. This is not fully true. All PSS focus on specific primary and end effects as per Figure 32. However, other aspects rather than those of primary concern may be considered to certain extent in addition. For example, energy efficiency (an operational-efficiency aspect) can also be considered in PSS3. We did this by replacing TeraFlex units in our analyses. This may further complicate the PSS assessment, but it allows to find PSS that come without massive burden shifting as per Figure 32.

A detailed PSS "cookbook" (decision matrix) will be provided in our final deliverable D4.5.

Influence of energy cost on PSS customer cost

It is sometimes stated that energy cost can be as much as 20% of total OpEx for network operators [23]. For a general overview on network-operator OpEx, also see [24].

Here we show that energy consumption, though significant in the TeraFlex case, is not a relevant cost driver for the respective PSS, even if electricity cost and related carbon-emission cost are considered. This is shown in Figure 62.

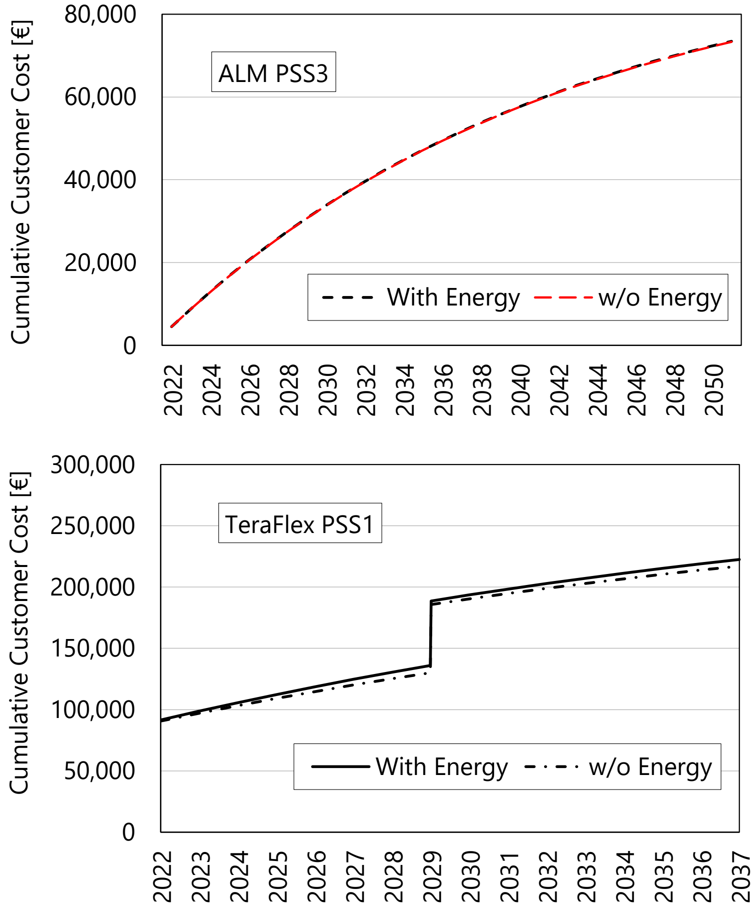


Figure 62. Cumulative customer cost with and without energy cost for the ALM in PSS3 (top) and for TeraFlex in PSS1 (bottom)

The upper diagram shows the customer-cost comparison with and without energy cost for the ALM over 30 years. This was calculated for PSS1, where for the other PSS, the difference is *very* small as well. The hardly visible difference is due to the fact that the ALM energy consumption is comparatively low. The lower diagram show the same cost comparison for TeraFlex and PSS1. Again, PSS2 would show almost identical results, and the cost difference for PSS3 is also in the same range.

Table 17 lists the relevant parameters that were used for the energy-cost assessment.

Table 17. Parameters used for energy-cost calculations

Electricity cost industrial customer, 2021	80 EUR/MWh
CAGR electricity cost	2%
Emission factors	As per Figure 36
Energy efficiency	As per Figure 37
Carbon tax [EUR/tCO_2e]	25 in 2021, linearly increasing by 8 EUR per tCO_2e per year. This leads, for example, to 65 EUR/tCO_2e in 2026, where this number and the start value have been taken from German carbon tax.

As a result, energy cost does not have an influence on PSS choice, although energy consumption may have an influence via the optimum-lifetime consideration.

External lifecycle cost

In the last chapter, we considered the contribution of use-phase energy to total resulting customer cost. What has not been considered so far are external environmental cost, as they are considered in lifecycle costing (LCC).

LCC of the ALM was already described in deliverable D4.2. For the ALM, comparatively small external cost were derived due to the low use-phase energy consumption of the active ALM systems.

Here, we investigate, following the same mechanism (monetizing the LCA endpoint categories), the external environmental cost of the TeraFlex system over 16 years, i.e., over the same period that was considered for the PSS analyses. We consider two scenarios, without any replacement in the 16 years, and with one replacement by a more efficient successor after 8 years. Since EoL has a very small impact and all transportation, production and use is the same for the three PSS, the analysis is independent from the respective PSS to first approximation. The result is shown in Figure 63.

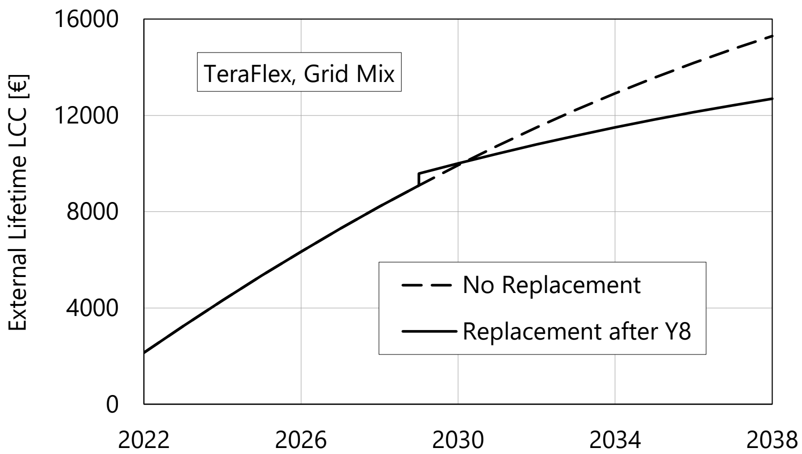


Figure 63. Comparison of two scenarios (replacement after 8 years, no replacement) for external lifetime LCC. EU grid mix with respective emission factors was considered here. The step in the middle for the replacement scenario results from the production of the replacement unit.

Again, it can be derived that replacement for products with high UPR_{10} is necessary from environmental viewpoint. When comparing Figure 63 to the bottom part of Figure 62, it can be derived that the additional external cost of TeraFlex is still relatively small (<10%). It must be noted that the LCC cost do not only depend on UPR_{10}, but rather on LCA and any specifics that are involved here, e.g., any critical materials. Therefore, external cost should be calculated for other EEE products, they cannot be derived from the results presented here.

6.2. Demonstrator testing at B2B facilities

6.2.1. Assessment of new sensors production batch

Door sensor

The newly developed ALM door sensors are passive fibre-optic sensors that are connected to the active ALM units. The combination of passive sensors and active units that can quickly and periodically monitor or interrogate a large number of sensors has significant environmental advantages over electrical sensors for the same application, if these are combined with suitable powering (either wired or with batteries) and means for remote interrogation. For older sensors for monitoring second-life batteries, an advantage as high as a factor of 6 over electrical sensors has been stated for fibre-optic sensors in [25].

The first design of the door sensor that was developed during the C-SERVEES project is shown in Figure 64. Its chassis was made of aluminium. Other parts include the fibre feed-throughs made of plastic, a metal bolt with a metal spring, a bending element (metal or aluminium) and metal screws and fixing elements for the fibre.

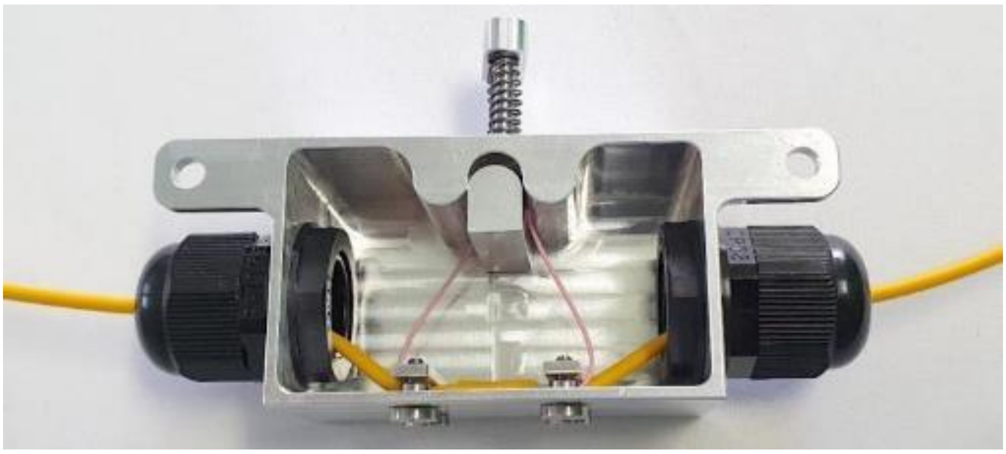


Figure 64. Door sensor, first design

Without going into fibre-optic details, the working principle is simple. If a door or something similar is opened, it moves the metal bolt against the spring force into the sensor chassis. Here, it moves the bending element inside the chassis. This either releases or produces bending loss inside the fibre that is passed between the bending element and the respective counter part of the chassis, inside the chassis. In Figure 64, this can be seen in upper middle of the sensor. The added bending loss can be detected in real time by the active ALM unit, using suitable optical-signal analysis.

The first sensor design would have given the choice of aluminium (including recycled aluminium), metal and plastic for the main part, the chassis. However, it showed problems regarding the mechanical design of bending the fibre. Therefore, a second design was developed. It is shown in Figure 65.

The second design is based on a similar fibre-bending principle. It allows somewhat more space for the fibre to be bent and thus better control of the bending. Prototypes were made of plastic (plus metal spring and screws). For the chassis, the same choices exist as for the first version.

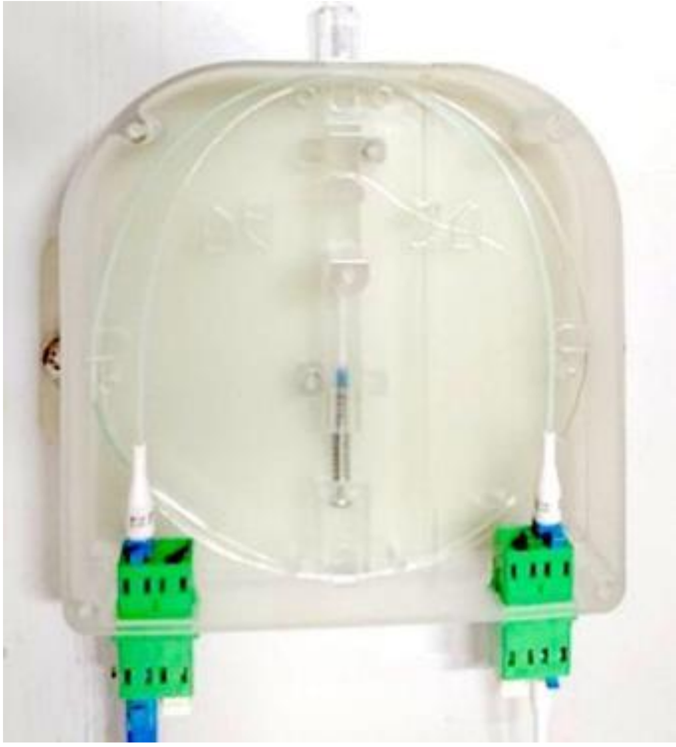


Figure 65. Door sensor, improved second design

The second version of the door sensor has gone into production. It was used for tests in commercial test plants. It will also be commercially deployed with suitable PSS, see Chapter 6.1.1.

For the production batch of the sensors, several material choices for the chassis existed. This includes several types of plastic (ABS, PC, PE), Zinc and several types of aluminium (primary, secondary, market). These were analysed with LCA. Relative midpoint results are summarized in Figure 66.

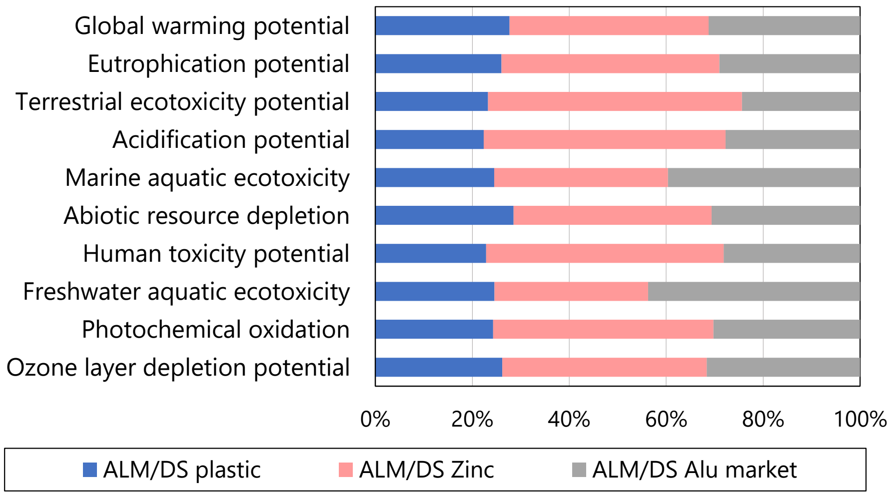


Figure 66. Door sensor, midpoint LCA for main material variants

It can be seen that Zinc performs worst across almost all midpoint categories. Therefore, the choice remains between plastic and aluminium. In addition to relative midpoint analysis, we investigated GWP in more detail. Results are shown in Figure 67 for the most relevant lifecycle phases.

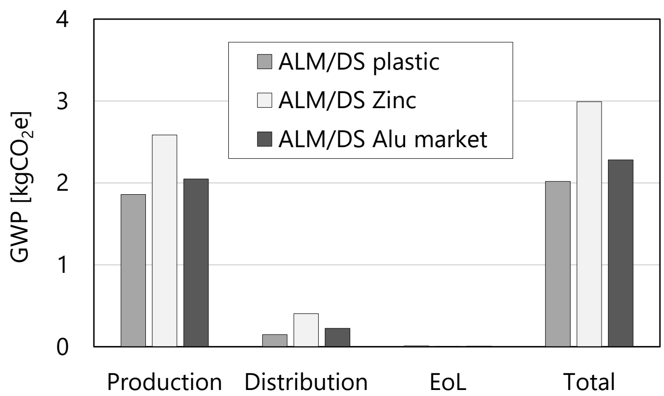


Figure 67. Door sensor, GWP contributions of main material variants

Figure 67 does not show contributions from our own activities since these are identical for all material choices. As expected, production dominates since the end product (the sensor) is passive and does not have any use-phase energy or consumables consumption. Again, Zinc performs worst.

Next, we investigated the different choices for plastic and aluminium, respectively. The GWP analysis for ABS, PC and PE is shown in Figure 68.

The different plastics behave pretty similar, with slight advantages for PE. Therefore, the choice between different plastic materials can be determined by the most suitable behaviour regarding ageing, since the lifetime of the sensors can easily achieve two decades or more. Whether this requires the addition of further softeners, with the related negative LCA effects, is for further study.

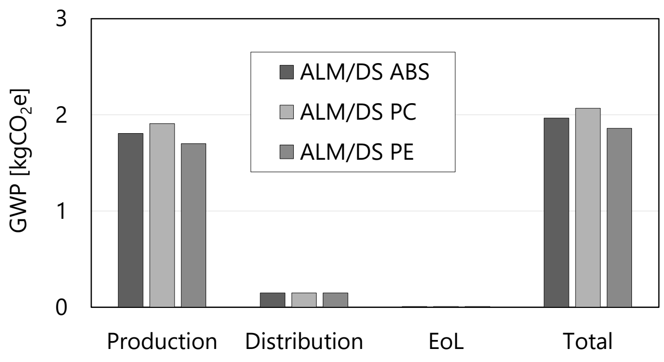


Figure 68. Door sensor, GWP contributions of plastic variants

For aluminium, severe differences in LCA result for virgin vs. recycled aluminium. We analysed three types of aluminium, primary (virgin), secondary (recycled) and market (mix). The GWP result is shown in Figure 69.

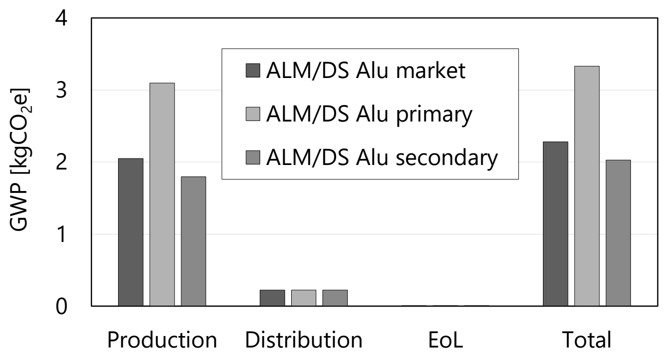


Figure 69. Door sensor, GWP contributions of aluminium variants

There is a difference of a factor of ~1.5 in GWP between primary and secondary aluminium. This means that secondary aluminium performs similar to plastic.

Fire sensor

The newly developed fire sensor is also based on the fibre-bending principle. It is smaller compared to the door sensors since it is directly attached to or integrated with standard sprinkler units.

The fire sensor was also developed in two successive design versions. The first version is shown in Figure 70. It consists of a small metal chassis that is screwed underneath the respective sprinkler unit. Inside the chassis is a spring that bends the fibre with the help of a small metal bending element. When a fire breaks out, the bulb in the sprinkler unit breaks, which in turn releases the water and also releases the fibre from being bent by the bending element. That way, the active sprinkler can immediately be detected.

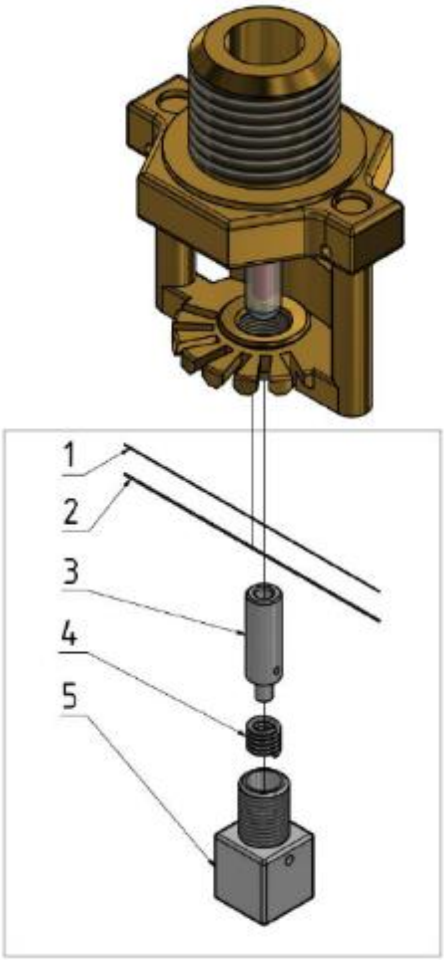


Figure 70. Fire sensor, first design. Top: standard sprinkler unit. Bottom: sensor screwed underneath the sprinkler unit. 1 and 2: fibre with coating (the fibre is concentrically coated). 3: bending element. 4: spring. 5: chassis.

Though being very effective in terms of material usage for a sensor that identifies active sprinkler units, there was one basic design problem – the sensor had to be screwed underneath the sprinkler, with the detecting fibre already attached. This is tricky at best with optical fibres, and a second design version was developed. The second version of the fire sensor is shown in Figure 71.

It has to be noted that both sensors (door, fire) are new fibre-optic sensors, based on novel remote interrogation. This explains that two versions each were necessary in order to develop suitable fibre-optic-mechanical designs.

In the second design of the fire sensor, the sensor consists of the same elements – fibre, spring, tension or bending element, and some form of chassis or mounting element. Here, the mounting element is screwed laterally onto the sprinkler unit, so that the problems with the fibre are avoided. In terms of material usage, it is similarly effective.

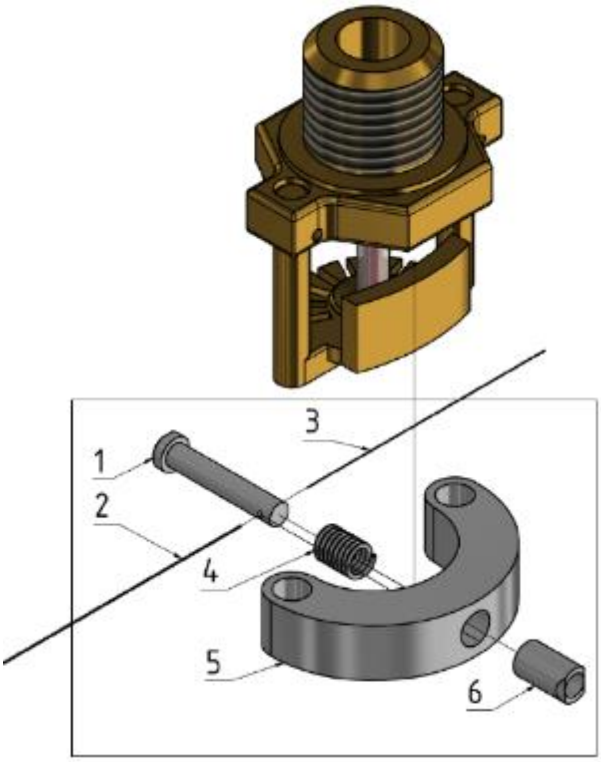


Figure 71. Fire sensor, final design. 1: tension element. 2 and 3: fibre with coating (the fibre is concentrically coated). 4: spring. 5. Mounting element. 6: sliding bushing.

The second version of the fire sensor has gone into production. It was used for tests in commercial test plants. It will also be commercially deployed with suitable PSS, see Chapter 6.1.1.

The LCA for the fire sensor is shown in Figure 72 for the main material variants. We only analyse the sensor, not the sprinkler unit it is attached to, since the sprinkler unit is identical in both cases (and would be installed, with whatever other sensors, anyway). We further only considered different aluminium variants because plastic is no alternative in the fire-sensor context.

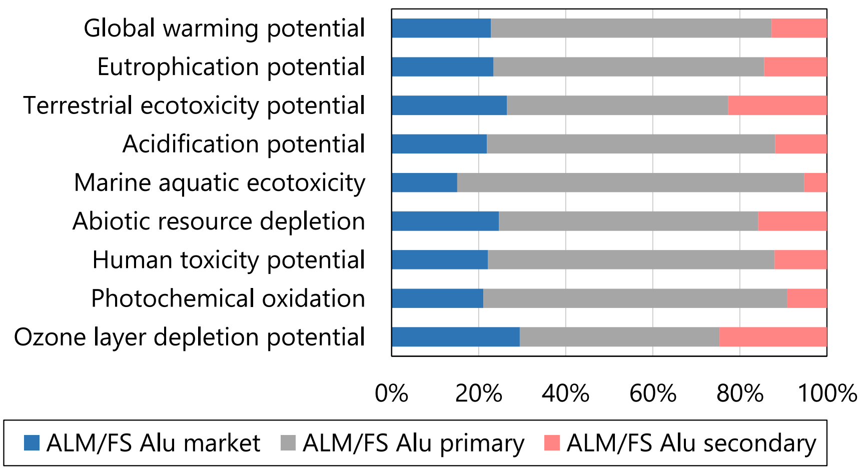


Figure 72. Fire sensor, midpoint LCA for main material (aluminium) variants

Figure 73 shows further results for the different aluminium variants. Distribution contribution is small and similar for all material choices du to similar weight. For all aluminium variants, there is a small negative EoL contribution that results from aluminium recycling.

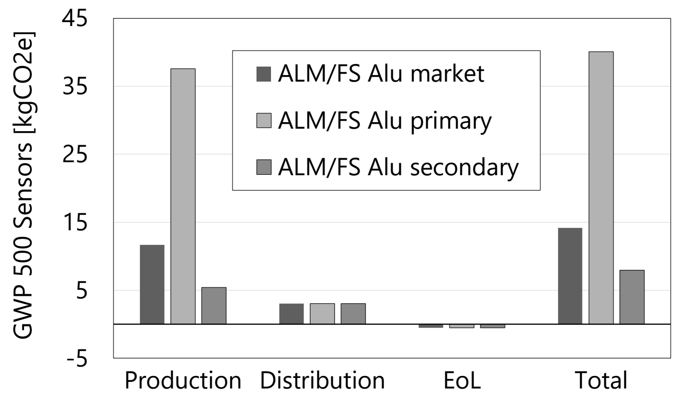


Figure 73. Fire sensor, GWP contributions of aluminium variants (500 sensors)

Production shows significant differences in particular between virgin and secondary / market aluminium. In order to reduce production impact, secondary aluminium or at least a blend of secondary and virgin (primary) aluminium should be used.

6.2.2. Test installations and results

Extensive tests of production samples of the sensors developed during the C-SERVEES project have been performed on the cabinet (door) and fire sensors in commercial test beds. In these measurements, parameters like the fibre-optic insertion loss depending on humidity and temperature were measured in order to capture the attenuation profile of the sensor. These measurements are required to get approval for the sensors for future deployments. Figure 74 shows such a measurement for the cabinet sensors where over more than 1000 measurements the temperature was cycled between -15°C and 30°C, together with humidity.

The tests were analysed in particular regarding reliable differential sensor insertion loss for the closed and opened states (which is the detection criterion, e.g., for an opened door). They revealed that the sensor is sufficiently insensitive against temperature and humidity, which allows its commercial application, e.g., to control door openings and similar in-door events. It needs to be noted that these sensors, together with the active ALM units, have very long lifetime (for the sensors: decades, for the active ALM units: at least 10-15 years), and that total environmental impact according to LCA is far better than the respective number of electrical sensors, as stated earlier already.

Figure 74. Temperature chamber measurements for the cabinet sensor: Insertion loss (red), humidity (orange) and temperature (blue).

As next step, a commercial contract was closed for a first installation of the new sensors for door-opening and fire detection, together with active ALM units. The contract covers a PSS1 according to our analysis, that is, selling the products plus maintenance services. The relevant aspect of this first (sensor) installation is that in particular the fire sensors will get official approval during the first year of their installation. This approval is also an (ADVA-internal) prerequisite for further deployments, in particular as PSS3. Excerpts of the respective maintenance contract are given in the next chapter.

Further future deployments, in particular of the ALM system, shall be done with PSS3. This results from the ALM-system characteristics as described in our analysis earlier. The main aspects pointing toward PSS3 are the system's UPR_{10} (relatively high maintenance effort), the fact that it does not require particular energy-efficiency or optimum-lifetime consideration (as per Ch. 6.1.3) and the fact that for many customers, the monitoring service itself must be offered. This holds, in particular, for all customers that are ***not*** network operators with own NOCs. For these customers, significant advantages of PSS3 are expected that result from offering the managed monitoring service.

Extension of PSS3 to WDM products like TeraFlex is for further internal discussion. Here, PSS3 is not regarded strictly necessary from the environmental viewpoint, as the environmental part of our PSS analysis revealed. However, the number of PSS1/PSS2 installations will be increased, following the ADVA-internal strategic goal of increasing service/maintenance revenue.

6.2.3. First commercial ALM PSS

ADVA intends to sell the ALM as a PSS. Due to the relative cost structure of the ALM, its sensors and the related maintenance, maintenance services are to be included in any way. This has been prepared during the project. Due to Covid-19 delays, this was delayed. In the next deliverable we will produce, as evidence, the related maintenance contract.

6.3. Testing of ICT functionalities

In the project, ADVA participated tests together with the project partner Circularise. We did not participate tests regarding logistics (transportation) optimization for two reasons.

1. Changing real logistics in a project is impossible since logistics are *mission-critical*. This is in particularly true since within the runtime of the project, severe relocations of our supply chain (following the US-China trade war) took place and everything possible had to be done to avoid supply disruptions. This badly interfered with the project, but it did not leave any space for tests of any changes in logistics whatsoever.
2. As described in deliverable D4.2, we developed, around 2014, logistics optimization for a very large customer, together with a large international logistics provider already. The functionality offered in the C-SERVEES project did not go massively beyond what we had developed years ago already together with the logistics provider, except for the additional data privacy and decentralisation features.

For the test of the Circularise Blockchain tool, we tried to answer initial questions we had:

1. How complex is the usage? Does it provide any deterrent? Can we derive an indication of acceptability by relevant future users, in particular our suppliers?
2. What in the end needs to be uploaded? It is not expected to already get a full answer here, since the content question refers to the Digital Twin or Asset Administration Shell [26], which goes well beyond the scope of the C-SERVEES project, with lots of ongoing discussion and standardization.
3. Can the tool (with later extensions) help the increasing number of customer queries we get regarding materials and substances embedded in the components that comprise our products (e.g., REACh, SVHC)?

The test with the Blockchain-based tool is still ongoing. Complete findings will be provided in a later deliverable. However, first results are summarized hereinafter.

On question 1. Usage of the tool at the time of the first tests was limited. In particular, no file upload was possible. This, however, is necessary in cases where more complex data is to be uploaded. For example, full material declarations (FMD) of components can easily comprise >100 lines of material (substances) data. Over time, it must therefore be possible to upload such data in a file format. This is planned for future tool versions.

The most relevant aspect remains, though. We believe that the data base behind the tool in the end must be unique in the sense that value-chain partners do not need to fill several similar – competitive – data bases. The respective single data base may be served by several competing tools, but the process of providing the data must be done only once. Otherwise, the effort for filling several data bases will become prohibitive, interworking will be at least questionable (for competing data bases), and acceptance by the relevant value-chain participants, in particular components suppliers, will go down severely. How this can be achieved is for further study and should be considered in future frame works, e.g., Horizon Europe.

Circularise has declared publicly its intentions to assure said full interoperability of data. The company is currently in the process of setting up a foundation for the joint and public development of a communication protocol guaranteeing the described data interoperability between tools.

On question 2. After discussion with Circularise, ADVA decided to conduct a test with full material declarations. FMDs contain the complete list of all substances that are contained in all components that comprise a product. This is done on the basis of the components' weight and the fraction of that weight that the respective material or substance contribute to. All substances are named unambiguously with their CAS numbers. CAS numbers are unique numerical identifiers assigned by the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature. Since complex EEE easily can have a 4-digit number of components (TeraFlex is an example for that), and components can contain dozens of substances, such an FMD can easily comprise several thousand lines of data. FMDs are required in the context of the EU REACh Regulation and the declarations of substances of very high concern (SVHC). It must be noted that compiling complete FMDs with data from the supply chain leads to very high effort.

A very short excerpt of the first 46 lines of the FMD of an ALM64 system is provided in Figure 75. The complete ALM64 FMD contains almost 3000 lines of data in XLSX format.

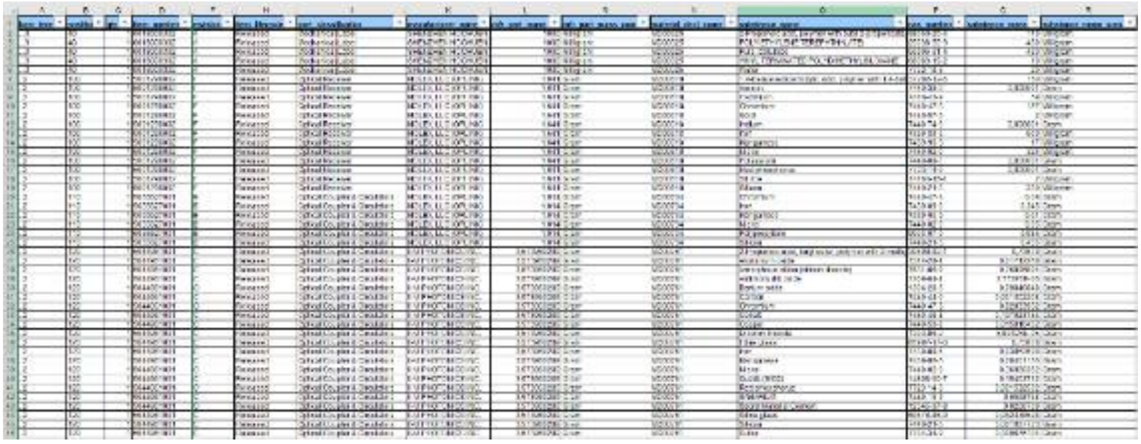


Figure 75. The first 46 lines of the full material declaration of the ALM64.

The main question is whether or not such level of detail is of any practical use, in particular in recycling. For other CE loops like reuse it is even more unclear how FMDs shall help. In turn, it is not yet automated in many cases to provide *aggregated* substances information on a module or product level. This would at least cause substantive effort in the beginning. In addition, the information where the respective substances are contained might get lost. However, exactly this information (location of components with certain substances) may be of interest, e.g., to recyclers. In turn, many recyclers today could not make use of detailed information that includes the location of components/substances within a larger module or product since they do not break down the incoming WEEE to such a detailed level. Today, this would require extensive manual disassembly, which in many cases is not done. Instead, WEEE often goes into shredding, which is then followed by one or very few default processing pathways. In order to really make use of detailed (WEEE) product data, and enable getting significant amounts of precious metal, rare-earth elements and other valuable substances in recycling, first the treatment of the incoming WEEE would have to be changed. (The recycling pathways like hydro-or pyro-metallurgy do exist.) Therefore, also this question is partially open and for further study. Part of this will likely be done under the upcoming Asset Administration Shell research.

The ICT tools by Circularise are indeed in the process of being optimized further in order to ease and standardise the data input. For the data output of the exact data needed, the Smart Questioning being developed contains a questioning functionality that focuses on the calculation and answers of only the data needed by the questioning stakeholder at each moment to reduce complexity, while assuring data availability for questions of the future in the background.

On question 3. This aspect partially refers to the first questions. The number of queries related to material content of products is heavily increasing, driven by both, customers and regulation. Here, it must be noted that, e.g., the REACh Regulation does have an impact on circular economy and its requirement for longevity. Since REACh is regularly complemented by new substances, risk is that an already existing product, which in the beginning complied to REACh, may not do so later due to complements to the regulation. In such cases, it may even have to be taken out of service.

The main problem with the multitude of materials/substances-related queries is the same as with the first two questions. Any data base to be filled is only acceptable when the process of providing data only needs to be done once. Everything else leads to prohibitive effort and will likely not be accepted in the value chain. Therefore, to channelize and reduce the number of often proprietary queries for REACh and other data, it is necessary to provide a standardized, global data base. Since concerns regarding REACh/SVHC data and its security, integrity and accessibility are similar to, e.g., concerns regarding data on content of recycled material, it is believed that the data base and its tool investigated in the C-SERVEES project can also help regarding the increasing number of materials/substances-related reporting requirements. The relevant aspect remains that there needs to be a *single* data base, to be filled only once.

Circularise's approach on solving this is by making sure data can be communicated in the same format as any other upcoming data management, across different services and providers decentrally. A centralised database would entail the risk of data leakages of sensitive data, which is why a decentralised tool is much saver. Monopolisation of the service always comes with its own challenges, which is why a 100% interoperability (similar to email protocols and email providers) can assure a competitive market while using data formats that communicate with each other seamlessly.

6.4. Update of the Ecodesign Guide

As explained in Ch. 6.1.2, all efficient product-service systems must be supported by certain product features. These features can be categorized:

1. Features in the context of the application. Examples include reconfigurations or protection switching in ICT systems.
2. Features that allow remote monitoring, control, reconfigurations. For ICT infrastructure systems, these features are often implemented anyway. For products in other areas, they would have to be added. This can be done using IoT (Internet of Things) technologies.
3. Ecodesign features, including energy efficiency and DfX (Design for X, with X including disassembly, maintainability, recycling etc.)

Product features under 1. are application dependent. They must be considered and implemented in each individual application context. In general, they should aim at avoiding truck rolls, maintenance actions where applicable, single points of failure etc.

Features in the second category provide remote monitoring, analysis and, to certain extent, control. The latter may include certain repair actions like protection switching in ICT networks. These features again aim at avoiding unnecessary maintenance actions like truck rolls. They may also allow failure prediction and this, scheduled or preventive maintenance. These features are common in ICT networks. In other application areas, equivalents may have yet to be developed, subject to cost, feasibility etc.

The third category contains dedicated ecodesign features. These may still depend on application and on main product characteristics. The latter must be derived from lifecycle assessments and consequent lifetime optimization.

ADVA had a first collection of ecodesign rules for its products already at the beginning of the C-SERVEES project. These *Environmental Requirements* were revised during the project, following new findings (in particular from WP4).

In addition, the implementation of the Environmental Requirements in ADVA's process landscape and tools have been changed. The Requirements were implemented in Polarion, the main tool for managing the Product Lifecycle Process (PLCP). This implementation acts as blueprint for other *Global Requirements* to follow. These are requirements that are not specific to a certain product line, examples include design for maintainability or design for security.

Two major changes have been applied to the Environmental Requirements. First, following the Polarion implementation, they have been made mandatory for all new hardware developments, including new releases of older products. Then, a severity has been added to each requirement. Severities are *Major*, *Normal*, and *Minor*. The severity provides a certain degree of flexibility for not considering certain requirements, e.g., in cases where they contradict other Global Requirements like Design for Security or Design for Cost.

Regarding content, the requirements have been newly grouped, and individual requirements have been added, deleted, changed or complemented, as compared to the old set of Requirements. This holds in particular for the longevity and plastic-parts sections. The latter, for example, was influenced by the findings from the disassembly of several active ALM units by project partners during the project. These were described in deliverable D4.2.

Hereinafter, we describe relevant sections of the Environmental Requirements that have been changed through input by the project. Sections that are out of scope of the C-SERVEES project, e.g., energy efficiency or packaging, will not be discussed.

As the first example, requirements regarding longevity are listed in Figure 76.

3 Design for Long Product Lifetime and Life Extension

Environmental impacts of a product can be reduced by prolonging its lifetime up to an optimum that can be derived from lifecycle assessments (refer to the **Annex**) and is determined by technology progress (e.g., in energy efficiency, emission factors etc.).

Product lifetime requirements

ECO-13 - Estimate the optimum product lifetime. For products with 24/7 always-on use mode, this lifetime is likely limited by energy consumption and much higher energy efficiency of successor products. In that case, focus on energy efficiency.
[Major]

The following recommendations shall support this optimum lifetime, but not significantly more.

ECO-14 - Enable easy upgrade by using modular design so that new technology / modules can be incorporated into an older system. This includes shelf-controller and DC-supply concepts.
[Normal]

ECO-15 - Design for high reliability / high availability (i.e., high MTBF, mean time between failures)
[Normal]

ECO-16 - Design for easy serviceability / maintenance (i.e., low MTTR, mean time to repair). This can be achieved, e.g., by quick disassembly, easy accessibility of sub-modules, etc.
[Normal]

Figure 76. Excerpt from Environmental Requirements – longevity

This section of the Requirements now puts more emphasis on the lifetime optimization. The next section deals with parts reuse, see Figure 77.

4 Design for Parts Reuse

Partial reuse is an alternative to product lifetime extension. Parts / components being reused have lower environmental impact than parts being newly produced. Reuse of parts from used equipment can also help in cases where the respective parts have been discontinued but are still required in production. However, some limitations exist, refer to the section Design for Circular Economy in the **Annex**.

Parts reuse requirements

ECO-17 - Use common parts across product lines, wherever possible
[Major **]**

ECO-18 - Design to reuse subsystems and common parts, where possible (pluggables, PSUs, chassis ...)
[Major **]**

ECO-19 - Unify shelves where possible for reuse (e.g., FSP 150 family, all "pizza boxes")
[Major **]**

ECO-20 - Unify PSUs where possible for reuse (this would also increase respective numbers and likely decrease cost)
[Major **]**

Figure 77. Excerpt from Environmental Requirements – parts reuse

Parts reuse in infrastructure ICT systems is critical at best, which is mainly because parts, like complete systems, are subject to strong functional obsolescence. Combine with the relatively long lifetime of infrastructure equipment this strictly limits parts reuse. This leaves only few areas like shelves and power-supply units (PSU) where reuse can make sense, given it is enabled by design (i.e., components selection). The respective Requirements have been assigned highest severity.

The next section of the Requirements addresses recycling, with particular respect to disassembly, see Figure 78 and Figure 79.

5 Design for Recycling (DfR)

Since life extension and parts reuse are limited for most of our telecommunications infrastructure equipment, effective recycling is mandatory. Since WEEE (waste electrical and electronic equipment) has complex components and material mixtures, several requirements shall be considered. This mainly refers to design for quick and easy manual disassembly and avoidance of incompatible materials.

Additional requirements related to recycling of plastic parts can be found in **Ch. 7** hereinafter.

DfR requirements

ECO-21 - Reduce steps necessary for manual disassembly
[Normal]

ECO-22 - Avoid the need for specialty tools for manual disassembly
[Major]

ECO-23 - Avoid fixed connections, i.e., rivets, welds and adhesives, and minimize screws
[Major]

ECO-24 - Minimize adhesives for incompatible material combinations.
Examples are sealed batteries, PUR foam glued to steel / Al / plastic, wood glued to plastic, etc.
[Normal]

ECO-25 - Avoid sharp edges (because of the need for manual disassembly)
[Major]

ECO-26 - Enable quick detection of materials. This is mandatory for waste-stream sorting. This includes labelling of components (ideally, based on required waste stream) so that they can be identified and separated. For waste streams / incompatibilities, refer to the Metal Wheel in the **Annex**.
[Normal]

ECO-27 - Minimize components / clusters in a product that will cause losses in recycling due to incompatible material characteristics. Example: PCBs colored other than brown or green lead to contamination of PCB fraction with, e.g., colored plastics, or losses of PCBs to other recycled parts.
[Normal]

Figure 78. Excerpt from Environmental Requirements – recycling (1)

ECO-28 - Reduce the number of different materials, in particular for plastic parts (see **Ch. 7** hereinafter)
[Major]

ECO-29 - Design (sub-) units so that they match final recycling options (again, see the Metal Wheel / **Annex**).
Critical material should be clustered on separable sub-units / components. Examples include Al heat sinks on PCBs, separate PCBs for different functions (e.g., power boards with high Fe content that will be lost in the Cu / Pb processing path for standard PCBs), tantalum capacitors, batteries, etc.
[Normal]

ECO-30 - Avoid coating, plating or other surface treatment of mechanical parts if possible, use molded-in colors and finishes instead of paint, coatings or plating
[Normal]

ECO-31 - Avoid use of hazardous substances wherever possible (they are critical in recycling)
[Major]

Figure 79. Excerpt from Environmental Requirements – recycling (2)

In this section, severities were added. The next section addresses material efficiency and the use of recycled or recyclable material. It is shown in Figure 80.

6 Design for Material Efficiency and Use of recycled Materials

The consumption of resources (materials, energy) shall be kept to a minimum.

Components that have lower lifecycle environmental impact compared to alternative components are to be preferred. This can result from smaller / lighter components and components with better lifecycle assessment. The latter can be achieved with the use of recycled material, which also becomes a common customer requirement.

Material-efficiency / recycled-materials requirements

ECO-32 - Minimize material usage, e.g., smallest-possible (mechanical) parts and thickness of sheets
[Normal **]**

ECO-33 - Use components with high recycled content wherever possible, i.e., for plastic and metal parts
[Major **]**

ECO-34 - Use materials that can be easily recycled (e.g., metal better than most plastics)
[Normal **]**

ECO-35 - Reduce the amount of consumables during the product use phase, when possible
[Minor **]**

Figure 80. Excerpt from Environmental Requirements – material efficiency

The major change again was the addition of severities since the section existed before. The final section discussed here is on plastic parts. This section was complemented and changed through project input, which was mainly generated through the disassembly of several active ALM units by the project partners Indumetal and Gaiker. The plastic-parts section is shown in Figure 81.

8 Design concerning Plastic Parts

A broad range of plastics parts is in use today in electronic equipment, many of which are incompatible in recycling. Therefore, the most relevant recommendations here are the limitation of different plastics and the avoidance of incompatibilities. See the **Annex** for a thermoplastics compatibility matrix.

Plastic-parts requirements

ECO-44 - Reduce different plastics, when possible, and ideally to a single material. If two or more types of plastic are used, these must be compatible in recycling or separable.
[Major **]**

ECO-45 - Plastic casing parts of ≥25 g must consist of a single polymer or compatible polymer blend
[Normal **]**

ECO-46 - Plastic parts ≥25 g must not contain chlorinated polymers
[Normal **]**

ECO-47 - Mark the type of polymer, copolymer or polymer blends (including additives) for parts weighing ≥25 g and with a flat area of ≥200 mm^2 in conformance with ISO 11469:2000
[Normal **]**

ECO-48 - At least one plastic part of ≥25 g shall be made of reused or recycled plastic
[Major **]**

ECO-49 - Virgin-material plastics parts shall be unpigmented (white the next alternative). Recycled plastic parts (preferred!), on the other hand, can and likely will be dark-gray or black.
[Major **]**

ECO-50 - Fluoro-organic additives (used to improve the physical properties of plastic) shall not have concentrations greater than 0.1% by weight (see **REACh Regulation**) **[** Major **]**

ECO-198 - For PVC, the detailed content - material declaration - shall be provided **[** Normal **]**

ECO-51 - Plastic parts shall have no added lead or cadmium
[Major **]**

ECO-52 - Plastic parts shall have no metal inlays that cannot be separated easily, when possible
[Normal **]**

Figure 81. Excerpt from Environmental Requirements – plastic parts

This section is now pretty detailed. This followed the analyses mentioned and discussion of the Requirements with relevant project partners. Moreover, severities have been added. We did not find an equivalent in the literature or the web.

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7. TV sets and displays demonstrator

The activities conducted in the distribution and use 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 distribution and use phase, as presented in Table 24 in D2.5.

Table 18. Validated short-term TV-CIRCMODE Canvas Key Circular sub-components and their associated Circular Economy Actions relevant for the distribution and use phase.

TV-CIRCMODE Canvas Sub-Component	TV-CIRCMODE validated short-term Circular Economy Actions
TV_C1.1 Diversify circular activities	TV_A1.1.4 Develop renting model for B2B and B2C customers
TV_C3.3 Address partnerships' cultural issues that would encourage circular economy business models to be widely adopted	TV_A3.3.2 Obtain feedback of B2B customers via questionnaires.
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_A4.1.2 Develop new corporate B2B sales channels in Europe for renting TVs
TV_C5.3 Change traditional relationships with customers, for instance: can a customer become a supplier?	TV_A5.3.1 Initiate a take back collection system in Europe with a partner
TV_C7.2 Introduce and/or enhance offerings of leased, rented or shared product options	TV_A7.2.1 Develop a TV rent business model for Smart Boards and Digital Signage products
TV_C8.2 Adapt financial administration to enable economy business models such as leasing and renting options for both the B2B and B2C customer segments	TV_A8.2.1 Assess the feasibility of TV renting options

CE actions TV_A1.1.4, TV_A4.1.2, TV_A7.2.1 and TV_A8.2.1 are all related to the exploration and testing of new renting/leasing models for the TV set and are covered in sections 7.1 and 7.2. CE action TV_A3.3.2 is addressed together with WM_A3.3.2 and covered in sections 7.3.

The main objective of this phase was to use the target circular products, eco-designed and manufactured specifically for the demonstration, to test the feasibility of new eco-leasing models for Arçelik's TVs.

7.1. Assessment of new PSS for the TV sets

The feasibility study of the renting/leasing model was carried out for both the washing machine and the TV set products and the parameters and results are explained in section 4.1.2. Some of the insights concerning TVs are mentioned below:

- Arçelik's major competitor in Turkey attempted to initiate a rent TV system as a pilot where the product would be changed in 2 years including promotional offerings such as free access to entertainment platforms, but this system was not successful in Turkey and they do not currently offer this service. We do not have extensive knowledge to the reason why this attempt failed.
- Currently we have not come across rent TV offerings for the B2C segment in the market in Arçelik's competitors. The rent offerings are dominantly focused in the WM's followed by dishwashers and other major home appliances as well as other small domestic appliances.
- TV offering in the B2B segment proves to be more preferable especially in hotels and dormitories.
- In order to make it more attractive, the TV offering in the B2B- B2C needs to focus more on giving the service as a package to include the TV along with other consumer electronics such as Bluetooth speakers, headphone sets, free subscription to Netflix, Amazon Prime, etc.

Examples for the TV set sensitivity studies are provided below:

Table 19.TV set renting model feasibility in Spain

Price	% of increase in customers	NPV
-10%	-10%	-67%
-15%	-15%	-86%
-20%	-20%	-98%
-25%	-25%	Not feasible
no change	-10%	-51%
no change	-15%	-66%
no change	-20%	-76%
no change	-30%	-91%
no change	+10%	89%

Table 20.TV set renting model feasibility in Turkey

Price	**% of increase in customers**	**NPV**
-10%	-10%	-61%
-15%	-15%	-78%
-20%	-20%	-89%
-25%	-25%	-96%

no change	-10%	-46%
no change	-15%	-61%
no change	-20%	-72%
no change	-30%	-86%
no change	+10%	80%

7.2. Demonstrator testing at B2B facilities

100 demo products were produced according to eco-design principles, to be tested in the use phase of the demonstration. The technical details of these products, which were produced in accordance with the design and production TV-CIRCMODE actions, are given in detail in deliverable 4.2. In summary, TV products are 43" sized flat TV sets in smart concept that can receive DVB T/C/S broadcasts. The products contain a 30% recycled material in the back cover and a QR code for ICT functions.

The Covid-19 pandemic, which started at the end of 2019 and spread to the world in a short time, was effective at the decision point of the usage locations of the products.

The first detected case of the COVID-19 epidemic in Turkey was announced by the Ministry of Health on 11 March. The first death due to the virus in the country occurred on March 15, 2020. Health Minister, in a statement on April 1, 2020, announced that the coronavirus cases had spread all over Turkey.

As of the end of March, social life was stopped for Turkey. All hotels, restaurants and cafes were closed not only in Turkey but also in the whole world. The house restriction model, which will take a long time, has been passed.

Many hotels announced that they would not open their establishments during this period, including the summer period. For this reason, a research process took place for institutions that can be demoed outside the hotel. At the end, the location of the demo was decided as dormitory and elderly houses, with all the conditions and actions remaining the same. The products used in the common areas and the products used in the rooms are the same as the hotel scenario.

Although universities switched to remote education, students continued to stay in student dormitories to continue their education life. The demo products used are given to the use of the personnel of the universities who are trained and working in the field of health. Similarly, elderly homes continued their activities during covid-19.

In these locations, products are purchased and used similarly to the hotels and replaced with new products when they expire. The average lifetime of the products varies between 5-7 years, similar to the hotel scenario. For this reason, university dormitories and elderly homes are also similar markets for the product leasing model.

Information about demo locations, products used and use scenarios is provided below.

7.2.1. Bolu Abant Izzet Baysal University dormitories, Turkey

Bolu Abant İzzet Baysal University was established on 3 July 1992. The University, which has developed rapidly since this date, has campuses in Bolu city center and five districts (Gerede, Mengen, Mudurnu, Yeniçağa and Seben).

Currently, there are 17 faculties, 1 institute, 1 college, 8 vocational colleges and 19 research centers at the university. There are 1,509 lecturers and 757 administrative staff, about 30,582 students working in these units of the university.

Two dormitory blocks on the university's İzzet Baysal Campus serve to accommodate students. One of the dormitories was transferred to the University in 1993 and the other in 1994 ready for service. The dormitories run by the university have a capacity of 680 male and 680 female students. There are student canteens, reading halls, study halls, TV viewing halls, and painting and music study rooms that are always open in both dormitories.

25 demo TVs were installed in dormitories, TV lounges and their partners for demo use.

Figure 82. TV set in University dorm university demo location, Turkey

7.2.2. Credit and Hostels Institution Dormitories (Samsun Region), Turkey

The institution was established on 22 August 1961 for the fulfillment of these duties, which were declared to belong to the state by the constitution, after the provision in Article 50 of the 1961 Constitution: “The state provides the necessary assistance through scholarships and other means to enable successful students who lack financial means to reach the highest education degrees”. The Higher Education Credit and Hostels Institution was established with the Law No. 351, which entered into force on.

The institution has several main duties and responsibilities:

- To determine the dormitory needs, to provide all kinds of needs of the dormitories, to manage the dormitories, to make the relevant arrangements in the dormitory areas in order to meet the subsistence, accommodation and social needs of the students,
- To determine and implement the principles regarding the application, evaluation, registration and acceptance of the students to be accommodated in the dormitories, to meet the social, health, cultural and educational needs of the students staying in the dormitories, and to cooperate with the relevant institutions,
- Classifying dormitory services, determining their standards and determining their tariffs, etc.

The total number of dormitories spread across all Turkey for 2021 and other information is as follows:

- Total number of dormitories: 769
- Dormitory bed capacity: 719 thousand 567
- Dormitory bed types: 89% base and bed frame
- Number of provinces and districts with dormitories: 81 provinces and 241 districts

For the installation of the TVs used in the demo phase of the project, those in the Samsun region were selected from these dormitories. 22 products were installed in student rooms and common areas.

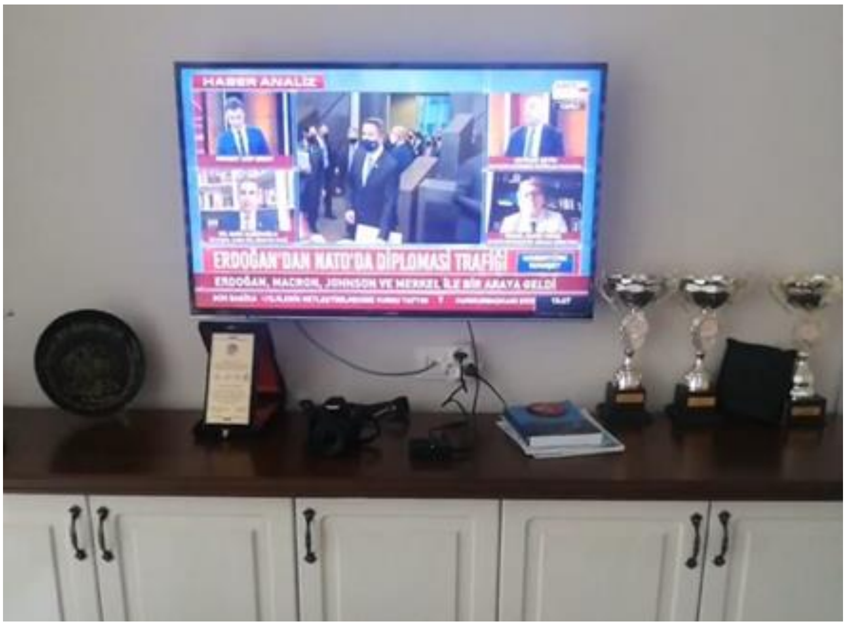


Figure 83. TV set in hostel demo location, Turkey

7.2.3. Fundacion Matia (Basque Country), Spain

Matia Foundation, based in San Sebastian (Spain), is a foundation with more than 130 years of experience in the provision of social and health services. It provides assistance and services to people with an illness, older people and people with a disability. The provision of services is carried out under a comprehensive and person-centered model based on the principles of autonomy, dignity and personalisation.

53 demo products were installed in the common areas and TV viewing rooms in 9 different campuses of the institution.

Figure 84. TV sets in Matia Foundation demo location, Spain

The use scenario of all installed demo products is the same. The products are used to watch national TV channels. And all TVs are used by people with different user habits, not just one person. The channel that users watch changes. TVs stay on for an average of 8-10 hours daily in demo locations.

7.3. Preparation for repair and refurbishment operations

Beko Spain, Arçelik R&D and Emaus are working together to implement standardised repair and refurbishment operations for the TV once the renting period is completed and/or the products need to be repaired/replaced. This part of the demonstration will take place once the testing period at the demo facilities is concluded (end of life phase), but preparation for reuse requires close collaboration between the manufacturer and the rest of the actors involved, so the analysis of TV most replaced spare parts and refurbishment operations, as well as repair protocols and documentation was initiated in advance. TV's parts were listed and action plans prepared. Most relevant parts for refurbishment operations are listed below:

- Remote Controller
- LED display
- Software
- Connectors
- Cosmetic parts and device cleaning

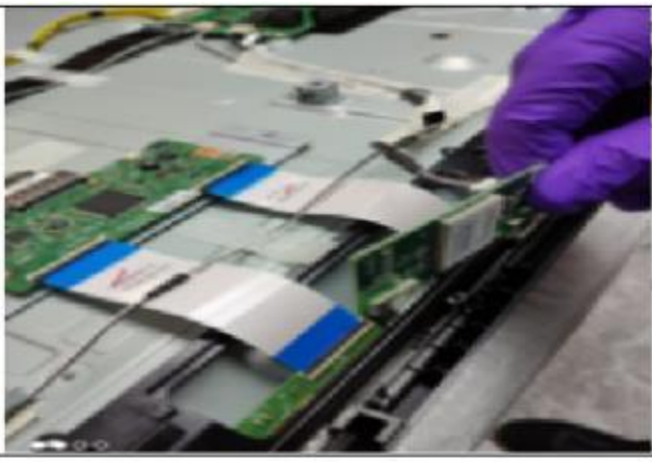
For these parts, replacement instructions and manuals were prepared by Arçelik R&D. Document languages are Turkish, English and Spanish. These documents will be used in the preparation for reuse operations to grant the used products a second life and sell them at Emaus facilities. For this reason, it is very important the technicians involved learn the procedures and follow the steps according to the manufacturer's instructions. During this period, Arçelik prepared and made these documents available and Beko Spain organized trainings for Emaus personnel. The manuals will also be accessible via the QR code on the TV's.

Excerpts from the Remote Controller and LED display refurbishment procedures are shown below:

Procedimiento / Procedure:		
A) Desmontaje / Disassemble		
1. Por uno de los lados, introducimos el cuchillo de plástico o espátula en la ranura que separa la tapa frontal de la trasera. 1. Introduce the plastic spatula in the slot between the front and back cover of the remote control.		
2. Una vez conseguido introducir la herramienta vamos deslizándola por todo el contorno haciendo palanca y de esa manera despegamos la parte frontal. 2. Slide the spatula along the outline and levering at the same time to separate both parts.		
3. Separamos las dos tapas y luego sacamos el circuito y la botonera de su alojamiento. 3. Separate both covers and take the circuit and buttons from their housing.		

9. Con un paño seco o con papel de celulosa limpiar y secar toda la superficie de las tapas. 9. Clean and dry both covers' surface by using a clean and dry cloth or cellulose paper.		
10. A continuación, mojar la brocha en el alcohol de la bandeja y limpiar la parte interior de la botonera, extendiendo el alcohol por todos las partes. 10. Soak the paintbrush in the tray of alcohol and clean the button group spreading the alcohol everywhere.		

Excerpt from Led Display repair manual:

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.	

7.4. Reverse logistics ICT tool

Similarly as for the analysis performed for the WM demo case, this section reports the input provided to the Logistic Platform for the TV demo case and the output of the analysis.

Also in this case the aim of the analysis is to define the order of the nodes among the different stakeholders (i.e. suppliers already existing or new ones) where to collect products or materials useful to create the final product and identify the number of trucks needed to minimize the total travel distance. The output also includes the best route connecting all the nodes of the supply chain to save CO_2 emissions, time and costs.

As explained in Section 4.4, one registration was created for ARÇELİK for RINA-C tool, Logistic Platform, and the tool has been populated with the inputs provided for both Arçelik demo cases. Therefore, also in this case, data referred to the TV demo case, in the following figure, have been highlighted in a box to distinguish them from the others.

The inputs include:

- Final destination of the goods (i.e. Arcelik warehouse in Turkey, see following figure)
- List of suppliers where to collect goods/materials (see following figure)
- List of products and their characteristics (i.e. volume, weight, supplier where the goods are available, availability date of the product)
- Type of truck used for the logistic operation

Destinations

action	Name	Location
EDIT DELETE	Warehouse 1 - Arçelik Ele. Plant	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Warehouse 2 - Arçelik Ele. Plant	Beylikdüzü/İstanbul, Turkey
EDIT DELETE	Warehouse - Arçelik WM Plant	Tuzla/İstanbul, Turkey

ADD

Suppliers

Action	Name	Headquarter	Warehouses
EDIT DELETE	Supplier 1	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Supplier 2	Göttingen, Germany	Göttingen, Germany
EDIT DELETE	Supplier 3	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ, Turkey
EDIT DELETE	Internal production (WM production plant)	Tuzla/İstanbul, Turkey	Tuzla/İstanbul, Turkey
EDIT DELETE	Supplier A	Gebze, Kocaeli, Turkey	Gebze, Kocaeli, Turkey
EDIT DELETE	Supplier B	Çerkezköy, Tekirdağ, Turkey	Çerkezköy, Tekirdağ
EDIT DELETE	Supplier C	Gebze, Kocaeli, Turkey	Gebze, Kocaeli

ADD

Products

Action	Name	Code	Supplier	Warehouse	Availability date	Volume	Weigth
EDIT DELETE	Front cover	000-2	Supplier 1	Supplier 1 warehouse	24/06/2021	1	1
EDIT DELETE	Ledbar	000-3	Supplier 2	Supplier 2 warehouse	24/06/2021	1	1
EDIT DELETE	Metal back cover for display	000-4	Supplier 1	Supplier 1 warehouse	24/06/2021	1	1
EDIT DELETE	Detergent Box Group	2412700600	Supplier A	Supplier A - warehouse	24/10/2021	0.008	0.5
EDIT DELETE	Front Door Group	2467200700	Supplier A	Supplier A - warehouse	26/10/2021	0.03456	1
EDIT DELETE	Motor	2843120300	Supplier B	Supplier B - warehouse	27/10/2021	0.005712000000000001	0.1
EDIT DELETE	Cabinet	2833790100	Internal production (WM production plant)	WM production plant	27/10/2021	0.26544	1.5
EDIT DELETE	Front Panel/Wall	2835953500	Internal production (WM production plant)	WM production plant	25/10/2021	0.01488	0.5

Figure 85. Arcelik collection data used for Reverse Logistic demonstration

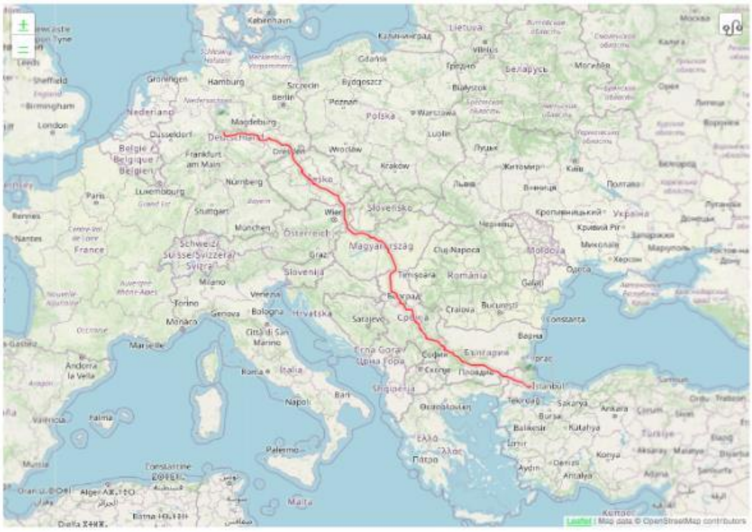
At the moment of the analysis not all the data related to products are available, as for example the number of pieces and therefore the volume and weight of the batch, but it is assumed that the total volume and weight is compatible with a Heavy Duty Trucks Rigid Type 1 (Max Load 23). It has been also assumed the class of the vehicle is Euro V, but comparison analysis using a different type of vehicle can be done.

In this demo the final destinations are two, and the analysis has been performed twice to consider both of them.

Case 1: destination Çerkezköy

Two of the three products are located in the same city, so the delivery needs only one truck to bring goods from Göttingen to Çerkezköy.

The following figure show the suggested route and the main results of the analysis.



Path	Total CO2 (kg)	Total Nox (kg)	Total PM10 (kg)	Total distance (km)
- [Çerkezköy-Türkiye, Göttingen-Deutschland]	1.453.00	6.41	0.28	2.228.53

Göttingen - Çerkezköy

Figure 86. Best route to connect warehouses for the TV demo case (destination Çerkezköy)

Case 1: destination Beylikdüzü

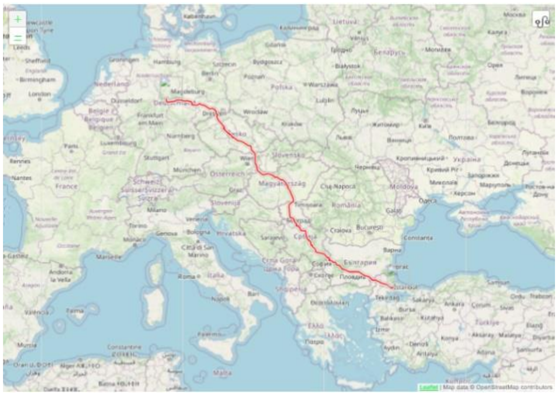
In this case different solutions can be possible, which include the use of 1 or 2 trucks, but as shown in the following figure the best one, in terms of CO2 emissions, is the solution with only one truck (highlighted in the box).

Path	Total CO2 (kg)	Total Nox (kg)	Total PM10 (kg)	Total distance (km)	Truck	Delivery Time	Shipment Date
› [Çerkezköy-Türkiye, Göttingen-Deutschland, Beylikdüzü-Türkiye]	1,550.05	6.84	0.30	2,377.38	2	Day 1 1:13:18	24/06/2021
› [Çerkezköy-Türkiye, Göttingen-Deutschland, Beylikdüzü-Türkiye]	1,541.67	6.80	0.30	2,364.53	2	Day 1 0:50:25	24/06/2021
⌄ [Göttingen-Deutschland, Çerkezköy-Türkiye, Beylikdüzü-Türkiye]	1,501.53	6.63	0.29	2,302.95	1	Day 1 0:12:19	24/06/2021
Göttingen-Deutschland -> Çerkezköy-Türkiye	1,453.00	6.41	0.28	2,228.53	Truck 1	23:11:21	24/06/2021
Çerkezköy-Türkiye -> Çerkezköy-Türkiye	0.00	0.00	0.00	0.00	Truck 1	0:0:0	24/06/2021
Çerkezköy,Türkiye -> Beylikdüzü,Türkiye	48.53	0.21	0.01	74.43	Truck 1	1:0:58	24/06/2021

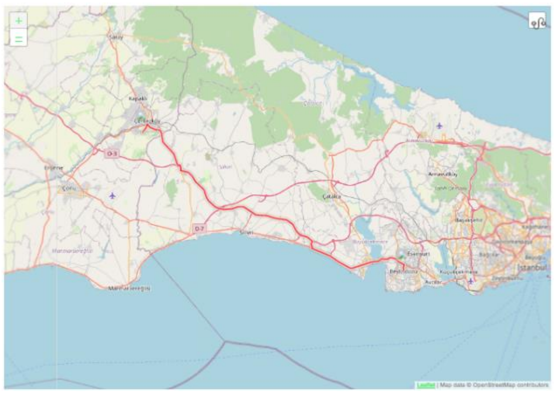
Figure 87. Logistic Platform Output for the TV demo case (destination Beylikdüzü)

The truck will collect goods in Göttingen first and Çerkezköy then, to proceed up to the final destination in Beylikdüzü.

The following figure shows the suggested routes.



Göttingen - Çerkezköy



Çerkezköy - Beylikdüzü

Figure 88. Best routes to connect warehouses for the TV demo case (destination Beylikdüzü)

7.5. Arçelik customer survey

A survey was created during the demo use phase to get customer feedback. From the content of this survey, besides the product-related information, feedback on the leasing model was received. The questionnaire was also shared in Turkish, English and Spanish via QR code.

1 **Your age:**

<18

18-25

25-40

40-60

60>

2 **After using this product; what do you think about renting your WM instead of purchasing a new one if the same quality aspects and warranty terms apply?**

I would purchase a new one

I would rent the product for a certain period, and then upgrade it with a newer version, again renting it.

I would only rent a product if it is going to be used first by me

I would rent a refurbished product knowing it had the exact quality aspects and warranty terms with a new

3 **Which feature of the product may be a factor/criteria in your rental?**

...

4 **How long would you like to rent the product?**

1 year

1 to 3 years

More than 3 years

5 **How often would you like to pay for renting?**

Monthly

For 3 months

For 6 months

Yearly

6 **How much would you like to pay for the product for 1 month usage? (please consider that product price is**

...

7 **How often would you like the product change/upgrade to be made?**

1

2

4

6

8 **Would you consider renting a connected TV/washing machine appliance, custom designed in accordance with your preference and receive customized services for spare parts?**

I would only buy a new product

I would only rent a product if it is going to be used the first time by me

I would rent a refurbished product knowing it had the same quality aspects and warranty terms with a new

9 **Which feature would you like to be updated without changing the product during the rental period? (paid**

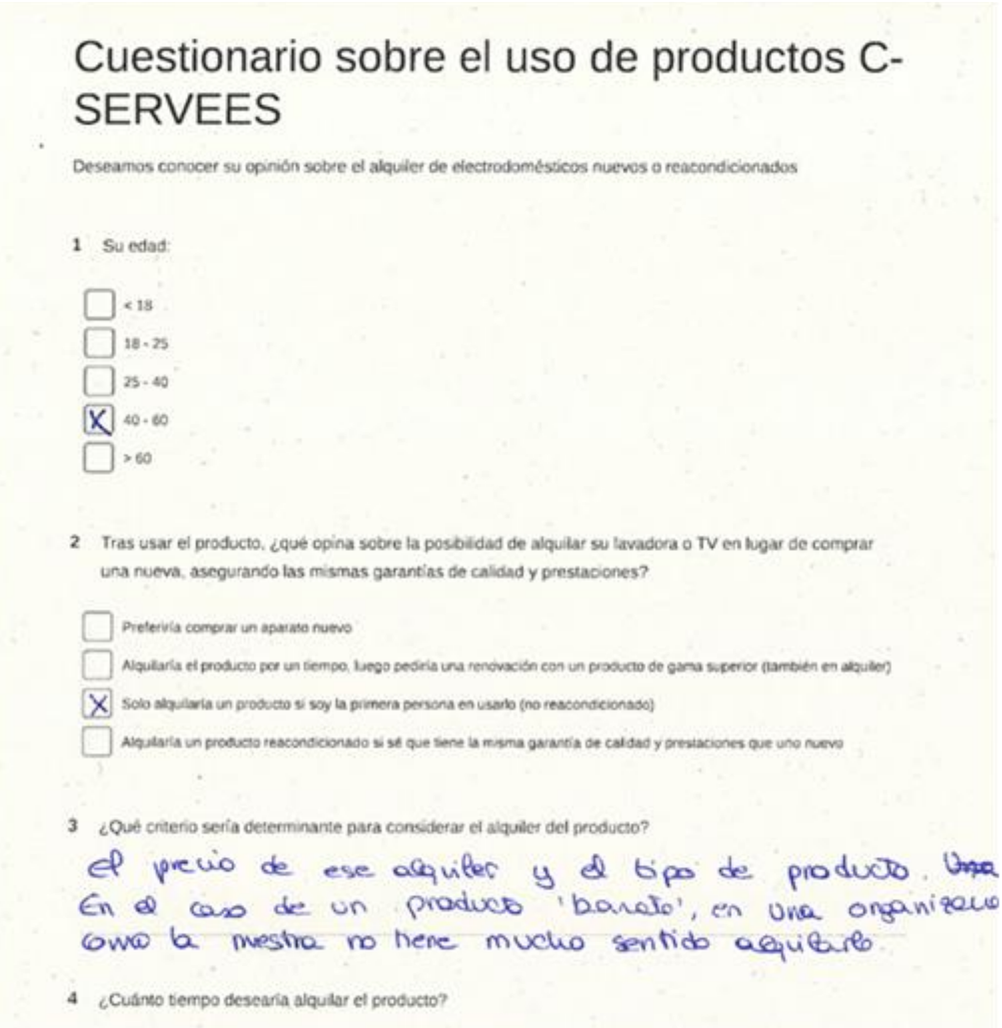
Number of revolutions (rotor speed)

Front panel color

Other (specify):

10	**What do yo think about a pay per use model for a connected WM if it was installed in your house but you only had to pay when you used it?** I would not prefer such a method I would be willing to try the product at home I would rather pay a fixed rental fee
11	**How would you feel about your favorite brand's reputation if you knew they were also offering circular business model alternatives such as products for rent, pay per use or refurbished products with the same** The brand image would deteriorate I would value the brand more as a sustainability conscious consumer for their efforts on resource efficiency and circular economy My opinion of the brand would not change
12	**What did you do with your latest home appliance before you got a new one?** Put it outside Called the service technicians to come and pick it up Sold it to a spot dealer Gave it to a friend/neighbor/relative/someone in need Other (specify):

An example of the answers is given below:



Cuestionario sobre el uso de productos C-SERVEES

Deseamos conocer su opinión sobre el alquiler de electrodomésticos nuevos o reacondicionados

1 Su edad:

- [ ] < 18
- [ ] 18 - 25
- [ ] 25 - 40
- [X] 40 - 60
- [ ] > 60

2 Tras usar el producto, ¿qué opina sobre la posibilidad de alquilar su lavadora o TV en lugar de comprar una nueva, asegurando las mismas garantías de calidad y prestaciones?

- [ ] Preferiría comprar un aparato nuevo
- [ ] Alquilaría el producto por un tiempo, luego pediría una renovación con un producto de gama superior (también en alquiler)
- [X] Solo alquilaría un producto si soy la primera persona en usarlo (no reacondicionado)
- [ ] Alquilaría un producto reacondicionado si sé que tiene la misma garantía de calidad y prestaciones que uno nuevo

3 ¿Qué criterio sería determinante para considerar el alquiler del producto?

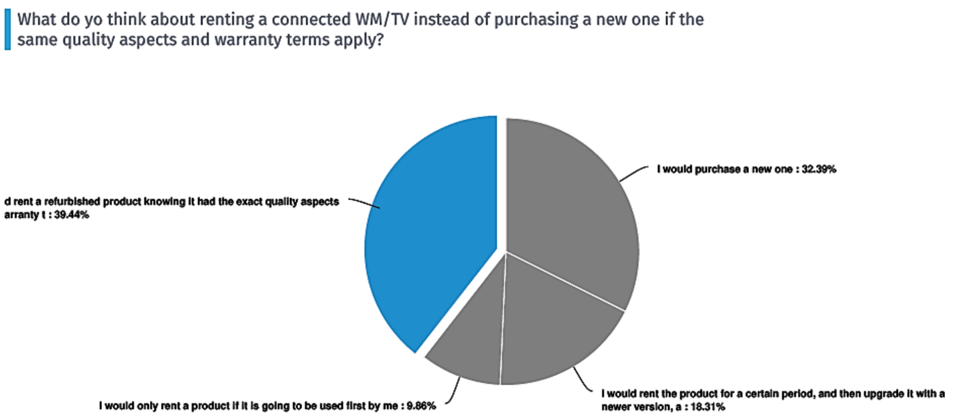
el precio de ese alquiler y el tipo de producto. Una
En el caso de un producto 'barato', en una organización
como la nuestra no tiene mucho sentido alquilarlo.

4 ¿Cuánto tiempo desearía alquilar el producto?

The survey, which was compiled in the use phase, had two important benefits. The first is the opportunity to compare with the results obtained with the survey made while preparing the CEBM mode. As the current survey was made during the use phase, it provides the reflections on the customer's thoughts related to the proposed business model. The second benefit was the use of the outputs here for the feasibility of the rental model. For example, learning that customers prefer the rental period to be no less than 3 years.

Now critical questions and answers are examined for the CEBM impact of specifics issues.

- First and most important question is "**After using this product; what do you think about renting your TV/WM instead of purchasing a new one if the same quality aspects and warranty terms apply?**". A similar question was asked while preparing the CEBM model. Currently, this question has been asked to B2B customers in locations where demo products are available. Some of the respondents in Spain answered this question as "I would only rent a product if it is going to be used first by me", while others replied "I would rent a refurbished product knowing it had the exact quality aspects and warranty terms with a new one". This result is similar to the feedback obtained during the first Survey.



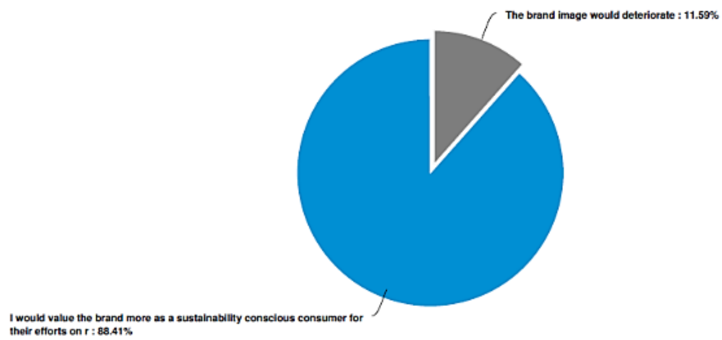
Answer	Count	Percent
I would purchase a new one	23	32.39%
I would rent the product for a certain period, and then upgrade it with a newer version, again renting it.	13	18.31%
I would only rent a product if it is going to be used first by me	7	9.86%
I would rent a refurbished product knowing it had the exact quality aspects and warranty terms with a new one	28	39.44%
Total	**71**	**100 %**

In the first survey, the most preferred option was to adopt the rental model as long as this option ensured the same product quality and warranty conditions. For this reason, the leasing model seems to be a good option for the customer as well.

- → Another important question is "**Which feature of the product may be a factor/criteria in your rental?**", an open-ended question. The most popular answer to this question is the price of the product. In addition, answers such as technological updates, performance, energy efficiency, continuous updating were also given at the same time. The fact that the biggest factor affecting the preference is the price shows that the rental model will be successful after a correct pricing is made.
- → The next question is "**How long would you like to rent the product?**", and a common answer to this question was "More than 3 years". Therefore, rental models under 3 years will not be accepted by the B2B customer. These data are very important as they also benefit the feasibility study.
- → Another relevant question that will contribute to the feasibility study is "**How much would you like to pay for the product for 1 month usage? (please consider that product price is near 400 euro)**". Although different answers can be given to this question, the answer generally received is that the 10-15 euros band is a reasonable level. It is seen that a figure above 20 euros will not be preferred much by the customer. Considering that the price is the most important criterion in product preference, it is a priority for the successful operation of the rental model that we consider the monthly rental price.
- → Another question in the form was "**How would you feel about your favorite brand's reputation if you knew they were also offering circular business model alternatives such as products for rent, pay per use or refurbished products with the same warranty terms?**". The answers received are without exception "I would value the brand more as a sustainability conscious consumer for their efforts on resource efficiency and circular economy". Therefore, we can say that the circular economy model will contribute to the value of the product and the brand. For this reason, the actions taken will be reflected in the business results in a short time.

  In addition, this answer shows parallelism with the result of the survey conducted at the beginning of CEBM. In this case, we cannot say that the customer has a negative perception of the model after experiencing the product.

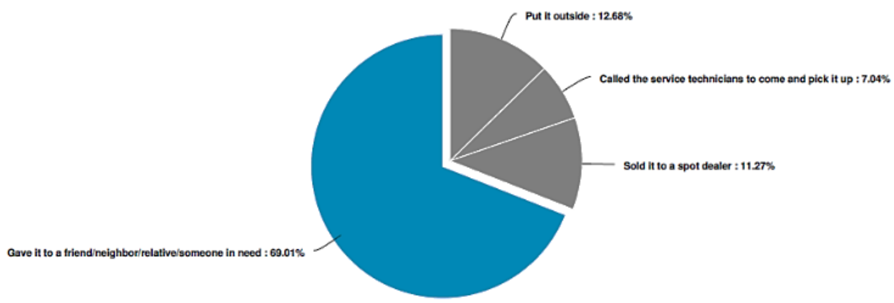
How would you feel about your favorite brand's reputation if you knew they were also offering circular business model alternatives such as products for rent, pay per use or refurbished products with the same warranty terms?



Answer	Count	Percent	20%	40%	60%	80%	100%
The brand image would deteriorate	8	11.59%					
I would value the brand more as a sustainability conscious consumer for their efforts on resource efficiency and circular economy	61	88.41%					
Total	69	100 %					

As a last question, B2B customers were asked how the products are used after the end of their life. The response shows that products can be reused for circular economy.

What did you do with your latest home appliance before you got a new one?



Answer	Count	Percent	20%	40%	60%	80%	100%
Put it outside	9	12.68%					
Called the service technicians to come and pick it up	5	7.04%					
Sold it to a spot dealer	8	11.27%					
Gave it to a friend/neighbor/relative/someone in need	49	69.01%					
Total	71	100 %					

For this reason, it is important to refurbish the products and reuse them. This model was also used in the feasibility study. Considering that the product lifespan for B2B customers is 6 years on average, it will be ensured that it stays in the economy longer with reuse.

8. Conclusions

The second stage of the C-SERVEES demonstrations in WP4 has been focused on the implementation of specific short-term circular economy actions for the distribution and use phase included in each of the four product-specific CEBMs developed in WP2, which were presented as D2.2, D2.3, D2.4 and D2.5. This second phase of the demos also included the testing of the ICT tools developed within WP3, namely the ICT-enabled certification of recycled material content by Circularise and the use of QR codes to enable secure information exchange, as well as the Rina-C platform for logistics optimization.

The activities planned for this second phase of the demonstrations have also suffered varying degrees of delay due to the COVID-19 situation. Even though a 6-month extension granted to the project was able to mitigate some of these delays, there were complications related to the pandemic which affected the implementation of some planned activities and required adaptations in order to ensure the demonstration success. None of the modifications adopted has significantly impacted the objectives and results of the demonstration activities.

On the other hand, some activities which were not completed during the first stage (e.g., the certification by ICT of the recycled content in demonstration products) were finalized during this second stage and are described in the deliverable.

The main conclusions of this work are listed below:

Washing machine and TV set demonstrations

- Feasibility studies for renting/leasing both products yielded positive NPVs considering both Spanish and Turkish markets, with results being slightly better for Turkey due to lower labor costs.
- For both products, customer numbers are the main factor impacting the economic viability of the leasing business model examined. In order for the model to be feasible, an increasing rate of new contracts as well as recurring customers would be needed. Thus, while the calculated NPV is positive, further assessments will need to be carried out by Arçelik as a company to determine the adoption of this business model.
- The results from the survey distributed by Arçelik among their employees in 2020 to learn about customer acceptance show that 39% of the respondents would be willing to rent a washing machine or TV instead of buying a new one, if the same quality and warranty terms apply.
- Customer acceptance of a second-hand product is highly dependent on price, according to the same survey. Up to 78% of the respondents stated they would be willing to buy a refurbished TV or WM only if a discount was applied. On the other hand, customer's perception of the brand would improve with these offerings.
- Students, singles and dormitory owners are much more interested in the renting/leasing offer compared to married couples and couples with children.

- The washing machines sold by Arçelik are not suited to the B2B segment since hotels or laundromats require an industrial type of washing machine. However, from the demo experience in the C-SERVEES project, elderly care homes and dormitories do provide an opportunity for this business line.
- In order to make TV offering attractive in the B2B-B2C segments, product as a service should be considered, e.g., including the TV along with other accessory consumer electronics and streaming platform subscription.

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 location provided the recyclers can adapt to the business case requirements. In a next step, ICT tool capabilities will be tested to provide support for this business case by granting access to essential documentation and facilitating information and feedback exchange.
- The analysis of the main issues influencing the potential for success of the refurbishment business case (i.e., cost and customer acceptance) reveals the importance of cosmetic criteria for refurbishing large products such as printers. It is shown that moving from 'equivalent to new' approach to 'potentially acceptable damages' can drive a significant cost reduction and play a major role in the final business case. On the other hand, substantial efficiency gains can be obtained with minimum investments to help the refurbishment operations and generate higher customer traction.
- For the purpose of B2B printer refurbishment, 3D printing technology has not demonstrated to be viable. Large cosmetic parts, which represent the highest cost issue in the refurbishment process, cannot be effectively 3D printed, and other large parts seem not appropriate for 3D printing either. On the other hand, smaller parts would not make this alternative interesting from a cost perspective.
- The outcomes from the study on the use of recycled materials from end-of-life printers and toner cartridges were positive despite some technical and operational problems encountered for classifying, grinding and obtaining quality secondary materials from printer parts according to Lexmark requirements. Cartridge housings made of recycled ABS from end-of-life toner cartridges passed every required test, from chemical analysis to finish good assembly and functional tests, and it was concluded that this material can be used in regular processes up to a maximum of 25% recycled content. Integrated in this study, the certification of the recycled content by ICT was finalized successfully using the Circularise platform. This innovative approach allows all stakeholders to verify the recycled content of the product (in this case, toner cartridge housings) in a secure environment by digital means.
- The extension of the current Lexmark Cartridge Collection Programme (LCCP) web platform to printers will facilitate and automate buy back and take back operations and accelerate Lexmark's circular economy projects in Europe. Implementation will

happen in the next demo stage. Rina-C ICT platform for the optimization of logistic operations was also tested and found interesting from the sustainability point of view.

ALM products demonstration

- The results from the lifetime optimization study considering not only the ALM but another ICT product in ADVA's portfolio, the TeraFlex, show the ideal replacement scenarios for the ALM system considering the type of energy in the use phase and the upcoming change in emission factors. The conclusion is that in the most realistic scenarios, the ALM should not be replaced due to improvements in energy efficiency, as it already consumes very little energy. This confirms the product is already eco-designed for longevity, and the circular economy improvement must come supported by new or enhanced PSS business models.
- For generalization to other ICT products, a characterization factor was defined, UPR10, which represents the ratio of 10 years use-phase GWP and the production GWP according to LCA. GWP was selected as the most relevant sustainability indicator in the LCA studies performed.
- Three PSS were analysed side-by-side using the ALM and TeraFlex products. No significant differences were found between the PSS from the environmental point of view, therefore the focus was directed towards revenue or NPV vs. customer cost and also vendor financing in the case of retaining product ownership (PSS3). In this last case, the PSS also presents the advantage of forcing the vendor toward the most efficient eco-design. For the ALM, with the new eco-designed fire and door sensors, the PSS with product ownership retained by the manufacturer means selling a managed service, which should make it very interesting for many of ADVA's customers.
- For generalization to other products beyond the ICT equipment, the PSS analysis must consider the CapEX vs. maintenance/operation costs, which is expressed as CMR10 (ratio of the product CapEx to the OpEx generated by 10 years of maintenance). This ratio will be further explored for other EEE products and integrated with lifetime optimisation analysis in the following demonstration phase, with the aim of creating a detailed decision matrix for best PSS applicable to any EEE product.
- A commercial contract was closed for a first installation of the new sensors for door-opening and fire detection, together with active ALM units. The contract covers a PSS1 according to ADVA's analysis, that is, selling the products plus maintenance services. This first deployment will allow obtaining official approval which is also an (ADVA-internal) prerequisite for further deployments, in particular as PSS3, which is the target PSS model for ADVA.
- No testing of ICT tools has been done for the use phase in the ALM demo, since the alternative offered by C-SERVEES did not go beyond what ADVA had already developed together with their logistics provider. Regarding the testing of blockchain-

based tool with Circularise, it is ongoing and the findings will be provided in next deliverables.

- An important outcome of the project activities at this stage is the update of ADVA's Eco-design Guide, which supports the main product features to be considered in order to attain efficient product-service systems. Several sections were complemented and changed through project inputs derived from demo activities and partners' feedback.

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

Table 21. 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
Renting/leasing models for B2B WMs	Printer parts recovery and reuse	Lifetime optimisation for ICT products	Renting/leasing models for B2B TVs
Renting/leasing models for B2C WMs	Use of secondary plastic materials from end-of-life printers and toner cartridges	PSS analysis for ICT products	Renting/leasing models for B2C TVs
3D printing of spare parts	3D printing of spare parts	Extension of lifetime optimisation + PSS: DSS for EEE products	3D printing of spare parts
Use of ICT tools to certify recycled content	Use of ICT tools to certify recycled content	Use of ICT tools to certify recycled content	Use of ICT tools to certify recycled content
Use of ICT tools for logistics optimisation	Use of ICT tools for logistics optimisation		Use of ICT tools for logistics optimisation

COLOR CODING

++ Good results
+ Potentially good results
+/- Unconclusive results
- Negative results
To be explored, results forthcoming

For the last stage of the C-SERVEES demonstrations, the main focus will be directed towards enhancing circular alternatives for the end-of-life, improving and promoting reuse and remanufacture, and considering new business models to be implemented that go beyond the current state of the art for recycling of EEE products.

Annex 1 (LEXMARK – Printer and toner cartridges demonstration)

5.4 Active Lobbying and PR Campaign" questionnaires

Generic questionnaire

Dear X,

Thank you for participating in our survey. We will not take more than 30 min. of your time.
We are currently taking part of an EU project called C-SERVEES. This is a consortium composed of industry, research centers, NGO's and academia.

Our goal is to help reducing the generation of waste and support the EU in meeting its energy and climate change policy targets and boosting the remanufacture and refurbishment of EEE products.

As sustainability becomes also more and more important to our customers, we would like to involve you into our journey in moving to greener business models. We have prepared several questions that would help us to better define your expectations and potential involvement in the Circular Economy. Your company and personal name will not be mentioned in the final published C-SERVEES report. We will only mention your company profile (e.g. SME) and industry sector (e.g. automotive sector).

1) Do you have a formal WEEE Policy/strategy?
   If yes, ca you please share it.
   What happens with your printers/MFP's/Copiers at their end of life?

2) Did you ever think of acquiring re-furbished products? If yes:
   Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
   Do you have any target in terms of % age of re-use/refurbished printers you procure?

3) What are your price and qualitative expectations toward refurbished products? Would you be willing to buy and use refurbished products with light cosmetic issues (e.g. little scratch, plastic color slightly different)?
   Would you accept EEE products that contain reused materials and components?

4) What do you see as pain points and enablers when acquiring and using refurbished products?
   Do you have any practical experience regarding using refurbished products?

5) What do you see as potential enablers to encourage the use of more refurbished products?
   Please list them. Where do you see the refurbished market in 3-5 years?

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
   Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
   What are your expectations toward Lexmark in this area?

Additional questions (depending on time):

- Who is for you the market industry leader in refurbishment? Why?
- Do you participate actively in other Circular Economy or EU funded projects?
  - If yes, what is/was your role in it? With whom?

Conclusion:

You can find more info on our C-SERVEES program on the Consortium website or on LinkedIn.
https://c-serveesproject.eu/
https://www.linkedin.com/in/cservees-project/
We stay also at your disposal for any follow up call to discuss our project and findings in more details.

Interview 1:

1) Do you have a formal WEEE Policy/strategy?
   - If yes, ca you please share it.
   - What happens with your printers/MFP's/Copiers at their end of life?

   95% of our products are leased. Once we are taking them back at end of life, we have three alternatives:
   1) Refurbish them inhouse and exchange some spart parts (represents less than 2-3%)
   2) Keep some good working printers in stock for exchange requests or spare parts needs (represents less than 2-3%)
   3) Sell them to a) recyclers or b) brokers which will export those products for second use in Africa or Eastern Europe. (represents around 95%)

   We don't sell collected printers back to the respective OEM's. We have never received any request to do so. We would not be opposed to sell our end-of-life printers to OEMs.

2) Did you ever think of acquiring re-furbished products?
   If yes:
   - Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
   - Do you have any target in terms of % age of re-use/refurbished printers you procure?

   Inhouse refurbishment is expensive and not price attractive. We miss large volumes to get spare parts at an attractive price. We don't buy refurbished products from OEM's or other partners. We prefer to buy the latest generation of printers at an attractive price. We don't have any specific volume targets for refurbished products.

3) What are your price and qualitative expectations toward refurbished products?
   - Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
   - Would you accept EEE products that contain reused materials and components?

   Our customers can accept products that have slight cosmetic defects. The customer who gets an attractive refurbished offer can accept products that don't look like new ones. To my opinion black color printers are easier to get into a perfect cosmetic change than beige or white ones.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
   Do you have any practical experience regarding using refurbished products?

   Many laser printers already have a high durability. This reduces the click price over the whole life cycle. The expected average lifetime of new printers is 5 years. If we refurbish them we can add 2/3 years life expectancy. Indeed, this will increase our click price after refurbishment as we would need to add a risk margin (around 10%) because of potential additional service and repair. It is easier to offer a climate neutral certificate for printers instead of refurbishing them if we need a good environmental story. We don't communicate actively on refurbished products and are not investing into this business model. The customer demand for refurbished products is very weak (also for administrations and schools).

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
   Where do you see the refurbished market in 3-5 years?

   We don't expect any significant increased demand for refurbished printers in the next years. Refurbishment is not yet attractive enough for us and our customers. We are concerned by potential warranty, security, firmware and software updates issues. The risk-benefit ratio is not interesting

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?

Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

We use an ID nr. approach to assess the quality and value of a product at end of life. A QR code could offer additional information to our customers (e;g. environmental information like CO2 or energy impact, Blue Angel compliance). The QR code approach will not boost our internal refurbishment processes.

- Who is for you the market industry leader in refurbishment?
  Why?

  We don't see a clear market leader in the Circular Economy world. Canon and Lexmark offer already developed CE solutions. Kyocera has a limited environmental approach on climate neutral printers.

Interview 2:

1) Do you have a formal WEEE Policy/strategy?
   - If yes, ca you please share it.
   - What happens with your printers/MFP's/Copiers at their end of life?

   Yes, we collect all printers from our clients that are at end of life. Most of our printers are working with a leasing model. We check the financial value and quality of end-of-life printers inhouse and decide if they get repaired, recycled or refurbished. In certain cases, we also dismantle the product and sell the respective valuable spare parts. The recycling is done by an external company; the repair, dismantling and refurbishment processes are done inhouse. All end-of-life options are feasible depending the best financial case (cherry picking approach). We collect every year 4K to 6K printers from our customers. We almost only refurbish high end printers -generally worth over 1000€- that have still market value (A3 and high end A4). We prefer to refurbish printers if they can be sold with an attractive margin. We only refurbish low or mid-range A4 printers if we need to solve an emergency for our customer and are under time pressure. We don't work on a project basis to sell a full batch of refurbished printers. We have a case-by-case approach and work with small volumes to satisfy specific customer demands. A project-based approach with larger refurbished volumes will automatically be in price competition with new products.

2) Did you ever think of acquiring re-furbished products? If yes:
   Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
   Do you have any target in terms of % age of re-use/refurbished printers you procure?

   We don't have a specific % refurbishment target. It depends on what we collect back from our customers. We currently collect and refurbish less than 5% of our products that are placed on the market. We are looking for a 30% to 50% margin calculation when selling refurbished printers. We often reach this margin by mixing refurbished with new printers (mixed calculation approach).

3) What are your price and qualitative expectations toward refurbished products?
   Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
   Would you accept EEE products that contain reused materials and components?

   We generally prepare and deliver Grade A refurbished products (min. of 500€ refurbishment investment) to our customers with the highest quality and security standards. We don't want to take any brand image or financial risk by selling grade B products to our customers. We ensure that service costs are not increasing for older (after 5 years use) and refurbished products. We want to make profit with refurbished products. Our customers are inclined to make some financial savings by buying refurbished products of high quality. Indeed, the buying decision is mostly financial and not environmental driven. We don't see any change with our customers in the short term.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
   Do you have any practical experience regarding using refurbished products?

   Customers are not yet convinced by the environmental story. Better storytelling and PR work from the OEM's and distributors is needed. A customer could for example get a "green" certificate with the acquisition of his/her refurbished printer. Circular Economy solutions still miss the right dynamics in the market. The best financial business case is generally to prolong the leasing contract (5 + 2 years) with the same customer via a refurbished product. This can provide a win-win approach and reduce the click price for the customer.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
   Where do you see the refurbished market in 3-5 years?

The refurbished market will only increase if it gets a strategic issue driven by company boards. The EU Commission work is often too slow and not coherent enough to accelerate Circular Business models at the SME level. We are sometimes frustrated about the EU legislative support.
Refurbishment could be an integral part of our “Office worlds of the future” concept that we are promoting with our customers. We continue to be optimistic.

Indeed, also the sales model of OEM’s would need to be adapted to more refurbished products. Attractive offers should combination of new and refurbished products. Such an approach is facilitated by a leasing concept.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

We are currently using our own inhouse code to assess the value of collected products and refurbish them if needed. The process is still manual and could be improved. We would be interested to test new QR solutions and better understand the C-SERVEES approach. Perhaps the QR code could also help us to better assess the value of an old printers and their spare parts. The value of an old printer at end of life can go from 5€ to 200€ for a high-end copier.
We would like to do some PR work around this interview with Lexmark and the C-SERVEES consortium. We are drafting a proposal to be communicated via our respective websites and social media channels.

Interview 3:

1) Do you have a formal WEEE Policy/strategy?
If yes, can you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

We mainly lease our printers to our customers and take them back at end of life after 4 or 5 years in the field. We refurbish ourselves the high-end products (mainly A3) and recycle the low end and middle range printers (mainly A4). We don't have yet a valid business case to refurbish standard A4 printers. A4 printers loose too much value at end of life to be refurbished and resold at an attractive price. Most new A 4 printers would be cheaper or equally priced to a refurbished printer. A4 machines loose most of their price value after 4 or 5 years.

2) Did you ever think of acquiring re-furbished products? If yes:

Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

We don't have a specific % target. We make a case-by-case decision to refurbish a printer (depending the business case). It mainly depends on the product quality at end of life. We need to assess how much resources/parts need to be invested to bring a refurbished product to the newest quality standard. Some products can also be obsolete because of missing software, security or cloud technology access. It's not only a question about parts. We don't extend the lease time of our products. We use refurbished products to create new lease contracts with other customers. We probably only refurbish 2% to 3% of our collected end of life products.

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

We prefer A graded products without cosmetic issues. Indeed, there is also a market demand for B graded products (depending the customer, e.g. logistic company where cosmetic criteria are secondary). We don't have big technical challenges to refurbish products as an A graded product. It is not too difficult to refurbish printers with a brand-new look (without scratches or different plastic colors). Customers still see that our refurbished products are not new. The optic look is not the same. Refurbished products need to be sold at 30 to 35% lower price than a new device. Customers expect a large price difference for refurbished products. Many customers prefer otherwise to add 5% premium to get a new device. The printer market is very price aggressive. Some OEM's (not Lexmark) have large volumes coming from their Asian based factories that need to be liquidated at any price.

We are not convinced that refurbished printers can be a valid alternative during delivery shortages (as being the case today). Doe OEM's have enough volume of refurbished products to deliver larger quantities of the same product model?

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

Customers would need to better understand the environmental advantages of acquiring and using a refurbished product. Customers should get data on how much energy is saved with a refurbished device compared to a new device. What is the CO_2 impact of a refurbished product versus a new one? Is the CO_2 impact negative, neutral or positive? The environmental story needs to be improved. This is also a way to move away from a pure price discussion.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.

Where do you see the refurbished market in 3-5 years?

We are optimistic that the refurbished market will increase quickly in the upcoming years. There is no need for additional legislation to boost refurbishment. Industry is already driving environmentally friendly solutions. The right environmental story telling will drive CE solutions.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

We currently use our EAP system to assess the quality and use phase of an end-of-life product. Our technicians use the printer serial number to gather information about the product history. Indeed, QR code could speed up the process and fully automatize the process. Indeed, users could get valuable environmental information on their products via a simple QR code scanning with their phone (e.g. CO_2 impact of the device, energy usage after big printing jobs). QR code could be readable via smartphone on the printers screen.

Others: There is no clear market leader in the industry regarding CE. Lexmark is certainly one of the more advanced CE players that provides transparent and objective environmental data.

We are interested to use model X as refurbished device in our company at a place where high printing volumes (e.g. shipping area) are requested. We would be willing to provide Lexmark with our user feedback. Please come back to us with a concrete proposal how to handle such a project.

Interview 4:

1) Do you have a formal WEEE Policy/strategy?
If yes, ca you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

We use 9 different Lexmark models from a simple black & white Single Function printer to a high end A3 MFP. We have two different approaches when to replace an "old" printer. 1) The repair gets too expensive for an older printer version or 2) The printer doesn't offer the latest security features and capabilities. We stopped our leasing business model a while ago and buy again printers from a dealer. They take our products back that are at end of life for a classical WEEE treatment. Those products are probably not repaired or refurbished. They end up in getting dismantled or recycled.

2) Did you ever think of acquiring re-furbished products? If yes:

Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

No, we don't use refurbished products. We never tried refurbished printers and other refurbished ICT devices. We don't have any short-term target on refurbished products. We didn't yet have the opportunity to assess the refurbishment case. We miss important information on:
-warranty
-pricing
-quality (equal to new?)
-how old those products would be (should still be relatively new; no more than 2 to 3 years of use)
-how secure those products would be

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g. little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

Most print volumes are done in the production and logistics area. Here it doesn't matter if products have slight cosmetic issues. Key is warranty and security. All refurbished products would need to get access to the latest firmware and software updates. Besides the latest Apps such as "Scan to one Drive" should be applicable to refurbished printers. Is this the case?

For the price we expect a refurbished price to cost approximately 30% less than a new device.

When delivery issues exist for new products (as being the case today) we could accept an attractive refurbished offer, instead waiting several months for new product delivery.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

Again, the highest Security level needs to be offered.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
Where do you see the refurbished market in 3-5 years?

The refurbished market will certainly increase in Germany in the next years. We estimate a refurbished market of 20% to 30% in the ICT market.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?

Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

We already receive information from OEMs about the print volume of each of our used devices in the company. This is sufficient to have a good picture of our printers' fleet and know when they should be replaced.

Others: We are interested to test a refurbished product and provide our feedback. We would prefer to get model X since we are already using those products in our fleet.

Interview 5:

1) Do you have a formal WEEE Policy/strategy?
If yes, can you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

Printers are repaired or refurbished at end of life by us. We have inhouse solutions. Sometimes, we also buy refurbished products from Lexmark if we need more products.

2) Did you ever think of acquiring re-furbished products? If yes:
Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

Today we buy less than 10% of re-use/refurbished printers from Lexmark; 90% of our acquired Lexmark printers are new. The refurbished market is still a niche market. With re-use/refurbished printers we can address markets that are not adapted to new products because of budget or technical constraints. Schools or very small customers that have high-cost pressure are interested in our re-use/refurbished printers. In the South of Italy, the demand of refurbished products is bigger since the cost pressure is higher.

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

Little scratches are not critical. Customers can accept older models that don't look new. The price will often be the only criterion and differentiator. Prices would need to be up to 60% lower for refurbished products compared to new ones.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

Price is key. Yes, we have experience regarding using refurbished products since several years. The demand is rising. The environment is not the key factor yet.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
Where do you see the refurbished market in 3-5 years?

The refurbished market will continue to increase in the next years. Refurbished products can satisfy some customer needs when flexibility and aggressive price offers are needed. Not all customers need the latest technology. Also, during delivery problems with new products, refurbished products are a valid alternative to satisfy the client's need in a fast way (e.g. delivery shortages as during today's Suez Canal blockage). The current Covid Pandemic will also certainly increase the pressure and costs and accelerate the demand for refurbished products.
For the time being, we acquire refurbished products from the OEM and also create our own refurbishment park (collect, refurbish or reuse) with printers that are at end of life with our customers.
Warranty is not an issue since we sell services. If the printer breaks, we will just exchange or repair it.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

A QR code could be a great solution for our customers. Customers could get health & safety information about the refurbished printer (e.g. various emission levels, energy consumption).

A QR code would also be helpful to help us to improve our inhouse refurbishment processes and save time & money.
Others: We are very satisfied with Lexmark environment approach and offer.

Interview 6:

1) Do you have a formal WEEE Policy/strategy?
If yes, ca you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

Yes, we have our own branch dealing with collecting, dismantling, recycling and refurbishment of EEE products. It is ISO 14001 certified. We give a second life to printers and computers while developing the inclusion of people with disabilities. We process nearly 300,000 machines every year. Those are received at our center in Domérat in France and then processed. The machines are, depending on their condition, destroyed or tested for reuse, then remastered and sold.

We take back printers and send them again as "second hand" or refurbished products to the customer. There are market opportunities for "second hand" and refurbished products. Some products are sold in batches to other end of life specialists which do their own refurbishment/repair (sometimes do 1 product out of two). There is a big mix of solutions in the market.

The solutions are easier to put in place for the B2B than for the B2C market. Refurbished products need to go through professional quality testing process before they are sold to the customer. A bad quality refurbished product can negatively impact the brand image of the OEM.

2) Did you ever think of acquiring re-furbished products? If yes:
Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

Refurbishment has a cost and "nobody" wants to pay its real price.

We distribute only new products. Sometimes, we take back products from the customer, refurbish them and put them back to the same customer. We don't sell refurbished products to new customers if we don't handle their old products. Customers don't have real interest to buy refurbished products. In some tenders customers can also ask for a small % of refurbished products. Warranty is a key issue for us for refurbished products. Who will cover the warranty? The OEM or the company that refurbished the product? A refurbished product will always have a shorter life than a new one. So the warranty can be a key cost factor.

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

One needs to differentiate between A and B grade products. Refurbished products need to be clearly classified depending their quality. Customers can be willing to buy B grade products if the price is 50% less than new ones. A customer can put B grade products in his factories or warehouses and A grade products in the HQ or sales offices.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

Second hand products can have various quality levels. Some had been used heavily for many years. Some others are almost new (e.g. demo unit). It depends on so many factors. Often, we don't know in which quality shape old products are.

We still need to push refurbished products since the demand is still weak.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
Where do you see the refurbished market in 3-5 years?

The second hand and refurbishment market will continue to increase in the next years. Circular Economy legislation (e.g. targets for refurbished products in public accounts), tax incentive (e.g.

lower VAT for second hand or refurbished products) or a carbon tax could further boost the reuse market.
Price still drives the reuse market. 5% to 10% discount for refurbished products is not sufficient to motivate customers. Customers would still prefer to buy new product. With the current Covid crisis price pressures are even getting higher. The economical impact is the main engine of our customers, not the environmental impact.
On top of an attractive tariff, it is important to provide buyers and customers with clear and transparent data on their environmental contribution (e.g. reduced carbon impact).
“A may contain” approach can be dangerous if the quality is not the expected one for the customer.
We need a harmonised European approach of solutions and not a country-by-country approach so that we can define European refurbishment solutions and processes that will reduce the cost structure.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

Yes, a QR code could be useful. A QR APP is already used for consumers in the food market (Yuka). The QR code would need to be placed on the product before it is put on the market. It could also help us to better reevaluate the quality of the product and reuse plastics in a smarter way. Automated processes are always helpful in this domain.

Interview 7:

1) Do you have a formal WEEE Policy/strategy?
If yes, ca you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

We are not a reseller, so we are not faced with this difficulty. As part of the recovery of equipment during deployment, we use our WEEE partner.

2) Did you ever think of acquiring re-furbished products?If yes:
Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

We use a lot of packaging for transporting parts to our technicians and are therefore sensitive to what we buy and prefer to buy recycled packaging. At the current stage, we don't have any specific targets for refurbished printers. We acknowledge that refurbishment is getting a real trend and we are sensitive to this aspect.

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

Our main expectation toward refurbished products is that they function as well as new equipment. Yes, we would also be willing to acquire products with light cosmetic issues as long as they are at the same operating level as new ones. Our main expectation is product performance. Cosmetic issues or reused materials and components are of secondary priority.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

We think that we are in the very early days in terms of refurbished hardware and that there are growing market opportunities in this field. Unfortunately, we are not yet taking opportunity of the refurbish market trend.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
Where do you see the refurbished market in 3-5 years?

We see several important enablers to encourage the use of refurbished products.

- The law could encourage manufacturers in this process with a bonus / penalty system.
- Manufacturers need to design their products to be repaired and put back into circulation.
- The law could oblige the manufacturers to produce spare parts necessary for the repair and functioning of the products.

We are moving towards more and more thoughtful and reasoned consumption, with the example of food consumption in a short circuit. The refurbished market should weigh around 30% of the market over the next 5 years.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

This sounds like a very interesting and innovative approach. We could imagine getting the following valuable information from a QR code:

a) The age of the product.
b) The percentage of reconditioned parts contained in this product.

c) The service to contact in the event of a breakdown or in the event of a need for consumables.

Others: Back Market is certainly one of the leaders in the refurbishment market in Europe.

Interview 8:

1) Do you have a formal WEEE Policy/strategy?
If yes, ca you please share it.
What happens with your printers/MFP's/Copiers at their end of life?

We work mainly with our subsidiaries on a printing leasing model.
We don't have a formal WEEE policy as such, but an industrial strategy on refurbishment policy. We have an internal activity center which is dedicated to second life products. Our activity center has been launched in 2020 with the main objective to refurbishing and recovering second hand spare parts.
Our main business challenge is to reach a critical size to industrialize the complete reconditioning and maintenance process. We mainly concentrate on our leasing concept but do also acquire products at end of life for inhouse refurbishment.
We mainly work on three end of life options:
a / If the machine is too old and/or in poor condition it enters the traditional WEEE flow.
b / If the product is in good working condition and we have sufficient capacity we go for inhouse refurbishment
c / We work with brokers to whom the machines are sold for part recovery or repair.

We recover approximately 30,000 machines per year and **12%** are used for inhouse refurbishment.

2) Did you ever think of acquiring re-furbished products?If yes:
Do you have any target in terms of % age of re-use/refurbished EEE products you procure?
Do you have any target in terms of % age of re-use/refurbished printers you procure?

Yes, we are already active in the refurbishment business. Price is the key issue for refurbished printers. Often high-quality refurbished printers are more expensive than new ones. We believe to have sufficient internal capacity to meet the market needs for refurbished products and achieve the 20% target imposed by recent French regulations.

We obtain missing spare parts by dismantling end-of-life products and reconditioning them or source new spare parts from OEMs at a higher cost.

3) What are your price and qualitative expectations toward refurbished products?
Would you be willing to buy and use refurbished products with light cosmetic issues (e.g.little scratch, plastic color slightly different)?
Would you accept EEE products that contain reused materials and components?

We think that one needs a 30% price difference between new and refurbished products to have a working business case. A 30% price difference doesn't' request any specific product guarantee. Below the 30% threshold many customers prefer to go for new devices.

4) What do you see as pain points and enablers when acquiring and using refurbished products?
Do you have any practical experience regarding using refurbished products?

The interest among our customers in refurbished products depends on the offered price points. The price remains the most important decision-making element for our customers.

The refurbished printer hardware is seen as potentially less reliable than a new device. There is a problem of customer perception. This is less the case for remanufactured cartridges.

5) What do you see as potential enablers to encourage the use of more refurbished products? Please list them.
Where do you see the refurbished market in 3-5 years?

There are four key enablers to accelerate the refurbishment business:

- Leasing

• Regulation
• Environmental awareness
• Price

We are currently reaching a 12% refurbished rate for our collected products at end of life.
We are optimistic to triple our refurbishment rate in in the next 3 to 5 years. A 5 years timeframe is probably more realistic.

6) Would Lexmark offer a QR code on its products that can be read with a smart phone, what kind of info would you like to get through it?
Do you have any smart appliances (e.g. web applications) that you are using or requesting related to your product?
What are your expectations toward Lexmark in this area?

We already have our own QR code in place on all products. As we are the owner of our printer fleet, we have a solid access to the key data/information.
We can track:

a) serial number
b) machine life related to its consumption
c) maintenance
d) spare parts
e) catalog

Indeed, we don't yet track any information on LCA, social LCA or other sustainability related data.
We are very interested to learn more about C-SERVEES in this regard.